

ARIZONA CLIMATE CHANGE ADVISORY GROUP

CLIMATE CHANGE ACTION PLAN AUGUST 2006



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EXECUTIVE SUMMARY

Executive Order 2005-02

On February 2, 2005, Governor Janet Napolitano signed Executive Order 2005-02 establishing the Climate Change Advisory Group (CCAG). Appointed by the Governor, the 35-member CCAG comprised a diverse group of stakeholders who brought broad perspective and expertise to the topic of climate change in Arizona. The Governor's Executive Order directed the CCAG, under the coordination of the Arizona Department of Environmental Quality (ADEQ), to:

- 1) prepare an inventory and forecast of Arizona greenhouse gas (GHG) emissions; and
- 2) develop a Climate Change Action Plan with recommendations for reducing GHG emissions in Arizona.

The Executive Order emphasized that “Arizona and other Western States have particular concerns about the impacts of climate change and climate variability on the environment, including the potential for prolonged drought, severe forest fires, warmer temperatures, increased snowmelt, reduced snow pack and other effects.”

The Executive Order also recognized that “actions to reduce GHG emissions, including increasing energy efficiency, conserving natural resources and developing renewable energy sources, may have multiple benefits including economic development, job creation, cost savings, and improved air quality.”

The CCAG Process

The CCAG held its first meeting on July 14, 2005, followed by a year of intensive fact-finding and consensus building, facilitated by the Center for Climate Strategies (CCS). The CCAG met six times during this period, and five sector-based technical work groups (TWGs) of the CCAG – Energy Supply (ES); Residential, Commercial, Industrial and Waste Management (RCI); Transportation and Land Use (TLU); Agriculture and Forestry (AF); and Cross-Cutting Issues (CC) – met a total of 40 times via teleconference.

The recommendations adopted by the CCAG underwent two levels of screening. First, a potential policy option being considered by a TWG was accepted as a “priority for analysis” and developed for full analysis only if it had a supermajority of support from CCAG members (with a “supermajority” defined as five or fewer “no” votes or objections). Second, after the analyses were conducted, only policy options that received at least majority support from CCAG members were adopted as recommendations by the CCAG and included in this report.

Of the 49 policy recommendations adopted by the CCAG, 45 received unanimous consent, two (2) received a supermajority of support, and two (2) received a majority of support.

Emissions Inventory and Forecast

Prior to the first meeting of the CCAG, a preliminary inventory and forecast of GHG emissions for Arizona for years 1990 through 2020 was produced pursuant to Executive Order 2005-02.

The inventory provided several critical findings, including:

- Between 1990 and 2005 Arizona's net GHG emissions increased by nearly 56%, from an estimated 59.3 million metric tons carbon dioxide equivalent (MMtCO₂e) to an estimated 92.6 MMtCO₂e.
- Arizona's GHG emissions are forecasted to increase by 148% from 1990 to 2020, taking into account the effects of recent energy efficiency actions adopted by the State. Without these actions emissions growth in 2020 would be forecasted to increase by 159% over 1990 levels.
- The transportation and electricity sectors account for more than three-fourths – roughly 77% – of Arizona's total GHG emissions.

Figure E-1 below shows the relative amount of GHG emissions contributed by each sector in 2000.

Figure E-1 Arizona Greenhouse Gas (GHG) Emissions in 2000

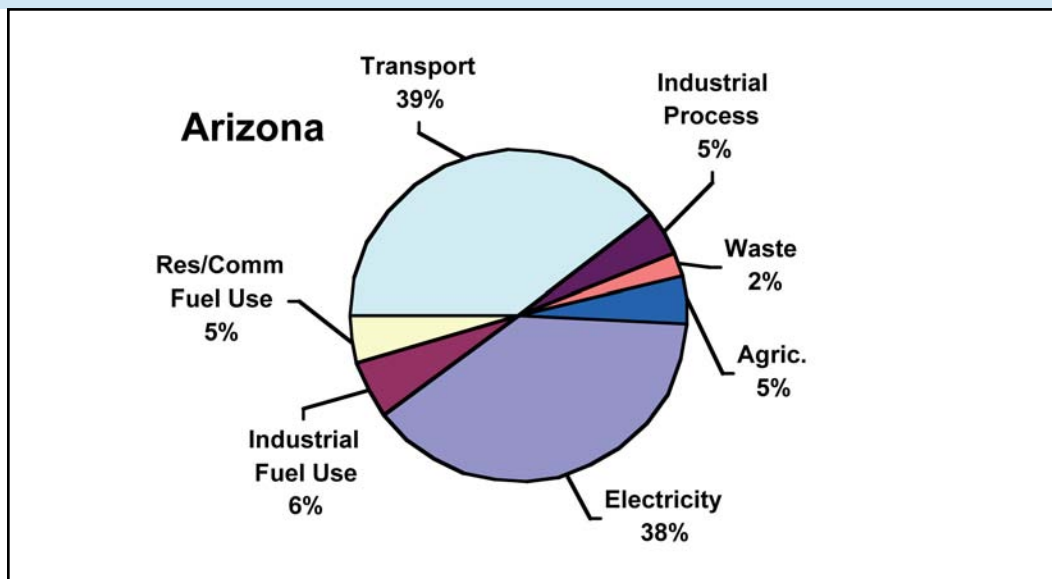
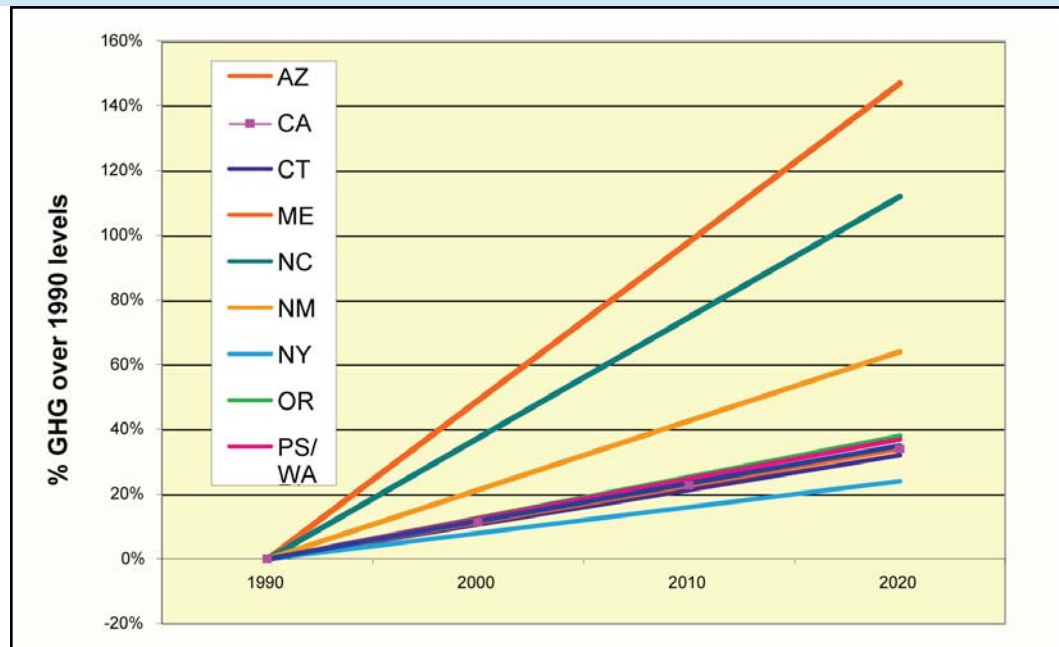


Figure E-2 below shows how Arizona’s projected growth in GHG emissions compares to the growth rates in other states with climate action plans.

Figure E-2 Comparison of 1990-2020 GHG Emissions Growth for States with Climate Plans



While Arizona’s high emissions growth rate presents challenges, it also provides major opportunities. Because more than three-fourths of Arizona’s GHG emissions are directly related to energy and transportation, the opportunity exists for Arizona to reduce its GHG emissions while continuing its strong economic growth by being more energy efficient, using more renewable energy sources, building new infrastructure “right” in the first place to produce lower GHG emissions and increasing the use of cleaner transportation modes, technologies and fuels.

The CCAG’s Recommended Policy Options

The CCAG is recommending a comprehensive set of 49 policy options to reduce GHG emissions in Arizona. The CCAG strongly recommends early and aggressive implementation of the recommendations and a corresponding set of incentives to promote their early adoption. The CCAG believes that early action and implementation of its policy recommendations are critical to put Arizona quickly on the path toward significant emissions reductions. The CCAG also urges that the policy options be implemented as a set, to the greatest extent practicable, to achieve the maximum GHG emissions reductions possible.

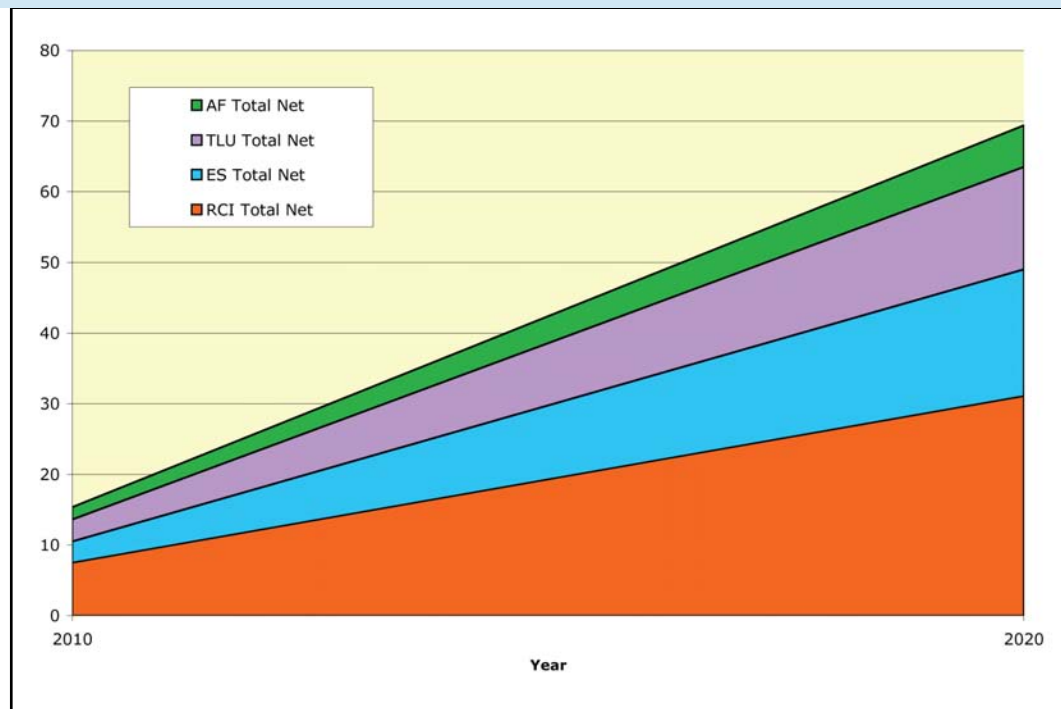
Overarching Recommendation: Set a State Goal to Reduce Arizona’s GHG Emissions to 2000 Levels by 2020 and to 50% below 2000 Levels by 2040.

As an overarching policy matter, the CCAG recommends that Arizona establish a statewide goal of reducing future GHG emissions to a level equal to 2000 emissions by the year 2020 and to 50% below the 2000 emissions level by the year 2040.

The recommended goal for reductions in Arizona’s GHG emissions reflects the CCAG’s policy options recommendations. In fact, the CCAG’s recommended policy options, if fully implemented, could reduce GHG emissions in Arizona by several million metric tons more than the amounts called for in the recommended goal. The CCAG’s policy options could cut Arizona’s GHG emissions by more than 69 MMtCO₂e in 2020, reducing GHG emissions to more than five percent (5%) below the 2000 level. Cumulative GHG emissions reductions from 2007-2020 for all the policy options combined could total more than 485 MMtCO₂e (adjusted for overlap to avoid double-counting of reductions).

Figure E-3 below shows the annual GHG reductions that could be achieved by sector through the CCAG’s recommended policy options from 2010 to 2020. As Figure E-3 illustrates, a significant portion of the achievable reductions are associated with energy efficiency and renewable energy policy options in the residential, commercial, and industrial sectors.

Figure E-3 2010 through 2020 GHG Reductions, by Sector



- AF – Agriculture and Forestry
- TLU – Transportation and Land Use
- ES – Energy Supply
- RCI – Residential Commercial Industrial (fuel use)

The recommended goal for Arizona is consistent with the goals set by other states, including those in the West, that are implementing GHG reduction strategies:

AZ	2000 levels by 2020; 50 percent below 2000 levels by 2040
CA	2000 levels by 2010; 1990 levels by 2020; 80 percent below 1990 levels by 2050
CT	1990 levels by 2010; 10 percent below by 2020; 75 percent below by 2100
MA	1990 levels by 2010; 10 percent below by 2020; 75 percent below by 2100
ME	1990 levels by 2010; 10 percent below by 2020; 75 percent below by 2100
NJ	3.5 percent below 1990 levels by 2005
NM	2000 levels by 2012; 10 percent below by 2020; 75 percent below 2050
NY	5 percent below 1990 by 2010; 10 percent below 1990 levels by 2020
OR	1990 levels by 2010; 10 percent below by 2020; 75 percent by 2050
RI	1990 levels by 2010; 10 percent below by 2020; 75 percent by 2100
WA (Puget Sound)	1990 levels by 2020; 70-80 percent below 1990 levels by 2050

Reducing Arizona's GHG emissions to the recommended levels through full implementation of all of the CCAG's recommendations also would result in significant economic benefits for the state, including substantial economic cost savings, new job creation and enhanced economic development. The Center for Climate Strategies (CCS) has calculated overall net economic cost savings from the CCAG's recommendations of more than \$5.5 billion between 2007-2020, with additional significant cost savings also expected between 2020-2040 (although not calculated by CCS). The CCS also has calculated an average net economic cost savings of nearly \$13 per ton of GHG emissions reduced under the CCAG's recommended policy options (if fully implemented).

The Policy Options

The CCAG is recommending a comprehensive set of forty-nine (49) policy options:

Cross-Cutting (CC) Issues

The CCAG is recommending five (5) policy options to facilitate reductions in Arizona's GHG emissions across economic sectors and address issues associated with climate change. These policy options include:

- Set a State GHG Reduction Goal (as stated above) (CC-1)
- Establish a GHG Emissions Reporting Mechanism (CC-2)
- Establish a GHG Emissions Registry (CC-3)
- Undertake Climate Action Education and Outreach (CC-4)
- Develop a State Climate Change Adaptation Strategy (CC-5)

Residential, Commercial, Industrial and Waste Management (RCI) Sectors

The CCAG is recommending a set of twelve (12) policy options to reduce emissions from the RCI sector, including improving energy efficiency, substituting lower-emissions energy resources, and strategies to reduce emissions from the production of electricity consumed by the RCI sector. The state's rapid growth and limited pursuit of energy efficiency to date offers particularly strong opportunities to reduce emissions through improving the efficiency of buildings, appliances and industrial practices. The RCI policy options include:

- Set Demand-Side Efficiency Goals and Establish Funds, Incentives, and Programs to Achieve Them (RCI-1)
- Establish State Leadership Programs to Achieve Energy Savings and Promote Clean Energy (RCI-2)
- Implement Enhanced Appliance Efficiency Standards (RCI-3)
- Adopt Building Standards/Codes/Design Incentives for Energy Efficiency and Smart Growth (RCI-4 & RCI 5)
- Encourage Distributed Generation of Renewable Energy and Combined Heat and Power (RCI-6 & RCI 7)
- Implement Electricity Pricing Strategies that Support Energy Conservation (RCI-8)
- Promote Low-Global-Warming-Potential Refrigerants in Commercial Operations (RCI-9)
- Provide Incentives for Consumers to Switch to Low GHG Energy Sources (RCI-10)
- Increase Recycling and Solid Waste Management and Reduction (RCI-12)
- Increase Water Use Efficiency and Promote Energy Efficiency and Renewable Energy Production from Water and Wastewater Management (RCI-13)

Energy Supply (ES) Sector

The CCAG is recommending a set of eight (8) policy options to significantly reduce GHG emissions from the ES sector. The principal challenge in addressing GHG emissions from Arizona's electricity sector is the state's extraordinary growth rate and the accompanying projected increase in energy demand. New policies are needed to increase utilization of Arizona's renewable energy resources, like solar, wind, biomass and geothermal, and reduce reliance on pulverized coal technology. The ES policy options include:

- Increase the Environmental Portfolio Standard by 1% each year through 2025 (ES-1)
- Provide Incentives for and Encourage Investment in Renewable Energy (ES-3)
- Explore Development of a National or Regional GHG Cap and Trade Program (ES-4)
- Implement Carbon Intensity Targets (ES-6)
- Reduce Barriers to Renewables and Distributed Generation of Clean Energy (ES-9)
- Implement Net Metering and Advanced Metering for Energy Consumption (ES-10)
- Implement Pricing Strategies to Promote Energy Conservation and Use of Renewable Energy (ES-11)
- Implement Integrated Resource Planning (ES-12)

Transportation and Land Use (TLU) Sector

The CCAG is recommending a set of thirteen (13) policy options to reduce GHG emissions reductions from the TLU sector, including improved vehicle fuel efficiency, increased usage of lower-emissions fuels, greater use of lower-emissions means of travel and land use and other strategies to decrease the growth in fuel use and vehicle miles traveled (VMT). GHG emissions from the TLU sector, which are expected to more than double by 2020 (over 1990 levels), are influenced by transportation technologies and fuels, along with population, economic growth and land use policies that affect the demand for transportation services. The TLU policy options include:

- Adopt the Clean Car Program (TLU-1)
- Implement Policies to Promote Smart Growth Planning, Infill, Increased Density and Transit-Oriented/Pedestrian Friendly Development (TLU-2)
- Promote Multi-Modal Transit (TLU-3)
- Reduce Vehicle Idling (TLU-4)
- Set Standards for Alternative Fuels (TLU-5)
- Provide Incentives for Hybrid Vehicles (TLU-7)
- Explore Feebates (TLU-8)
- Implement a Pilot Program for Pay-As-You-Drive Insurance (TLU-9)

- Encourage Low Rolling Resistance Tires and Promote Proper Tire Inflation (TLU-10)
- Provide Incentives for Accelerated Replacement/Retirement of High-Emitting Diesel Vehicles (TLU-11)
- Increase the Use of Biodiesel (TLU-12)
- Implement Practices and Procurement Policies to Achieve a Lower-GHG-Emitting State Vehicle Fleet (TLU-13)
- Reduce the Speed Limit to 60 mph for Commercial Trucks on Highways/Freeways (TLU-14)

Agriculture and Forestry (AF) Sectors

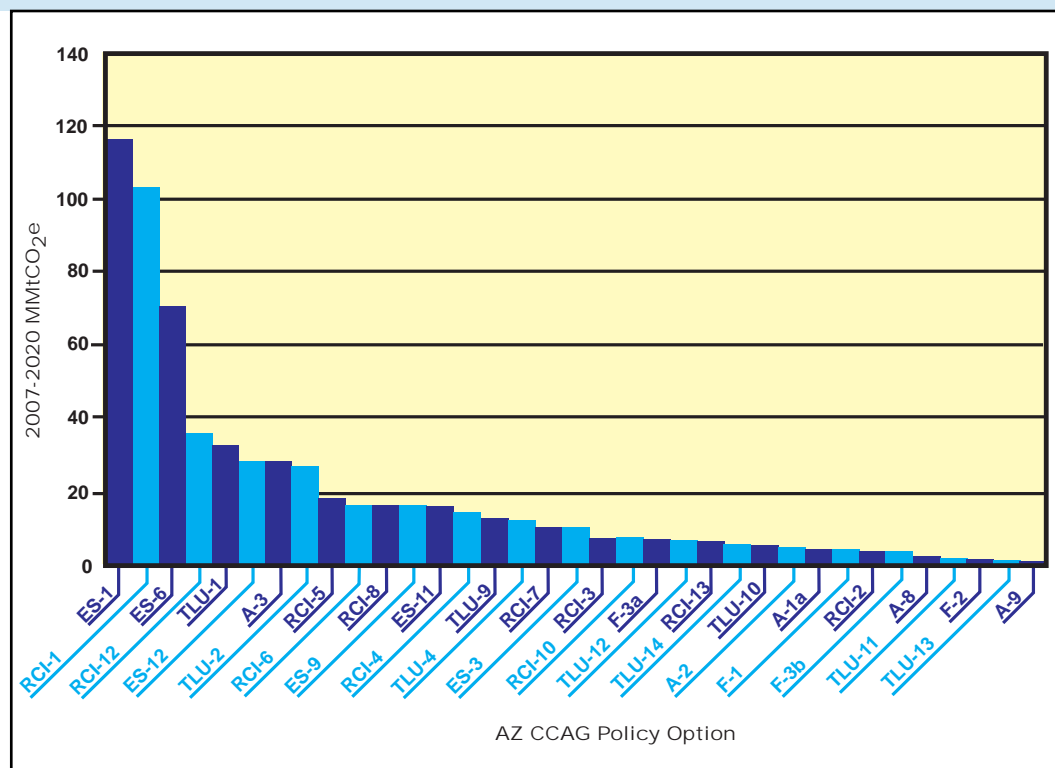
The CCAG is recommending eleven (11) policy options for the AF sectors. While the AF sectors are directly responsible for only a small amount of Arizona's current GHG emissions, there are opportunities for GHG reductions in the sectors, as well as reductions in overall GHG emissions in the state by increased carbon sequestration through new policies and practices in the AF sectors. The AF policy options include:

- Use Manure Digesters to Reduce Methane Emissions from Livestock Operations and Promote Energy Use of the Captured Methane (A-1)
- Use Biomass Feedstocks for Electricity or Steam Production (A-2)
- Increase Ethanol Production and Use (A-3)
- Convert Agricultural Land to Grassland or Forest to Increase Carbon Sequestration (A-7)
- Reduce Conversion of Farm and Rangelands to Developed Uses (A-8)
- Promote Consumption of Locally Produced Agricultural Commodities to Reduce Transportation Emissions (A-9)
- Decrease the Conversion of Forestland to Developed Uses (F-1)
- Increase Reforestation and Restoration of Forestland (F-2)
- Improve Forest Ecosystem Management (F-3a & 3b)
- Improve Commercialization of Biomass Gasification and Combined Cycle Technologies (F-4)

GHG Reductions from the Recommended Policy Options

Figure E-4 below shows the amount of GHG emissions reductions achievable under each individual, quantified policy option cumulatively from 2007-2020, ranked by its GHG reduction potential. The CCS was able to quantify the GHG emissions reduction potential for 35 of the 49 total recommended policy options.

Figure E-4 CCAG Recommended Policy Options, by Quantified Individual GHG Reduction 2007-2020

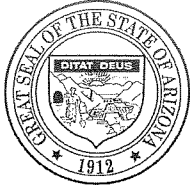


Policy Option	MMtCO ₂ e
Environmental Portfolio Standard/Renewable Energy Standard and Tariff (ES-1)	116.00
Demand-Side Efficiency Goals, Funds, Incentives, and Programs (RCI-1)	103.00
Carbon Intensity Targets (ES-6)	70.40
Solid Waste Management (RCI-12)	36.00
State Clean Car Program (TLU-1)	32.50
Integrated Resource Planning (ES-12)	28.00
Ethanol Production and Use (A-3)	28.00
Smart Growth Bundle of Options (TLU-2)	26.70
“Beyond Code” Building Design Incentives and Programs for Smart Growth (RCI-5)	18.00
Distributed Generation/Combined Heat and Power (RCI-6)	16.00
Electricity Pricing Strategies (RCI-8)	16.00
Reduce Barriers to Renewables and Clean Distributed Generation (ES-9)	16.00
Pricing Strategies (ES-11)	16.00
Building Standards/Codes for Smart Growth (RCI-4)	14.00
Pay-As-You-Drive Insurance (TLU-9)	12.30
Reduction of Vehicle Idling (TLU-4)	11.80
Distributed Generation/Renewable Energy Applications (RCI-7)	10.00
Direct Renewable Energy Support (ES-3) (including Tax Credits and Incentives, R&D, and siting/zoning)	10.00
Appliance Standards (RCI-3)	7.00
Demand-Side Fuel Switching (RCI-10)	7.00
Forest Ecosystem Management – Residential Lands (F-3a)	6.40

Policy Option	MMtCO₂e
Biodiesel Implementation (TLU-12)	6.20
Water Use and Wastewater Management (RCI-13)	6.00
60 mph Speed Limit for Commercial Trucks (TLU-14)	5.20
Low Rolling Resistance Tires and Tire Inflation (TLU-10)	4.80
Biomass Feedstocks for Electricity or Steam Production (A-2)	4.54
Manure Management – Manure Digesters (A-1)	3.82
Forestland Protection from Developed Uses (F-1)	3.73
State Leadership Programs (RCI-2)	3.00
Forest Ecosystem Management – Other Lands (F-3b)	2.90
Reduce Conversion of Farm and Rangelands to Developed Uses (A-8)	1.59
Accelerated Replacement/ Retirement of High-Emitting Diesel Fleet (TLU-11)	1.20
Reforestation/Restoration of Forestland (F-2)	0.65
State Lead-By-Example (via Procurement and SmartWay) (TLU-13)	0.40
Programs to Support Local Farming/Buy Local (A-9)	0.15

The data presented illustrate the potential “stand alone” GHG emissions reductions achievable separately under each individual policy option if the option was implemented solely by itself and not in conjunction with other policy options. The potential GHG emissions reduction figures do not account for overlaps that could occur between reductions achievable under individual policy options if the options were implemented together.

For example, while Figure E-4 shows cumulative GHG emissions reductions of 116 MMtCO₂e for policy option ES-1 as a “stand alone” option, the total would become 70.3 MMtCO₂e if the option were implemented in conjunction with all of the other recommended policy options, due to overlaps (especially with the RCI sector). See pages H-3 to H-4 in Appendix H. The same principle applies for ES-6, which changes from 70.4 MMtCO₂e to 50.3 MMtCO₂e. See page H-18 in Appendix H. When adjusted for overlaps to avoid double counting, the cumulative GHG emissions reductions potentially achievable from 2007-2020 through full implementation of all of the CCAG’s recommended policy options is 485.4 MMtCO₂e. See Table 1-3 on page 24 and footnote 15.



Janet Napolitano
Governor

ARIZONA DEPARTMENT OF ENVIRONMENTAL QUALITY

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Stephen A. Owens
Director

August 30, 2006

The Honorable Janet Napolitano
Governor of the State of Arizona
1700 W. Washington St.
Phoenix, Arizona 85007

Re: Climate Change Action Plan

Dear Governor Napolitano:

On behalf of the Climate Change Advisory Group (CCAG), I am pleased to submit the Climate Change Action Plan, prepared pursuant to Executive Order 2005-02.

The Action Plan is the product of more than a year's effort by the 35-member CCAG and its five Technical Working Groups (TWGs). The full CCAG met six times between July 2005 and June 2006, and the TWGs met a total of 40 times via teleconference during this time.

The Action Plan contains a comprehensive set of 49 recommendations for addressing and reducing greenhouse gas (GHG) emissions in Arizona. Of the 49 policy recommendations adopted by the CCAG, 45 received unanimous consent, two received a supermajority of support and two received a majority of support.

Pursuant to Executive Order 2005-02, the CCAG prepared an inventory and forecast of GHG emissions in Arizona, which found that between 1990 and 2005 Arizona's net GHG emissions increased by nearly 56%. Arizona's GHG emissions are projected to increase by 148% from 1990 to 2020.

As the Action Plan states, "While Arizona's high emissions growth rate presents challenges, it also provides major opportunities. Because more than three-fourths of Arizona's GHG emissions are directly related to energy and transportation, the opportunity exists for Arizona to reduce its GHG emissions while continuing its strong economic growth by being more energy efficient, using more renewable energy sources, building new infrastructure "right" in the first place to produce lower emissions and increasing the use of cleaner transportation modes, technologies and fuels."

On behalf of the CCAG, thank you for the opportunity to participate in this important effort.

Sincerely,

Stephen A. Owens
Director

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ARIZONA CLIMATE CHANGE ADVISORY GROUP

CLIMATE CHANGE ACTION PLAN AUGUST 2006



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G. RCI, and Waste - detailed policy description/analysis	
H. Energy Supply - detailed policy description/analysis	
I. Transportation and Land Use - detailed policy description/analysis	
J. Agriculture and Forestry - detailed policy description/analysis	

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Thomas D. Peterson and The Center for Climate Strategies, whose dedicated team of professionals contributed extraordinary amounts of time, energy and expertise in facilitation of the CCAG process and preparation of the CCAG's documents and recommendations:

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Lewis Lem	David von Hippel
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Special thanks goes as well to the following ADEQ employees, whose excellent service and commitment helped ensure an open, public process that supported the CCAG's work and its recommendations:

Nancy Wrona	Brian Davidson
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Philip Amorosi	Thomas Marcinko
Scott Baggione	Lynn Ott
Emily Bonanni	Steven Peplau
Amber Chapa	Randy Sedlacek
Cortland Coleman	

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A very special "thank you" goes to Cinda Briggs, George Copeland, Ray Palmer, Kate Widland and other staff at the Salt River Project who graciously allowed the use of their conference room facilities for CCAG meetings and provided other support for the CCAG's public meetings.

Finally, the CCAG recognizes the many individuals who participated in the CCAG's sector-based Technical Work Groups. For a complete listing of these individuals by work group, see Appendix C.

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EXECUTIVE SUMMARY

Executive Order 2005-02

On February 2, 2005, Governor Janet Napolitano signed Executive Order 2005-02 establishing the Climate Change Advisory Group (CCAG). Appointed by the Governor, the 35-member CCAG comprised a diverse group of stakeholders who brought broad perspective and expertise to the topic of climate change in Arizona. The Governor's Executive Order directed the CCAG, under the coordination of the Arizona Department of Environmental Quality (ADEQ), to:

- 1) prepare an inventory and forecast of Arizona greenhouse gas (GHG) emissions; and
- 2) develop a Climate Change Action Plan with recommendations for reducing GHG emissions in Arizona.

The Executive Order emphasized that “Arizona and other Western States have particular concerns about the impacts of climate change and climate variability on the environment, including the potential for prolonged drought, severe forest fires, warmer temperatures, increased snowmelt, reduced snow pack and other effects.”

The Executive Order also recognized that “actions to reduce GHG emissions, including increasing energy efficiency, conserving natural resources and developing renewable energy sources, may have multiple benefits including economic development, job creation, cost savings, and improved air quality.”

The CCAG Process

The CCAG held its first meeting on July 14, 2005, followed by a year of intensive fact-finding and consensus building, facilitated by the Center for Climate Strategies (CCS). The CCAG met six times during this period, and five sector-based technical work groups (TWGs) of the CCAG – Energy Supply (ES); Residential, Commercial, Industrial and Waste Management (RCI); Transportation and Land Use (TLU); Agriculture and Forestry (AF); and Cross-Cutting Issues (CC) – met a total of 40 times via teleconference.

The recommendations adopted by the CCAG underwent two levels of screening. First, a potential policy option being considered by a TWG was accepted as a “priority for analysis” and developed for full analysis only if it had a supermajority of support from CCAG members (with a “supermajority” defined as five or fewer “no” votes or objections). Second, after the analyses were conducted, only policy options that received at least majority support from CCAG members were adopted as recommendations by the CCAG and included in this report.

Of the 49 policy recommendations adopted by the CCAG, 45 received unanimous consent, two (2) received a supermajority of support, and two (2) received a majority of support.

Emissions Inventory and Forecast

Prior to the first meeting of the CCAG, a preliminary inventory and forecast of GHG emissions for Arizona for years 1990 through 2020 was produced pursuant to Executive Order 2005-02.

The inventory provided several critical findings, including:

- Between 1990 and 2005 Arizona's net GHG emissions increased by nearly 56%, from an estimated 59.3 million metric tons carbon dioxide equivalent (MMtCO_{2e}) to an estimated 92.6 MMtCO_{2e}.
- Arizona's GHG emissions are forecasted to increase by 148% from 1990 to 2020, taking into account the effects of recent energy efficiency actions adopted by the State. Without these actions emissions growth in 2020 would be forecasted to increase by 159% over 1990 levels.
- The transportation and electricity sectors account for more than three-fourths – roughly 77% – of Arizona's total GHG emissions.

Figure E-1 below shows the relative amount of GHG emissions contributed by each sector in 2000.

Figure E-1 Arizona Greenhouse Gas (GHG) Emissions in 2000

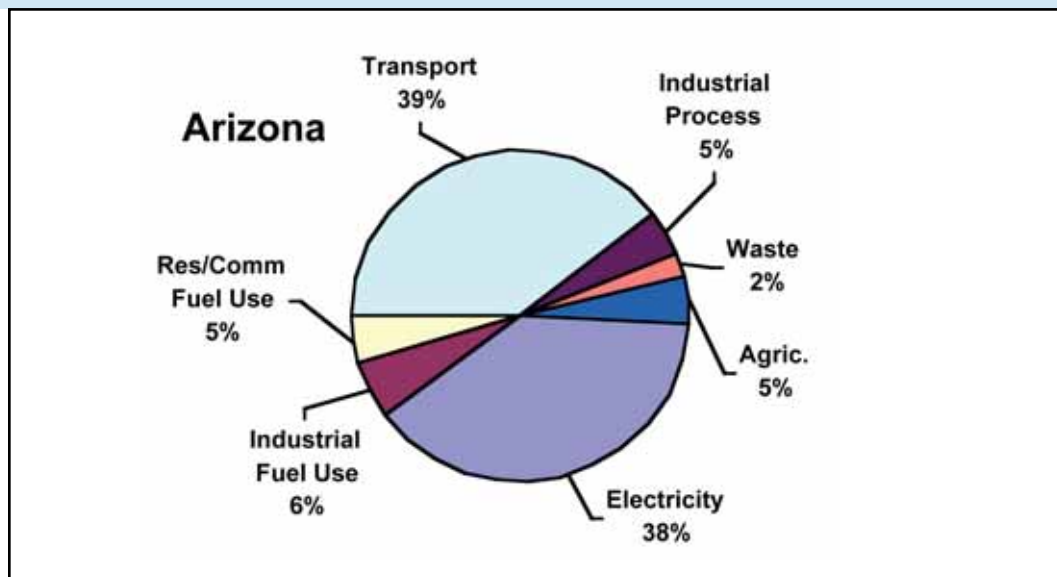
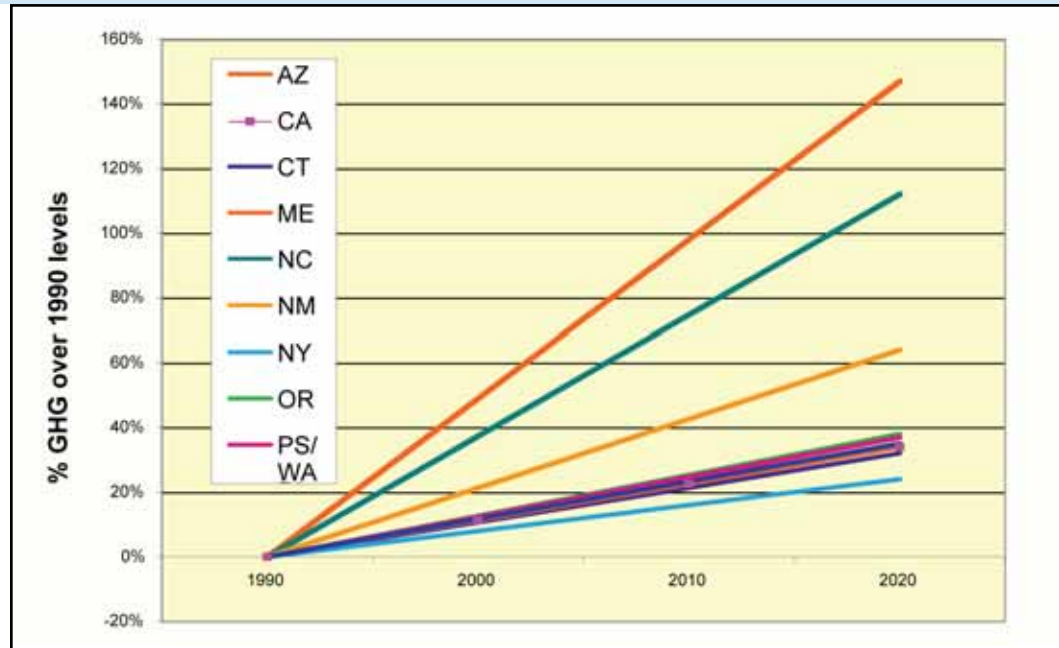


Figure E-2 below shows how Arizona’s projected growth in GHG emissions compares to the growth rates in other states with climate action plans.

Figure E-2 Comparison of 1990-2020 GHG Emissions Growth for States with Climate Plans



While Arizona’s high emissions growth rate presents challenges, it also provides major opportunities. Because more than three-fourths of Arizona’s GHG emissions are directly related to energy and transportation, the opportunity exists for Arizona to reduce its GHG emissions while continuing its strong economic growth by being more energy efficient, using more renewable energy sources, building new infrastructure “right” in the first place to produce lower GHG emissions and increasing the use of cleaner transportation modes, technologies and fuels.

The CCAG’s Recommended Policy Options

The CCAG is recommending a comprehensive set of 49 policy options to reduce GHG emissions in Arizona. The CCAG strongly recommends early and aggressive implementation of the recommendations and a corresponding set of incentives to promote their early adoption. The CCAG believes that early action and implementation of its policy recommendations are critical to put Arizona quickly on the path toward significant emissions reductions. The CCAG also urges that the policy options be implemented as a set, to the greatest extent practicable, to achieve the maximum GHG emissions reductions possible.

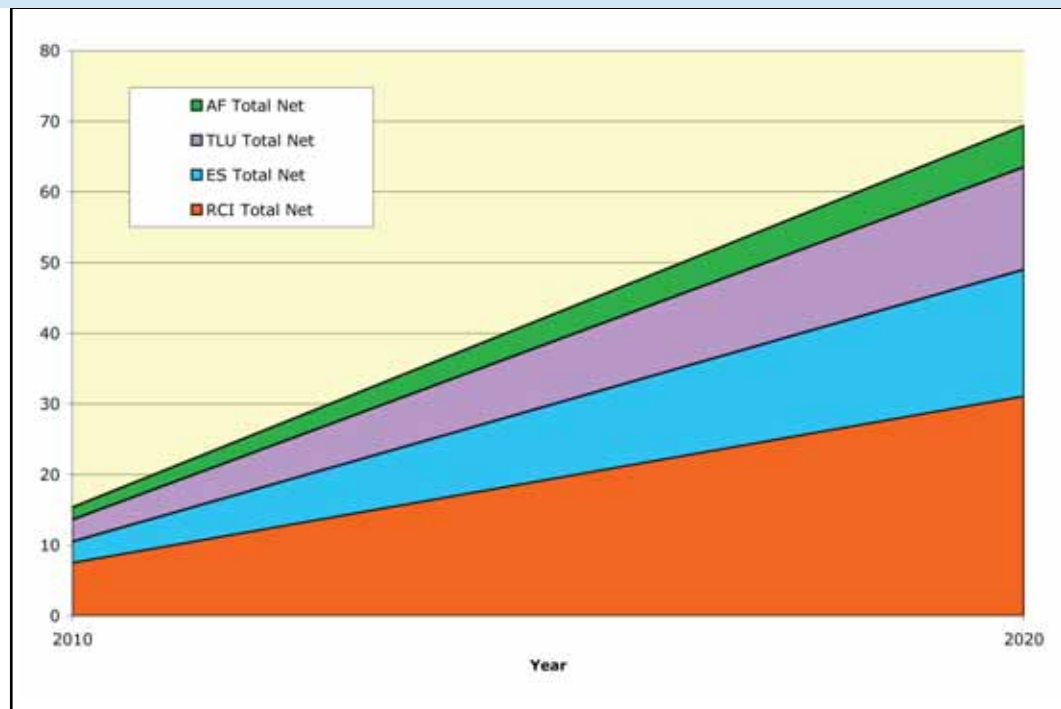
Overarching Recommendation: Set a State Goal to Reduce Arizona’s GHG Emissions to 2000 Levels by 2020 and to 50% below 2000 Levels by 2040.

As an overarching policy matter, the CCAG recommends that Arizona establish a statewide goal of reducing future GHG emissions to a level equal to 2000 emissions by the year 2020 and to 50% below the 2000 emissions level by the year 2040.

The recommended goal for reductions in Arizona’s GHG emissions reflects the CCAG’s policy options recommendations. In fact, the CCAG’s recommended policy options, if fully implemented, could reduce GHG emissions in Arizona by several million metric tons more than the amounts called for in the recommended goal. The CCAG’s policy options could cut Arizona’s GHG emissions by more than 69 MMtCO₂e in 2020, reducing GHG emissions to more than five percent (5%) below the 2000 level. Cumulative GHG emissions reductions from 2007-2020 for all the policy options combined could total more than 485 MMtCO₂e (adjusted for overlap to avoid double-counting of reductions).

Figure E-3 below shows the annual GHG reductions that could be achieved by sector through the CCAG’s recommended policy options from 2010 to 2020. As Figure E-3 illustrates, a significant portion of the achievable reductions are associated with energy efficiency and renewable energy policy options in the residential, commercial, and industrial sectors.

Figure E-3 2010 through 2020 GHG Reductions, by Sector



- AF – Agriculture and Forestry
- TLU – Transportation and Land Use
- ES – Energy Supply
- RCI – Residential Commercial Industrial (fuel use)

The recommended goal for Arizona is consistent with the goals set by other states, including those in the West, that are implementing GHG reduction strategies:

AZ	2000 levels by 2020; 50 percent below 2000 levels by 2040
CA	2000 levels by 2010; 1990 levels by 2020; 80 percent below 1990 levels by 2050
CT	1990 levels by 2010; 10 percent below by 2020; 75 percent below by 2100
MA	1990 levels by 2010; 10 percent below by 2020; 75 percent below by 2100
ME	1990 levels by 2010; 10 percent below by 2020; 75 percent below by 2100
NJ	3.5 percent below 1990 levels by 2005
NM	2000 levels by 2012; 10 percent below by 2020; 75 percent below 2050
NY	5 percent below 1990 by 2010; 10 percent below 1990 levels by 2020
OR	1990 levels by 2010; 10 percent below by 2020; 75 percent by 2050
RI	1990 levels by 2010; 10 percent below by 2020; 75 percent by 2100
WA (Puget Sound)	1990 levels by 2020; 70-80 percent below 1990 levels by 2050

Reducing Arizona's GHG emissions to the recommended levels through full implementation of all of the CCAG's recommendations also would result in significant economic benefits for the state, including substantial economic cost savings, new job creation and enhanced economic development. The Center for Climate Strategies (CCS) has calculated overall net economic cost savings from the CCAG's recommendations of more than \$5.5 billion between 2007-2020, with additional significant cost savings also expected between 2020-2040 (although not calculated by CCS). The CCS also has calculated an average net economic cost savings of nearly \$13 per ton of GHG emissions reduced under the CCAG's recommended policy options (if fully implemented).

The Policy Options

The CCAG is recommending a comprehensive set of forty-nine (49) policy options:

Cross-Cutting (CC) Issues

The CCAG is recommending five (5) policy options to facilitate reductions in Arizona's GHG emissions across economic sectors and address issues associated with climate change. These policy options include:

- Set a State GHG Reduction Goal (as stated above) (CC-1)
- Establish a GHG Emissions Reporting Mechanism (CC-2)
- Establish a GHG Emissions Registry (CC-3)
- Undertake Climate Action Education and Outreach (CC-4)
- Develop a State Climate Change Adaptation Strategy (CC-5)

Residential, Commercial, Industrial and Waste Management (RCI) Sectors

The CCAG is recommending a set of twelve (12) policy options to reduce emissions from the RCI sector, including improving energy efficiency, substituting lower-emissions energy resources, and strategies to reduce emissions from the production of electricity consumed by the RCI sector. The state's rapid growth and limited pursuit of energy efficiency to date offers particularly strong opportunities to reduce emissions through improving the efficiency of buildings, appliances and industrial practices. The RCI policy options include:

- Set Demand-Side Efficiency Goals and Establish Funds, Incentives, and Programs to Achieve Them (RCI-1)
- Establish State Leadership Programs to Achieve Energy Savings and Promote Clean Energy (RCI-2)
- Implement Enhanced Appliance Efficiency Standards (RCI-3)
- Adopt Building Standards/Codes/Design Incentives for Energy Efficiency and Smart Growth (RCI-4 & RCI 5)
- Encourage Distributed Generation of Renewable Energy and Combined Heat and Power (RCI-6 & RCI 7)
- Implement Electricity Pricing Strategies that Support Energy Conservation (RCI-8)
- Promote Low-Global-Warming-Potential Refrigerants in Commercial Operations (RCI-9)
- Provide Incentives for Consumers to Switch to Low GHG Energy Sources (RCI-10)
- Increase Recycling and Solid Waste Management and Reduction (RCI-12)
- Increase Water Use Efficiency and Promote Energy Efficiency and Renewable Energy Production from Water and Wastewater Management (RCI-13)

Energy Supply (ES) Sector

The CCAG is recommending a set of eight (8) policy options to significantly reduce GHG emissions from the ES sector. The principal challenge in addressing GHG emissions from Arizona's electricity sector is the state's extraordinary growth rate and the accompanying projected increase in energy demand. New policies are needed to increase utilization of Arizona's renewable energy resources, like solar, wind, biomass and geothermal, and reduce reliance on pulverized coal technology. The ES policy options include:

- Increase the Environmental Portfolio Standard by 1% each year through 2025 (ES-1)
- Provide Incentives for and Encourage Investment in Renewable Energy (ES-3)
- Explore Development of a National or Regional GHG Cap and Trade Program (ES-4)
- Implement Carbon Intensity Targets (ES-6)
- Reduce Barriers to Renewables and Distributed Generation of Clean Energy (ES-9)
- Implement Net Metering and Advanced Metering for Energy Consumption (ES-10)
- Implement Pricing Strategies to Promote Energy Conservation and Use of Renewable Energy (ES-11)
- Implement Integrated Resource Planning (ES-12)

Transportation and Land Use (TLU) Sector

The CCAG is recommending a set of thirteen (13) policy options to reduce GHG emissions reductions from the TLU sector, including improved vehicle fuel efficiency, increased usage of lower-emissions fuels, greater use of lower-emissions means of travel and land use and other strategies to decrease the growth in fuel use and vehicle miles traveled (VMT). GHG emissions from the TLU sector, which are expected to more than double by 2020 (over 1990 levels), are influenced by transportation technologies and fuels, along with population, economic growth and land use policies that affect the demand for transportation services. The TLU policy options include:

- Adopt the Clean Car Program (TLU-1)
- Implement Policies to Promote Smart Growth Planning, Infill, Increased Density and Transit-Oriented/Pedestrian Friendly Development (TLU-2)
- Promote Multi-Modal Transit (TLU-3)
- Reduce Vehicle Idling (TLU-4)
- Set Standards for Alternative Fuels (TLU-5)
- Provide Incentives for Hybrid Vehicles (TLU-7)
- Explore Feebates (TLU-8)
- Implement a Pilot Program for Pay-As-You-Drive Insurance (TLU-9)

- Encourage Low Rolling Resistance Tires and Promote Proper Tire Inflation (TLU-10)
- Provide Incentives for Accelerated Replacement/Retirement of High-Emitting Diesel Vehicles (TLU-11)
- Increase the Use of Biodiesel (TLU-12)
- Implement Practices and Procurement Policies to Achieve a Lower-GHG-Emitting State Vehicle Fleet (TLU-13)
- Reduce the Speed Limit to 60 mph for Commercial Trucks on Highways/Freeways (TLU-14)

Agriculture and Forestry (AF) Sectors

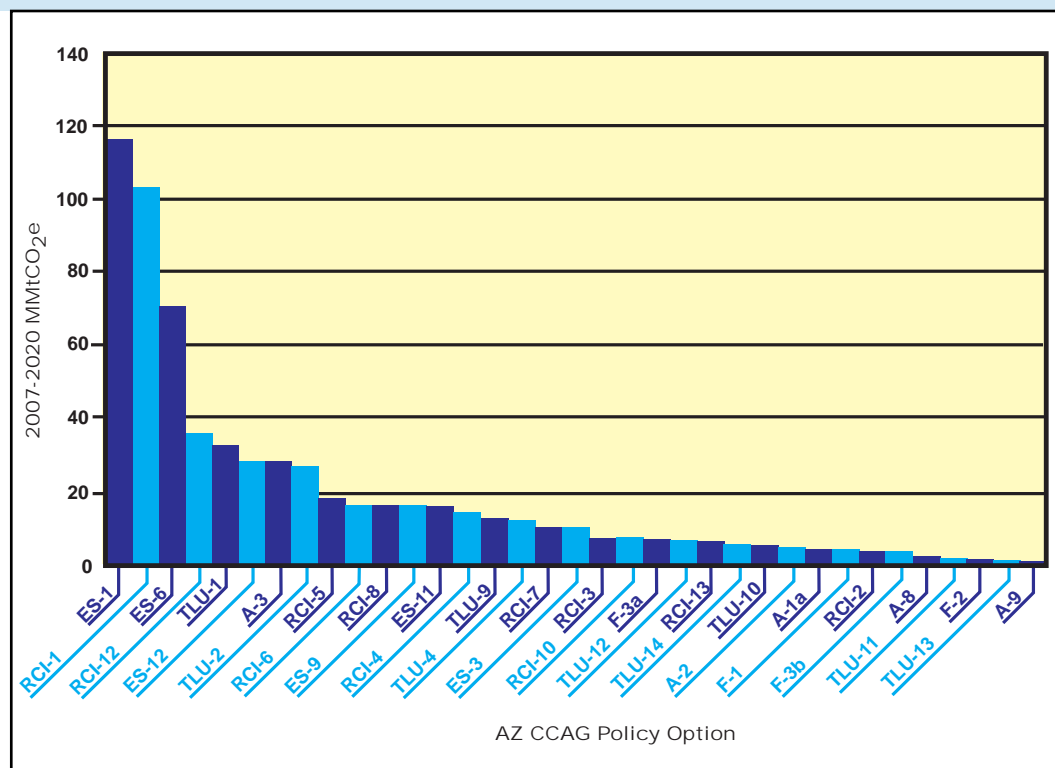
The CCAG is recommending eleven (11) policy options for the AF sectors. While the AF sectors are directly responsible for only a small amount of Arizona's current GHG emissions, there are opportunities for GHG reductions in the sectors, as well as reductions in overall GHG emissions in the state by increased carbon sequestration through new policies and practices in the AF sectors. The AF policy options include:

- Use Manure Digesters to Reduce Methane Emissions from Livestock Operations and Promote Energy Use of the Captured Methane (A-1)
- Use Biomass Feedstocks for Electricity or Steam Production (A-2)
- Increase Ethanol Production and Use (A-3)
- Convert Agricultural Land to Grassland or Forest to Increase Carbon Sequestration (A-7)
- Reduce Conversion of Farm and Rangelands to Developed Uses (A-8)
- Promote Consumption of Locally Produced Agricultural Commodities to Reduce Transportation Emissions (A-9)
- Decrease the Conversion of Forestland to Developed Uses (F-1)
- Increase Reforestation and Restoration of Forestland (F-2)
- Improve Forest Ecosystem Management (F-3a & 3b)
- Improve Commercialization of Biomass Gasification and Combined Cycle Technologies (F-4)

GHG Reductions from the Recommended Policy Options

Figure E-4 below shows the amount of GHG emissions reductions achievable under each individual, quantified policy option cumulatively from 2007-2020, ranked by its GHG reduction potential. The CCS was able to quantify the GHG emissions reduction potential for 35 of the 49 total recommended policy options.

Figure E-4 CCAG Recommended Policy Options, by Quantified Individual GHG Reduction 2007-2020



Policy Option	MMtCO ₂ e
Environmental Portfolio Standard/Renewable Energy Standard and Tariff (ES-1)	116.00
Demand-Side Efficiency Goals, Funds, Incentives, and Programs (RCI-1)	103.00
Carbon Intensity Targets (ES-6)	70.40
Solid Waste Management (RCI-12)	36.00
State Clean Car Program (TLU-1)	32.50
Integrated Resource Planning (ES-12)	28.00
Ethanol Production and Use (A-3)	28.00
Smart Growth Bundle of Options (TLU-2)	26.70
“Beyond Code” Building Design Incentives and Programs for Smart Growth (RCI-5)	18.00
Distributed Generation/Combined Heat and Power (RCI-6)	16.00
Electricity Pricing Strategies (RCI-8)	16.00
Reduce Barriers to Renewables and Clean Distributed Generation (ES-9)	16.00
Pricing Strategies (ES-11)	16.00
Building Standards/Codes for Smart Growth (RCI-4)	14.00
Pay-As-You-Drive Insurance (TLU-9)	12.30
Reduction of Vehicle Idling (TLU-4)	11.80
Distributed Generation/Renewable Energy Applications (RCI-7)	10.00
Direct Renewable Energy Support (ES-3) (including Tax Credits and Incentives, R&D, and siting/zoning)	10.00
Appliance Standards (RCI-3)	7.00
Demand-Side Fuel Switching (RCI-10)	7.00
Forest Ecosystem Management – Residential Lands (F-3a)	6.40

Policy Option	MMtCO₂e
Biodiesel Implementation (TLU-12)	6.20
Water Use and Wastewater Management (RCI-13)	6.00
60 mph Speed Limit for Commercial Trucks (TLU-14)	5.20
Low Rolling Resistance Tires and Tire Inflation (TLU-10)	4.80
Biomass Feedstocks for Electricity or Steam Production (A-2)	4.54
Manure Management – Manure Digesters (A-1)	3.82
Forestland Protection from Developed Uses (F-1)	3.73
State Leadership Programs (RCI-2)	3.00
Forest Ecosystem Management – Other Lands (F-3b)	2.90
Reduce Conversion of Farm and Rangelands to Developed Uses (A-8)	1.59
Accelerated Replacement/ Retirement of High-Emitting Diesel Fleet (TLU-11)	1.20
Reforestation/Restoration of Forestland (F-2)	0.65
State Lead-By-Example (via Procurement and SmartWay) (TLU-13)	0.40
Programs to Support Local Farming/Buy Local (A-9)	0.15

The data presented illustrate the potential “stand alone” GHG emissions reductions achievable separately under each individual policy option if the option was implemented solely by itself and not in conjunction with other policy options. The potential GHG emissions reduction figures do not account for overlaps that could occur between reductions achievable under individual policy options if the options were implemented together.

For example, while Figure E-4 shows cumulative GHG emissions reductions of 116 MMtCO₂e for policy option ES-1 as a “stand alone” option, the total would become 70.3 MMtCO₂e if the option were implemented in conjunction with all of the other recommended policy options, due to overlaps (especially with the RCI sector). See pages H-3 to H-4 in Appendix H. The same principle applies for ES-6, which changes from 70.4 MMtCO₂e to 50.3 MMtCO₂e. See page H-18 in Appendix H. When adjusted for overlaps to avoid double counting, the cumulative GHG emissions reductions potentially achievable from 2007-2020 through full implementation of all of the CCAG’s recommended policy options is 485.4 MMtCO₂e. See Table 1-3 on page 24 and footnote 15.

CHAPTER 1: OVERVIEW

Executive Order 2005-02

On February 2, 2005, Governor Janet Napolitano signed Executive Order 2005-02 establishing the Climate Change Advisory Group (CCAG). Appointed by the Governor, the 35-member CCAG comprised a diverse group of stakeholders who brought broad perspective and expertise to the topic of climate change in Arizona. The Governor's Executive Order directed the CCAG, under the coordination of the Arizona Department of Environmental Quality (ADEQ), to:

- 1) prepare an inventory and forecast of Arizona greenhouse gas (GHG) emissions; and
- 2) develop a Climate Change Action Plan with recommendations for reducing GHG emissions in Arizona.

The Executive Order declared that “scientific consensus has developed that increasing emissions of carbon dioxide (CO₂), methane and other greenhouse gases released to the atmosphere are affecting the Earth's climate” and emphasized that “Arizona and other Western States have particular concerns about the impacts of climate change and climate variability on the environment, including the potential for prolonged drought, severe forest fires, warmer temperatures, increased snowmelt, reduced snow pack and other effects.”

The Executive Order also recognized that “a number of states are addressing climate change and greenhouse gas emissions on an individual and/or regional basis” and declared that “actions to reduce GHG emissions, including increasing energy efficiency, conserving natural resources and developing renewable energy sources, may have multiple benefits including economic development, job creation, cost savings, and improved air quality.”

The CCAG Process

The CCAG held its first meeting on July 14, 2005, followed by a year of intensive fact-finding and consensus building. The CCAG met six times, with its last formal meeting on June 22, 2006. During this period, five sector-based technical work groups (TWGs) of the CCAG met a total of 40 times via teleconference, beginning in August 2005 and concluding in May 2006.

The TWGs consisted of CCAG members as well as other individuals with interest and expertise in the issues being addressed by each TWG. The five TWGs were: Energy Supply (ES); Residential, Commercial, Industrial and Waste Management (RCI); Transportation and Land Use (TLU); Agriculture and Forestry (AF); and Cross-Cutting Issues (CC).

The CCAG process involved a model of informed self-determination through a facilitated stepwise consensus building approach. Under the oversight of ADEQ, the process was conducted by The Center for Climate Strategies (CCS), an independent, expert facilitation and technical analysis

team, based on procedures that CCS consultants have used in a number of other state climate change planning initiatives since 2000, adapted specifically for Arizona.

During the course of the process, the CCAG reached technical consensus on specific mitigation options and evaluative findings related to benefits, costs, and ancillary and feasibility issues associated with options, followed by development of policy consensus on individual recommendations. The CCAG process sought but did not mandate consensus, and it explicitly documented the level of CCAG support for individual policy recommendations and key findings established through a voting process, including barriers to consensus where they existed.

The recommendations adopted by the CCAG and presented in this report underwent two levels of screening by the CCAG. First, a potential policy option being considered by a TWG was accepted as a “priority for analysis” and developed for full analysis only if it had a supermajority of support from CCAG members (with a “supermajority” defined as five or fewer “no” votes or objections). Second, after the analyses were conducted, only policy options that received at least majority support from CCAG members were adopted as recommendations by the CCAG and included in this report.

In total, of the 49 policy recommendations adopted by the CCAG, 45 received unanimous consent, two (2) received a supermajority of support, and two (2) received a majority of support (see later chapters in this report and the Appendices for details).

Arizona GHG Emissions Inventory and Forecast

Prior to the first meeting of the CCAG, a preliminary inventory and forecast of GHG emissions for Arizona for years 1990 through 2020 was produced pursuant to Executive Order 2005-02. This document, entitled “Arizona GHG Emissions Inventory and Reference Case Projections, 1990–2020,” was completed in June 2005, and then approved by unanimous consent at the CCAG’s December 2005 meeting following technical review and revision by the CCAG. This assessment included detailed coverage of all economic sectors and GHGs in Arizona, including future emissions trends and assessment issues related to energy, economic and population growth. Figure 1-1 depicts the level of emissions from each sector in Arizona in year 2000. For comparison, Figure 1-2 shows GHG emissions in the United States as a whole by economic sector.

Figure 1-1 Arizona Greenhouse Gas (GHG) Emissions in 2000

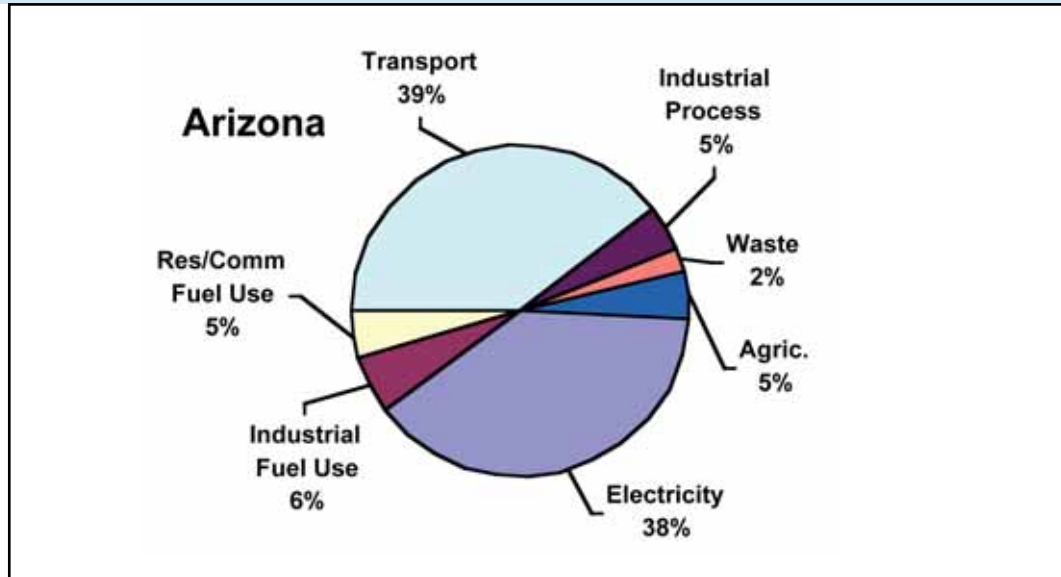
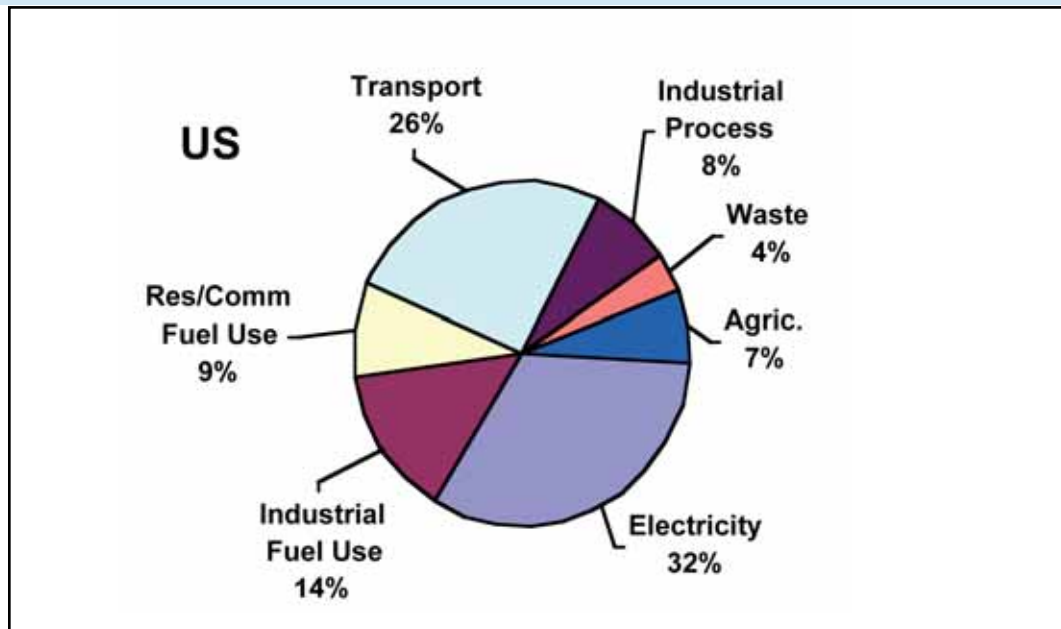


Figure 1-2 US Greenhouse Gas (GHG) Emissions in 2000



The inventory of Arizona's GHG emissions provided several critical findings, including:

- Between 1990 and 2005 Arizona's net GHG emissions increased by nearly 56%, from an estimated 59.3 million metric tons carbon dioxide equivalent (MMtCO₂e) to an estimated 92.6 MMtCO₂e.¹
- Arizona's GHG emissions have increased more than the nation as a whole, driven by Arizona's high population and economic growth combined with relatively high levels of energy use and carbon intensive energy sources, particularly coal and petroleum. The State's GHG emissions are forecasted to increase by 148% from 1990 to 2020², while national emissions are forecasted to rise by about 42% over this same period.³
- Arizona's per capita GHG emissions (the total level of statewide emissions divided by state population) of 14 metric tons carbon dioxide equivalent (tCO₂e) are less than the national average of 22 tCO₂e because of the relative absence of heavy industry in the State and other factors, such as lower than average heating needs for buildings and facilities.
- The transportation and electricity sectors account for more than three-fourths – roughly 77% – of Arizona's total GHG emissions, and are higher than the national average. Both sectors are growing at relatively high rates as well.
- Other fossil fuels usage – such as natural gas, oil products, and coal – in the residential, commercial, and industrial sectors contributes another 11% of the state total, while other industrial processes, agriculture and waste account for about 12% combined.
- The storage of forest carbon was found to have a significant offsetting effect to emissions from other sources.

The emissions forecast revealed substantial emissions growth rates and related policy challenges. Arizona's projected GHG increase of 148% over 1990 levels by the year 2020 (without further mitigation actions) is the highest known projected emissions growth rate in the country.⁴

Arizona's rate is almost five times the average growth rate for the West Coast and Northeastern states that have completed climate action plans. (The average projected GHG emissions growth rate for these states during the 1990-2020 period is 33%.) Figure 1-3 compares Arizona's projected GHG emissions growth with the growth in other states that are addressing their GHG emissions (expressing the increase from 1990-2020 as a percentage of 1990 levels for each state). Figure 1-4 provides a detailed breakdown of forecasted GHG emissions in Arizona by sector.⁵

¹ Arizona's GHG emissions in 2000 were an estimated 82.3 MMtCO₂e, a 40% increase over 1990 levels.

² These growth figures take into account the projected effects of recent energy efficiency related actions for the RCI sectors adopted by the State. Taking these actions into account, Arizona's GHG emissions are projected to be roughly 147 MMtCO₂e in 2020. Without these actions emissions growth in 2020 would be forecasted to increase by 159% over 1990 levels for a total of nearly 154 MMtCO₂e in 2020.

³ U.S. Energy Information Administration CO₂ inventory and forecast data from 1990 to 2030, available at www.eia.doe.gov/environment.html.

⁴ These emissions estimates do not include black carbon and organic carbon contributions, such as soot, smoke and fine particulate matter from diesel emissions. These contributions are difficult to convert into CO₂ equivalents, but application of available methods indicates that black carbon and organic carbon emissions may have accounted for 3 to 6 MMtCO₂e in Arizona in 2002.

⁵ The figures used for projected GHG emission increases do not take into account impacts on energy demand resulting from higher temperatures due to climate change; rather, the figures assumed current, business-as-usual scenarios.

Figure 1-3 Comparison of 1990-2020 GHG Emissions Growth for States with Climate Plans

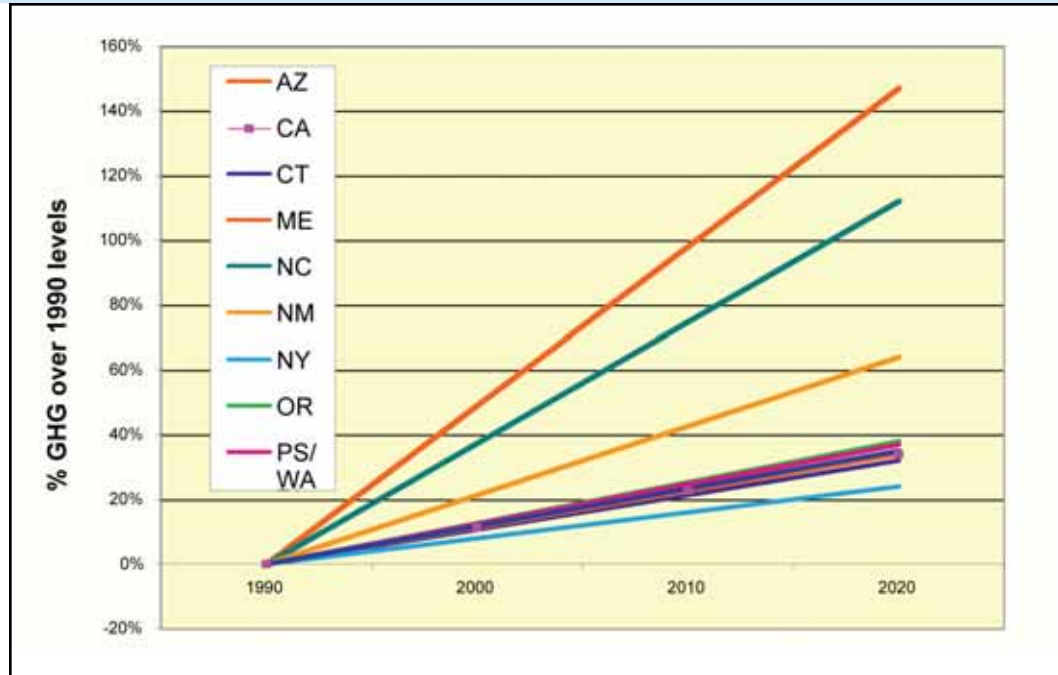
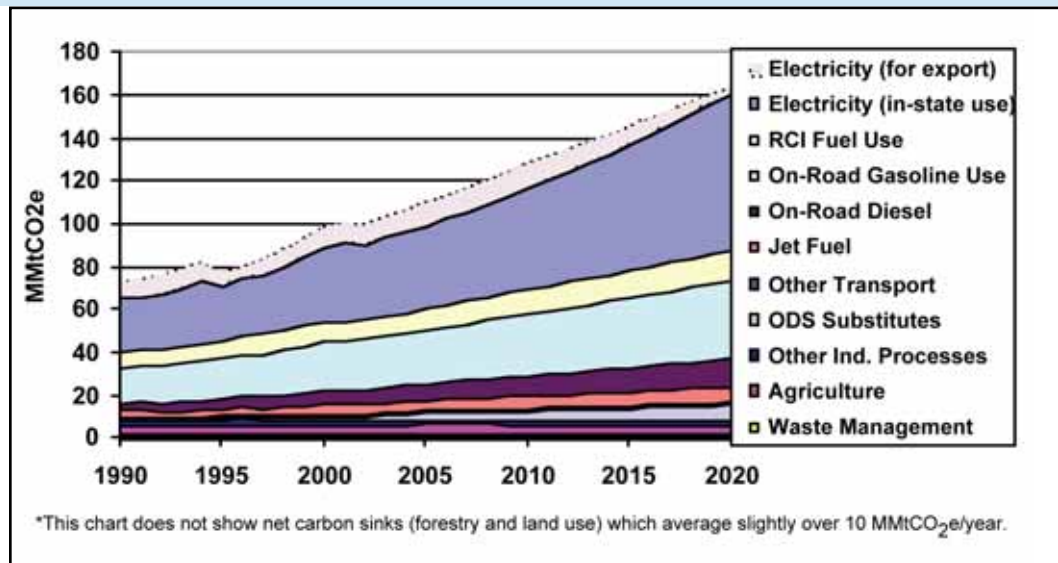


Figure 1-4 Chart of Projected Arizona GHG Emissions from 1990-2020



MMtCO₂e - Million Metric Tons Carbon Dioxide Equivalent

RCI - Residential Commercial Industrial

ODS - Ozone Depleting Substances

While Arizona’s high emissions growth rate presents challenges, it also provides major opportunities. Because more than three-fourths of Arizona’s GHG emissions are directly related to energy and transportation, the opportunity exists for Arizona to reduce its GHG emissions while continuing its strong economic growth by being more energy efficient, using more renewable energy sources, building new infrastructure “right” in the first place to produce lower GHG emissions and increasing the use of cleaner transportation modes, technologies and fuels.

The CCAG's Policy Options

A. The Overarching Recommendation:

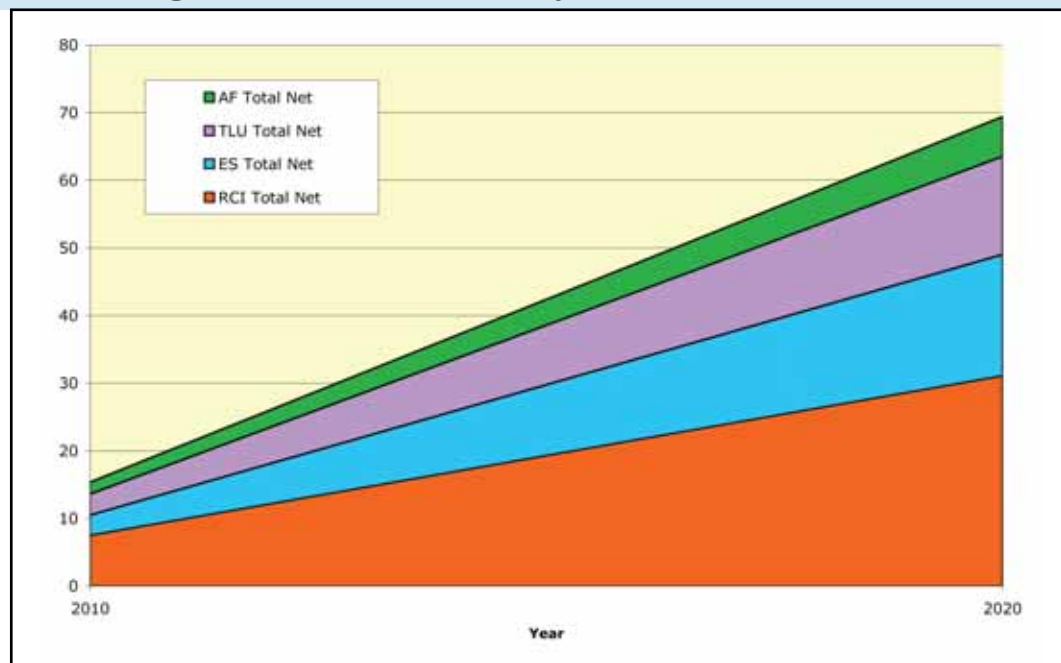
Set a State Goal to Reduce Arizona's GHG Emissions to 2000 Levels by 2020 and to 50% below 2000 Levels by 2040

As an overarching policy matter, the CCAG recommends that Arizona establish a statewide goal of reducing future GHG emissions to a level equal to 2000 emissions by the year 2020, and to 50% below the 2000 emissions level by the year 2040.

The recommended goals for significant reductions in Arizona's GHG emissions reflect the CCAG's recommendations for 49 specific policy recommendations and extensive consideration of benefits, costs, and feasibility issues. In fact, the CCAG's recommended policy options, if fully implemented, could reduce GHG emissions in Arizona by several million metric tons more than the amounts called for in the recommended goal. The CCAG's policy options could cut Arizona's GHG emissions by more than 69 MMtCO₂e in 2020, reducing GHG emissions to more than five percent (5%) below the 2000 level. Cumulative GHG emissions reductions from 2007-2020 for all the policy options combined could total more than 485 MMtCO₂e (adjusted for overlaps to avoid double-counting of reductions).

The GHG reductions between 2010 and 2020 achievable by sector under the CCAG's recommendations are shown in Figure 1-6, which illustrates that a significant portion of the achievable reductions are associated with energy efficiency and renewable energy policy options in the residential, commercial, and industrial sectors.

Figure 1-5 2010 through 2020 GHG Reductions, by Sector



AF – Agriculture and Forestry
TLU – Transportation and Land Use

ES – Energy Supply
RCI – Residential Commercial Industrial (fuel use)

The recommended goal for Arizona is consistent with the goals set by other states, including those in the West, that are implementing GHG reduction strategies. Table 1-1 below shows how the CCAG's recommendation compares to the goals set by other states:

Table 1-1 Greenhouse Gas (GHG) Reduction Goals & Timelines by State

STATE	GHG REDUCTION GOALS & TIMELINES BY STATE
AZ	2000 levels by 2020; 50 percent below 2000 levels by 2040
CA	2000 levels by 2010; 1990 levels by 2020; 80 percent below 1990 levels by 2050
CT	1990 levels by 2010; 10 percent below by 2020; 75 percent below by 2100
MA	1990 levels by 2010; 10 percent below by 2020; 75 percent below by 2100
ME	1990 levels by 2010; 10 percent below by 2020; 75 percent below by 2100
NJ	3.5 percent below 1990 levels by 2005
NM	2000 levels by 2012; 10 percent below by 2020; 75 percent below 2050
NY	5 percent below 1990 levels by 2010; 10 percent below by 2020
OR	1990 levels by 2010; 10 percent below by 2020; 75 percent by 2050
RI	1990 levels by 2010; 10 percent below by 2020; 75 percent by 2100
WA (Puget Sound)	1990 levels by 2020; 70-80 percent below 1990 levels by 2050

While the CCAG's recommended goal calls for a somewhat lower percentage reduction in GHG emissions against a base year of 1990 than in other states, the goal is aggressive in light of Arizona's record projected baseline growth rate. Moreover, the CCAG's recommended goal also is consistent with the scale of reductions estimated by the IPCC and the National Academies of Science (NAS) needed to stabilize future GHG emissions.⁶

The CCAG strongly recommends the early and aggressive implementation of the recommendations in this Action Plan, and a corresponding set of incentives to promote such early adoption. The CCAG believes that early action and implementation of its policy recommendations are critical to put Arizona quickly on the path toward significant emissions reductions. The CCAG also urges that the policy options be implemented as a set, to the greatest extent practicable, to achieve the maximum GHG emissions reductions possible.

⁶ IPCC, Third Assessment Report, Summary for Policymakers, 2001, p. 20. <http://www.ipcc.ch/pub/un/syrenng/spm.pdf>

B. Overview of the Policy Options

The CCAG is recommending a comprehensive set of 49 policy options to reduce GHG emissions in Arizona. These recommendations are summarized in Table 1-2 at the end of this chapter and include: 12 actions in the Residential, Commercial, Industrial and Waste Management (RCI) sectors; 8 actions in the Energy Supply (ES) sector; 13 actions in the Transportation and Land Use (TLU) sector; 11 actions in the (AF) Agriculture and Forestry sectors⁷; and 5 Cross Cutting (CC) issues across all sectors. The detailed descriptions of these recommendations presented in this report and its appendices also include a wide variety of potential implementation approaches considered by the CCAG.

Although not prepared in coordination with other state and regional actions, the recommendations adopted by the CCAG are consistent with and supportive of resolutions adopted by the Western Governors Association (WGA), including those adopted at its June 2006 annual meeting in Sedona, Arizona, pertaining to “Regional and National Policies Regarding Global Climate Change,”⁸ “Clean and Diversified Energy for the West,”⁹ and “Transportation Fuels for the Future,”¹⁰ as well as the recommendations of the WGA’s Clean and Diversified Energy Advisory Committee (CDEAC).¹¹

In addition to substantially reducing Arizona’s GHG emissions, implementation of the CCAG’s recommendations would produce significant economic benefits for the state. The Center for Climate Strategies (CCS) has calculated overall net economic cost savings from the CCAG’s recommendations of more than \$5.5 billion between 2007-2020, with additional significant cost savings also expected between 2020-2040 (although not calculated by the CCS). The CCS also has calculated an average net economic cost savings of nearly \$13 per ton of GHGs removed under the CCAG’s recommended policy options (if fully implemented).

The CCAG’s recommendations also complement other efforts underway, including those by the Growing Smarter Oversight Council, which is addressing issues associated with current and projected growth in Arizona. This underscores the potential co-benefits of the CCAG’s recommended policy options.

Finally, the CCAG has recommended that, while taking action to reduce GHG emissions in Arizona, the Governor also should develop a State climate change adaptation strategy that identifies – and outlines steps for responding to – the potential impacts of climate change on the State. Because of the current build-up in the atmosphere of GHGs and the length of time (100 years or longer) that GHGs like CO₂ will remain in the atmosphere, Arizona will experience the effects of climate change for years to come, even if immediate action is taken to reduce future GHG emissions. As such, it is essential that Arizona develop a strategy to manage the projected impacts of ongoing climate

⁷ Policy options F-3a and F-3b address Forest Ecosystem Management, on residential lands and other lands, respectively. While they are summarized collectively in the narrative of this Action Plan, they are counted separately for the total number of policy options.

⁸ Resolution 06-3 <http://www.westgov.org/wga/policy/06/climate-change.pdf>

⁹ Resolution 06-10 <http://www.westgov.org/wga/policy/06/clean-energy.pdf>

¹⁰ Resolution 06-20 <http://www.westgov.org/wga/policy/06/futurefuels.pdf>

¹¹ <http://www.westgov.org/wga/meetings/am2006/CDEAC06.pdf>

change, and to that end, the CCAG recommends, among other actions, that the Governor consider appointing a task force or advisory group to develop recommendations for the State adaptation strategy.

C. Summary of the Recommended Individual Policy Options

Short summaries of the 49 policy options recommended by the CCAG are listed below.¹² More detailed descriptions of individual policy options can be found in the sector chapters which follow. Fully detailed descriptions of the individual policy options that were presented to and approved by the CCAG can be found in the Technical Appendices.

CROSS-CUTTING (CC) ALL SECTORS

State Greenhouse Gas Reduction Goal (CC-1)

Arizona should establish a statewide GHG reduction target to lower GHG emissions to 2000 levels by 2020 and to 50% below 2000 GHG levels by 2040. The emissions reductions achievable through the specific recommendations adopted by the CCAG can exceed these goals in 2020.

State Greenhouse Gas Reporting (CC-2)

Arizona should implement a GHG reporting mechanism to support tracking and management of GHG emissions. A reporting mechanism will assist in future emissions inventories, promote awareness and action to reduce GHG emissions, and is an essential precursor enabling a GHG registry and possible future trading opportunities. To the greatest extent possible, GHG reporting should be structured collaboratively with other interested states.

State Greenhouse Gas Registry (CC-3)

Arizona should implement a GHG registry mechanism – preferably on a regional basis in concert with other interested states – to enable tracking, management, crediting, and “baseline protection” for entities that reduce GHG emissions.

State Climate Action Education and Outreach (CC-4)

Arizona should undertake extensive climate change education and outreach activities to create a foundation of public awareness to ensure the long-term success of the State’s mitigation and adaptation actions.

State Climate Change Adaptation Strategy (CC-5)

Arizona should develop and implement a comprehensive state climate change adaptation strategy to manage the projected impacts of climate change while simultaneously taking action to reduce its GHG emissions. The Governor may wish to appoint a CCAG-like task force or advisory group to develop this strategy.

¹² More detailed descriptions and discussion of the policy options are presented in chapters 4-8 of this Action Plan and in the Appendices to the Action Plan (see <http://www.azclimatechange.us/template.cfm?FrontID=4670>). Gaps in the numbers sequence of policy options reflect options that the CCAG did not approve for recommendation in this Action Plan.

RESIDENTIAL, COMMERCIAL, INDUSTRIAL (RCI) AND WASTE MANAGEMENT SECTORS

Demand-Side Efficiency Goals, Funds, Incentives, and Programs (RCI-1)

Arizona should set energy savings goals for electricity and natural gas, as well as programs and funding mechanisms to achieve these goals:

- 1) Electricity (energy savings target): 5% savings by 2010, 15% savings by 2020;
- 2) Natural Gas (utility spending target): ramp up to spending 1.5% of gas utility revenues by 2015.

State Leadership Programs (RCI-2)

Arizona should establish “Lead by Example” initiatives to achieve energy cost savings and promote clean energy technologies by the public and private sectors. Initiatives include a further 15% reduction in energy use per square foot in State buildings from 2011 to 2020; standards for new State buildings; green procurement strategies; and promotion of new combined heat and power (CHP) facilities in State buildings.

Appliance Standards (RCI-3)

Arizona should implement State appliance efficiency standards for appliances not covered by federal standards or where higher-than-federal standard efficiency requirements are appropriate.

Building Standards/Codes for Smart Growth (RCI-4)

Arizona should adopt and implement improved energy efficiency building codes, including potentially establishing a statewide code or strongly encouraging local jurisdictions to adopt and maintain state-of-the-art codes.

“Beyond Code” Building Design Incentives and Programs for Smart Growth (RCI-5)

Arizona should ensure that new and existing buildings achieve high levels of energy efficiency by implementing energy performance standards for State-funded and other government buildings, and by providing incentives for private and other buildings.

Distributed Generation/Combined Heat and Power (RCI-6)

Arizona should encourage distributed generation/combined heat and power (DG/CHP) systems through a combination of regulatory changes and incentive programs.

Distributed Generation/Renewable Energy Applications (RCI-7)

Arizona should promote increasing use of renewable distributed generation through direct incentives for system purchase, market-based incentives for system operation (including “net metering”), State goals or directives, and favorable rules for interconnecting renewable generation systems with the electricity grid.



Electricity Pricing Strategies (RCI-8)

Arizona should implement changes in Arizona electricity pricing and tariffs to provide improved incentives for end-users to conserve energy (through inverted block rates) and to adjust the timing of energy use to the extent this reduces GHG emissions.

Mitigating High Global Warming Potential Gas Emissions (RCI-9)

Arizona should consider promoting the use of low “global warming potential” refrigerants in retail food stores, restaurants, and refrigerated transport vehicles (trucks and railcars) through voluntary agreements, specifications, and incentives.

Demand-Side Fuel Switching (RCI-10)

Arizona should encourage consumers to switch from high-carbon fuels (coal and oil) to lower-carbon fuels (natural gas) or “low or zero carbon” energy sources (solar water heating or biofuels) through a combination of incentives and targeted research.

Solid Waste Management (RCI-12)

Arizona should ensure that curbside recycling programs are provided in all communities over 50,000 in population; increase the penetration of recycling in multi-family dwellings; create new recycling programs for the commercial sector (including construction materials); develop markets for recycled materials; increase participation/recovery rates for existing recycling programs; develop a statewide recycling goal; and reduce waste generation.

Water Use and Wastewater Management (RCI-13)

Arizona should accelerate investment in water use efficiency, increase the energy efficiency of all water and wastewater treatment operations, increase renewable energy production by water and wastewater agencies; encourage and create incentives for technologies with the capability to reduce water use associated with power generation; and ensure that power plants use the best management practices and economically feasible technology available to conserve water.

ENERGY SUPPLY (ES) SECTOR

Environmental Portfolio Standard /Renewable Energy Standard and Tariff (ES-1)

Arizona should adopt a more aggressive renewable energy mandate than the current Environmental Portfolio Standard. It would start with the 2005 requirement for 1% renewables and increase it 1% each year to 26% in 2025, allowing out-of-state renewables and renewable energy credits (RECs) trading. Further, the CCAG recommends applying this requirement to generation statewide, not only to Arizona Corporation Commission (ACC) jurisdictional utilities.

Direct Renewable Energy Support (ES-3)

Arizona should encourage investment in renewables by providing direct financial incentives and by removing siting and zoning barriers to renewable energy facilities. *(Note: This recommendation is brought forward by the CCAG jointly with recommendation RCI-7 concerning Distributed Generation/Renewable Energy Applications.)*

GHG Cap and Trade Program (ES-4)

Arizona should explore the development of a regional or national, economy-wide cap and trade program for GHG emissions. *(Note: While this recommendation originated in the Energy Supply workgroup and focused initially on utilities, the CCAG “economy-wide” reference explicitly recommends that a multi-sector cap and trade program be investigated.)*

Carbon Intensity Targets (ES-6)

Arizona should implement a mandatory carbon intensity target that begins in 2010 (i.e., equal to carbon intensity in 2010) and declines by 3 percent annually through 2025. The carbon intensity target would be translated annually into a cap, and trading would be allowed under that cap.

Reduce Barriers to Renewables and Clean Distributed Generation (ES-9)

Arizona should remove barriers to renewable energy and clean distributed generation (DG) to enable more clean generation to enter Arizona’s energy supply mix. This would have the effect of displacing fossil fuel generation, thereby reducing CO₂ emissions. *(Note: This recommendation is brought forward by the CCAG jointly with recommendation RCI-6 concerning Distributed Generation/Combined Heat and Power.)*

Metering Strategies (ES-10)

Arizona should implement two effective metering strategies:

Net metering allows owners of grid-connected distributed generation (generating units on the customer side of the meter) to generate excess electricity and sell it back to the grid, effectively “turning the meter backward.”

Advanced metering allows electricity customers much greater opportunity to manage their electricity consumption, such as setting a meter to turn off or turn down air conditioning while away.



Pricing Strategies (ES-11)

Arizona should implement pricing strategies such as “*real-time pricing*” in which utility customer rates are not fixed, but reflect the varying costs that utilities actually pay for power; “*time-of-use*” rates, which differ for different times of the day and/or different seasons; “*increasing block*” rates whereby prices increase with higher consumption; and *green pricing* whereby customers are given the opportunity to purchase electricity with a renewable or cleaner mix than the standard supply mix offered by the utility.

Integrated Resource Planning (ES-12)

Arizona should implement an Integrated Resource Planning (IRP) process, which integrates technology and policy options on the demand side with supply side options to satisfy anticipated future demand for energy. (Traditional approaches simply focus on supply-side options to meet forecasted load growth.) Demand-side measures include energy efficiency, distributed generation, waste energy recycling, and peak-shaving measures.

TRANSPORTATION AND LAND USE (TLU) SECTOR

State Clean Car Program (TLU-1)

Arizona should adopt the State Clean Car Program emissions standards adopted by 11 states in order to reduce the net emissions of GHGs from passenger vehicle operation. The standards, which must still be approved by the U.S. Environmental Protection Agency (EPA), would take effect in Model Year 2011 (calendar year 2010).

Smart Growth Bundle of Options (TLU-2)

Arizona should implement a bundle of options to reduce GHG emissions through land use practices and policies. The options include:

- 1) infill and brownfield redevelopment;
- 2) transit-oriented development;
- 3) pedestrian and bicycle friendly development;
- 4) smart growth planning, modeling and tools;
- 5) promoting use of multi-modal transit options;
- 6) increased density.

Multi-Modal Transit Options (TLU-3)

Arizona should implement a bundle of options to reduce GHG emissions through land use practices and policies that specifically promote the use of multi-modal transit options.

Reduction of Vehicle Idling (TLU-4)

Arizona should implement policies to reduce idling from diesel and gasoline heavy-duty vehicles, buses, and other vehicles through the combination of a statewide anti-idling rule and by promoting and expanding the use of technologies that reduce heavy-duty vehicle idling. These technologies include:

- 1) automatic engine shut down/start up system controls;
- 2) direct fired heaters (for providing heat only);
- 3) auxiliary power units;
- 4) truck stop electrification.

Standards for Alternative Fuels (TLU-5)

Arizona should develop and enforce a State standard for neat biodiesel (B100), biodiesel blends, and ethanol blends to ensure fuel quality and reduce emissions and performance problems with these fuels, and to enable more widespread acceptance of these fuels.

Hybrid Promotion and Incentives (TLU-7)

Arizona should encourage government programs to promote and incentivize the purchase of hybrid vehicles, including reduction in fees and taxes (such as the State's Vehicle License Tax) and giving preferential infrastructure access to hybrids on carpool lanes or metered parking spaces.

Feebates (TLU-8)

Arizona should study the desirability/feasibility of a "feebate" program to incentivize greater consumer choices and purchase of vehicles that produce lower emissions of GHGs while conserving fuel, including:

- 1) a fee on relatively high emissions/lower fuel economy vehicles and
- 2) a rebate or tax credit on low emissions/higher fuel economy vehicles.

Pay-As-You-Drive Insurance (TLU-9)

Arizona should implement a pilot program to test the feasibility of allowing "pay as you drive" (PAYD) insurance under which insurance rates would be based on the miles driven.

Low Rolling Resistance Tires and Tire Inflation (TLU-10)

Arizona should establish a tire replacement program for low-rolling resistance tires, which manufacturers currently use on new vehicles but are not easily available to consumers as replacement tires. Arizona also should promote proper tire inflation to improve mileage and reduce emissions.

Accelerated Replacement/Retirement of High-Emitting Diesel Fleet (TLU-11)

Arizona should reduce GHG black carbon emissions from heavy-duty diesel vehicles by developing and implementing an incentives program in Arizona to accelerate the replacement and/or retirement of the highest-emitting diesel vehicles.

Biodiesel (TLU-12)

Arizona should implement a series of proposals to increase the use of biodiesel in Arizona.

State Lead-By-Example via Vehicle Procurement and SmartWay (TLU-13)

Arizona state agencies should "lead by example" by adopting procurement policies and practices and/or joining the EPA SmartWay program to achieve a lower-emitting vehicle fleet for the State.

60 MPH Speed Limit for Commercial Trucks (TLU-14)

Arizona should reduce the speed limit for commercial trucks to 60 mph on Arizona highways and freeways.

AGRICULTURE (A) AND FORESTRY (F) SECTORS

Manure Management - Manure Digesters (A-1)

Arizona should reduce methane emissions from livestock manure through the use of manure digesters installed at dairies and promote energy utilization of the methane captured (e.g., electricity production).

Biomass Feedstocks for Electricity or Steam Production (A-2)

Arizona should implement programs to displace fossil fuel use through the use of agricultural waste (e.g., orchard trimmings, and other crop residue) as a feedstock for electricity or steam production.

Ethanol Production and Use (A-3)

Arizona should provide incentives for the production of ethanol from crops, agricultural waste, or other materials to offset fossil fuel (gasoline) use.

Convert Agricultural Land to Grassland or Forest (A-7)

Arizona should increase carbon sequestration in agricultural land by converting marginal land used for annual crops to permanent cover (grassland or forests).

Reduce Conversion of Farm and Rangelands to Developed Uses (A-8)

Arizona should reduce the rate at which existing crop and rangelands are converted to developed uses.

Programs to Support Local Farming/Buy Local (A-9)

Arizona should promote consumption of locally-produced agricultural commodities, which would offset consumption of commodities transported from other states or countries.

Forestland Protection from Developed Uses (F-1)

Arizona should implement policy initiatives to decrease the conversion of forest and woodlands to urban and other developed uses.

Reforestation/Restoration of Forestland (F-2)

Arizona should expand forest cover (and associated carbon stocks) by regenerating or establishing forests in areas with little or no present forest cover.

Forest Ecosystem Management (F-3a & 3b)

Arizona should use 50% or more of biomass extracted from residential and non-residential lands for wood products and/or energy production; accelerate current and planned fuels treatments in Arizona; and have the Governor's Forest Health Oversight Council and Forest Health Advisory Council review forest management practices and policies aimed at GHG reduction and carbon sequestration.

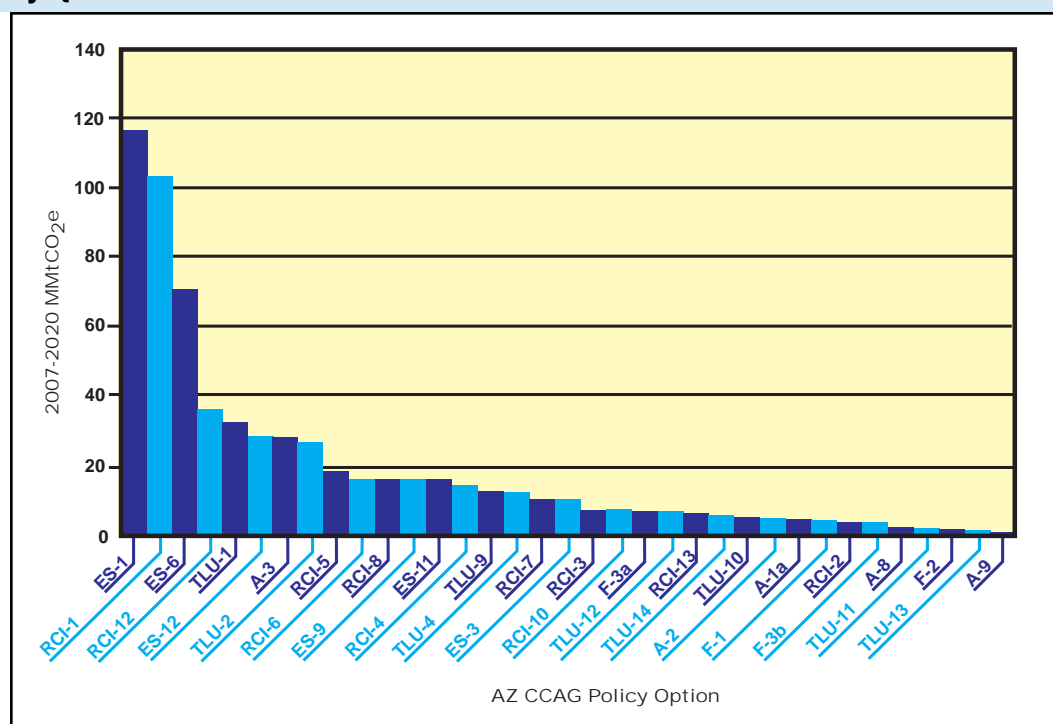
Improved Commercialization of Biomass Gasification and Combined Cycle (F-4)

Arizona should accelerate the rate of technology development and market deployment of biomass gasification and combined cycle (BGCC) technologies.

Policy Option Rankings by Reductions and Savings/Costs

Figures 1-7 and 1-8 and Table 1-2 below show the amount of GHG emissions reductions achievable from 2007-2020 under each individual, quantified policy option.¹³ The CCS was able to quantify the GHG emissions reduction potential for 35 of the 49 total recommended policy options. Figure 1-8 ranks the CCAG’s recommended policy options by total savings/cost per ton GHG removed over this same period.

Figure 1-7 CCAG Recommended Policy Options, by Quantified Individual GHG Reduction 2007-2020

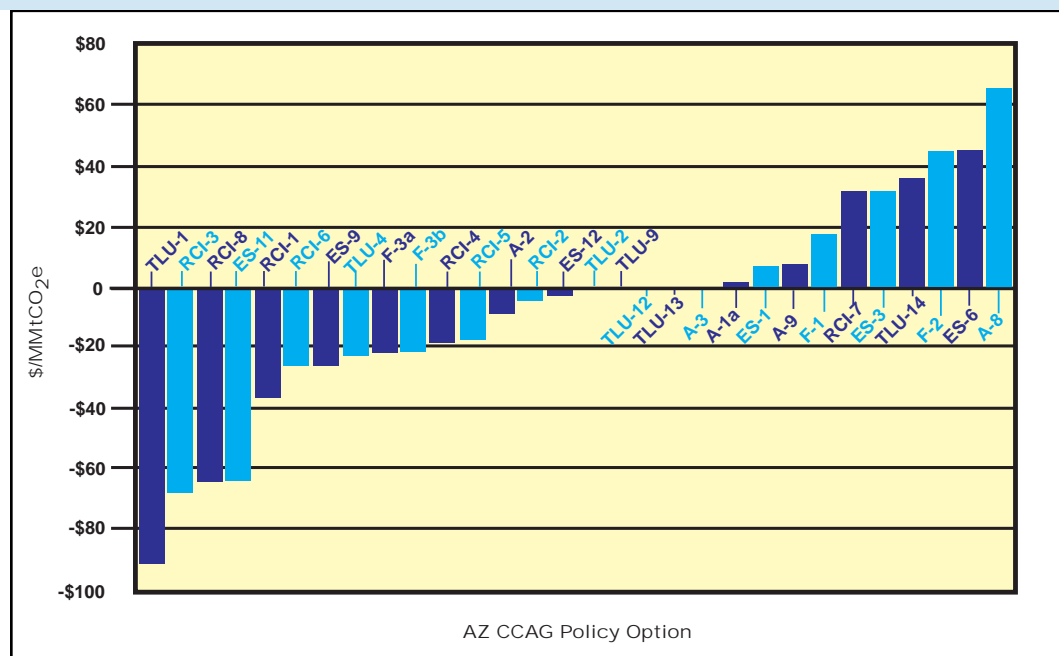


Policy Option	MMtCO ₂ e
Environmental Portfolio Standard/Renewable Energy Standard and Tariff (ES-1)	116.00
Demand-Side Efficiency Goals, Funds, Incentives, and Programs (RCI-1)	103.00
Carbon Intensity Targets (ES-6)	70.40
Solid Waste Management (RCI-12)	36.00
State Clean Car Program (TLU-1)	32.50
Integrated Resource Planning (ES-12)	28.00
Ethanol Production and Use (A-3)	28.00
Smart Growth Bundle of Options (TLU-2)	26.70
“Beyond Code” Building Design Incentives and Programs for Smart Growth (RCI-5)	18.00
Distributed Generation/Combined Heat and Power (RCI-6)	16.00
Electricity Pricing Strategies (RCI-8)	16.00
Reduce Barriers to Renewables and Clean Distributed Generation (ES-9)	16.00
Pricing Strategies (ES-11)	16.00

¹³ Quantification reflects potential GHG reduction if each option is implemented alone, rather than as part of a comprehensive package of CCAG-recommended options. Results would appear lower when overlaps and duplication are taken into account.

Policy Option	MMtCO ₂ e
Building Standards/Codes for Smart Growth (RCI-4)	14.00
Pay-As-You-Drive Insurance (TLU-9)	12.30
Reduction of Vehicle Idling (TLU-4)	11.80
Distributed Generation/Renewable Energy Applications (RCI-7)	10.00
Direct Renewable Energy Support (ES-3) (including Tax Credits and Incentives, R&D, and siting/zoning)	10.00
Appliance Standards (RCI-3)	7.00
Demand-Side Fuel Switching (RCI-10)	7.00
Forest Ecosystem Management – Residential Lands (F-3a)	6.40
Biodiesel Implementation (TLU-12)	6.20
Water Use and Wastewater Management (RCI-13)	6.00
60 mph Speed Limit for Commercial Trucks (TLU-14)	5.20
Low Rolling Resistance Tires and Tire Inflation (TLU-10)	4.80
Biomass Feedstocks for Electricity or Steam Production (A-2)	4.54
Manure Management – Manure Digesters (A-1)	3.82
Forestland Protection from Developed Uses (F-1)	3.73
State Leadership Programs (RCI-2)	3.00
Forest Ecosystem Management – Other Lands (F-3b)	2.90
Reduce Conversion of Farm and Rangelands to Developed Uses (A-8)	1.59
Accelerated Replacement/ Retirement of High-Emitting Diesel Fleet (TLU-11)	1.20
Reforestation/Restoration of Forestland (F-2)	0.65
State Lead-By-Example (via Procurement and SmartWay) (TLU-13)	0.40
Programs to Support Local Farming/Buy Local (A-9)	0.15

Figure 1-8 CCAG Recommended Policy Options, by Quantified Cost Per Ton GHG Removed
Cost savings are shown below the axis. Net costs are shown above the axis.



Policy Option	Cost/Cost Savings per Ton GHG Removed
State Clean Car Program (TLU-1)	-\$90
Appliance Standards (RCI-3)	-\$66
Electricity Pricing Strategies (RCI-8)	-\$63
Pricing Strategies (ES-11)	-\$63
Demand-Side Efficiency Goals, Funds, Incentives, and Programs (RCI-1)	-\$36
Distributed Generation/Combined Heat and Power (RCI-6)	-\$25
Reduce Barriers to Renewables and Clean Distributed Generation (ES-9)	-\$25
Reduction of Vehicle Idling (TLU-4)	-\$22
Forest Ecosystem Management – Residential Lands (F-3a)	-\$21
Forest Ecosystem Management – Other Lands (F-3b)	-\$21
Building Standards/Codes for Smart Growth (RCI-4)	-\$18
“Beyond Code” Building Design Incentives and Programs for Smart Growth (RCI-5)	-\$17
Biomass Feedstocks for Electricity or Steam/Production (A-2)	-\$8
State Leadership Programs (RCI-2)	-\$4
Integrated Resource Planning (ES-12)	-\$2
Smart Growth Bundle of Options (TLU-2)	\$0
Pay-As-You-Drive Insurance (TLU-9)	\$0
Biodiesel Implementation (TLU-12)	\$0
State Lead-By-Example (via Procurement and SmartWay) (TLU-13)	\$0
Ethanol Production and Use (A-3)	\$0
Environmental Portfolio Standard/Renewable Energy Standard and Tariff (ES-1)	\$6
Programs to Support Local Farming/Buy Local (A-9)	\$6
Manure Management – Manure Digesters (A-1)	\$7
Forestland Protection from Developed Uses (F-1)	\$17
Distributed Generation/Renewable Energy Applications (RCI-7)	\$31
Direct Renewable Energy Support (ES-3) (including Tax Credits and Incentives, R&D, and siting/zoning)	\$31
60 mph Speed Limit for Commercial Trucks (TLU- 14)	\$35
Reforestation/Restoration of Forestland (F-2)	\$44
Carbon Intensity Targets (ES-6)	\$44
Reduce Conversion of Farm and Rangelands to Developed Uses (A-8)	\$65

Table 1-2 CCAG Recommended Policy Options, By Sector

RESIDENTIAL, COMMERCIAL, INDUSTRIAL (RCI) AND WASTE MANAGEMENT					
	CCAG Policy Option	2010 Annual GHG Reduction (MMtCO₂e)	2020 Annual GHG Reduction (MMtCO₂e)	2007-2020 Cumulative Reduction (MMtCO₂e)	Cost/Cost Savings Per Ton GHG Removed (\$/tCO₂e)
RCI-1	Demand-Side Efficiency Goals, Funds, Incentives, and Programs	3.1	15.1	103	-\$36
RCI-2	State Leadership Programs	0.04	0.4	3	-\$4
RCI-3	Appliance Standards	0.2	1.0	7	-\$66
RCI-4	Building Standards/Codes for Smart Growth	0.3	2.2	14	-\$18
RCI-5	“Beyond Code” Building Design Incentives and Programs for Smart Growth	0.2	3.1	18	-\$17
RCI-6	Distributed Generation Combined Heat and Power	0.4	2.7	16	-\$25
RCI-7	Distributed Generation Renewable Energy Applications	0.1	2.1	10	\$31
RCI-8	Electricity Pricing Strategies	1.1	1.5	16	-\$63
RCI-9	Mitigating High Global Warming Potential (GWP) Gas Emissions (HFCs, SFCs, PFCs)	Not available			
RCI-10	Demand-Side Fuel Switching	0.1	1.2	7	Not available
RCI-12	Solid Waste Management	2.2	3.7	36	Not available
RCI-13	Water Use and Wastewater Management	0.2	0.8	6	Not available

Notes

Numbers are rounded to the nearest one-tenth.

Cost savings are shown as negative costs. All costs are estimated using a real discount rate of 5% (see Appendix G for details).

RCI-9: Lack of specific policy design and lack of data prevented estimation of tons and costs.

RCI-10: Lack of data prevented estimation of costs.

RCI-12: Lack of data prevented estimation of costs.

RCI-13: Lack of data prevented estimation of costs.

Table 1-2 CCAG Recommended Policy Options, By Sector

ENERGY SUPPLY (ES)					
	CCAG Policy Option	2010 Annual GHG Reduction (MMtCO₂e)	2020 Annual GHG Reduction (MMtCO₂e)	2007-2020 Cumulative Reduction (MMtCO₂e)	Cost/Cost Savings Per Ton GHG Removed (\$/tCO₂e)
ES-1	Environmental Portfolio Standard/Renewable Energy Standard and Tariff	4.2	16.4	116.0	\$6
ES-3	Direct Renewable Energy Support (including Tax Credits and Incentives, R&D, and siting/zoning)	0.1	2.1	10.0	\$31
ES-4	National or Regional GHG Cap and Trade	- 0.28— 0.18	2.0— 18.5	7 - 88	\$7 - \$19
ES-6	Carbon Intensity Targets	0.0	14.0	70.4	\$44
ES-9	Reduce Barriers to Renewables and Clean Distributed Generation	0.4	2.7	16.0	-\$25
ES-10	Metering Strategies	Not available			
ES-11	Pricing Strategies	1.1	1.5	16.0	-\$63
ES-12	Integrated Resource Planning	0.1	5.4	28.0	-\$2

Notes

Cost savings are shown as negative costs. All costs are estimated using a real discount rate of 5% (see Appendix H for details).

ES-3: This option is quantified under RCI-7, Distributed Generation/Renewable Energy Applications. Values are shown above for completeness, but not included in cumulative totals to prevent double-counting.

ES-4: These estimates are based on U.S. Energy Information Administration (EIA) modeling of a national cap-and-trade policy and the likely impact on Arizona's power sector based on simple apportionment. The above values reflect the range of results for GHG reductions and costs from four scenarios modeled by EIA. These values are not included in the cumulative totals because Arizona cannot implement a national or regional cap-and-trade policy unilaterally and to avoid duplicative counting of reductions based on overlaps with other policy option recommendations.

ES-9: This option is quantified under RCI-6, Distributed Generation/Combined Heat and Power. Values are shown above for completeness, but not included in cumulative totals to prevent double-counting.

ES-10: This option is an enabling policy for RCI-6 and RCI-7; its quantification is incorporated as part of those options.

ES-11: This option is quantified under RCI-8, Electricity Pricing Strategies. Values are shown above for completeness, but not included in cumulative totals to prevent double-counting.

ES-12: This option overlaps substantially with ES-1, Environmental Portfolio Standard, and ES-6, Carbon Intensity Targets. Values are shown above for completeness, but not included in cumulative totals to prevent double-counting.

Table 1-2 CCAG Recommended Policy Options, By Sector

TRANSPORTATION AND LAND USE (TLU)					
	CCAG Policy Option	2010 Annual GHG Reduction (MMtCO₂e)	2020 Annual GHG Reduction (MMtCO₂e)	2007-2020 Cumulative Reduction (MMtCO₂e)	Cost/Cost Savings Per Ton GHG Removed (\$/tCO₂e)
TLU-1	State Clean Car Program	0.3	5.6	32.5	-\$90
TLU-2	Smart Growth Bundle of Options	1.5	4.0	26.7	\$0
TLU-3	Promoting Multimodal Transit	Not available			
TLU-4	Reduction of Vehicle Idling	0.7	1.3	11.8	-\$22
TLU-5	Standards for Alternative Fuels	Not available			
TLU-7	Hybrid Promotion and Incentives	Not available			
TLU-8	Feebates	Not available			
TLU-9	Pay-As-You-Drive Insurance	0.0	2.8	12.3	\$0
TLU-10	Low Rolling Resistance Tires and Tire Inflation	0.0	0.8	4.8	Not available
TLU-11	Accelerated Replacement/ Retirement of High-Emitting Diesel Fleet	0.2	0.03	1.2	Not available
TLU-12	Biodiesel Implementation	0.1	1.1	6.2	\$0
TLU-13	State Lead-By-Example (via Procurement and Smart Way)	0.03	0.04	0.4	\$0
TLU-14	60 mph Speed Limit for Commercial Trucks	0.3	0.5	5.2	\$35

Notes

Cost savings are shown as negative costs. All costs are estimated using a real discount rate of 5% (see Appendix I for details).

TLU-3: This option was analyzed in tandem with TLU-2; its quantification is incorporated as part of that option.

TLU-5: This option is an enabling policy for TLU-12 and A-3; its quantification is incorporated as part of those options.

TLU-7: This option overlaps substantially with TLU-1; its quantification is incorporated as part of that option.

TLU-8: This option overlaps substantially with TLU-1. Insufficient data prevented estimation of cumulative GHG reductions and costs.

TLU-10: Insufficient data prevented estimation of costs.

TLU-11: Insufficient data prevented estimation of costs.

Table 1-2 CCAG Recommended Policy Options, By Sector

AGRICULTURE (A) AND FORESTRY (F)					
	CCAG Policy Option	2010 Annual GHG Reduction (MMtCO₂e)	2020 Annual GHG Reduction (MMtCO₂e)	2007-2020 Cumulative Reduction (MMtCO₂e)	Cost/Cost Savings Per Ton GHG Removed (\$/tCO₂e)
A-1	Manure Management – Manure Digesters	0.2	0.5	3.8	\$1
A-2	Biomass Feedstocks for Electricity or Steam Production	0.05	0.1	4.5	-\$8
A-3	Ethanol Production and Use	0.5	4.0	28.0	\$0
A-7	Convert Agricultural Land to Forest or Grassland	Not available			
A-8	Reduce Conversion of Farm & Rangelands to Developed Uses	0.1	0.2	1.6	\$65
A-9	Programs to Support Local Farming/Buy Local	0.01	0.02	0.1	\$6
F-1	Forestland Protection from Developed Uses	0.3	0.3	3.7	\$17
F-2	Reforestation/Restoration of Forestland	0.02	0.1	0.6	\$44
F-3a	Forest Ecosystem Management – Residential Lands	0.5	0.5	6.4	-\$21
F-3b	Forest Ecosystem Management – Other Lands	0.2	0.2	2.9	-\$21
F-4	Improved Commercialization of Biomass Gasification and Combined Cycle	Not available			

Notes

Cost savings are shown as negative costs. All costs are estimated using a real discount rate of 5% (see Appendix J for details).

A-7: Lack of specific policy design and lack of data prevented estimation of tons and cost.

F-4: This option overlaps substantially with F-3a and 3b, thus it was not estimated to prevent double-counting.

The GHG emissions reductions estimate for each policy option in Table 1-2 is presented as a “stand alone” figure, indicating the potential GHG emissions reductions achievable if the particular policy option was implemented solely by itself and not in conjunction with other policy options. To estimate the total quantity of GHG emissions reductions achievable if all of the CCAG’s recommended policy options were implemented together, the potential cumulative GHG emissions reduction figure for the combined policy options must be adjusted to account for overlaps between individual policy options to avoid double-counting of potential reductions.

For example, there would be overlaps between and among policy options in the RCI and ES sections, as reductions in electricity demand could also result in lower electricity production. As such, again for example, while ES-1 has a “stand alone” reduction estimate of 116 MMtCO_{2e} cumulatively from 2007-2020, the potential reductions from this policy option are an estimated 70.3 MMtCO_{2e} if all of the CCAG’s policy options were implemented together as a comprehensive package. See page H3 in Appendix H. The same principle would apply to ES-6, which would change from a “stand alone” GHG emissions reduction estimate of 70.4 MMtCO_{2e} to 50.3 MMtCO_{2e} cumulatively from 2007 to 2020 if it were implemented as part of a comprehensive package. See page H3 in Appendix H.

Table 1-3 below shows the total estimated GHG emissions reductions achievable if all of the CCAG’s recommended policy options were implemented together, with the appropriate adjustments made to account for overlaps and avoid double-counting of emissions reductions.

Table 1-3 Totals			
Total of all CCAG Options with Adjustments for Overlap (Detailed data may be found in the Tables presented in Chapters 4-8 and the Appendices.)	2010 Annual GHG Reduction (MMtCO_{2e})	2020 Annual GHG Reduction (MMtCO_{2e})	2007-2020 Cumulative Reduction (MMtCO_{2e})
	15.4	69.4	485.4 ¹⁴

The Center for Climate Strategies (CCS) has calculated overall net economic cost savings from the CCAG’s policy option recommendations of more than \$5.5 billion from 2007-2020. The CCS also has calculated that the average cost for each ton of GHGs removed would be -\$12.74, meaning that there would be a net economic cost savings of \$12.74 for each ton of GHGs removed.¹⁵

¹⁴ As noted, the potential cumulative GHG reduction figures have been adjusted to account for overlaps between reductions achievable under individual policy options to avoid double-counting of potential GHG emissions reductions. The CCAG notes that the cumulative figure represents the total potential GHG emissions reductions achievable if all of the recommended policy options are implemented and acknowledges that there may be challenges to full implementation of all the recommended policy options. The CCAG also notes that the cumulative figures do not include any potential emissions reductions from ES-4 Cap and Trade because only a range of estimates is presented in Table 1-2. The cumulative figures would be higher if reductions from a cap and trade program were included.

¹⁵ The overall net economic cost savings figure of more than \$5.5 billion and the average \$12.74 per ton net savings figure are based on the savings/costs for the cumulative GHG emissions reductions for which CCS was able to estimate savings/cost data, as indicated in Table 1-2, adjusted for overlaps to prevent double-counting of reductions.

CHAPTER 2: IMPACTS OF CLIMATE CHANGE

While some CCAG members may hold differing opinions about the science of climate change, the CCAG agreed at the outset of its deliberations not to debate climate change science in order to achieve the directive of Executive Order 2005-02 and move the CCAG process forward.¹⁶

As Governor Napolitano's Executive Order stated, a growing scientific consensus has emerged that increasing emissions of carbon dioxide, methane, nitrous oxides, and other GHGs are affecting the Earth's climate. The work of the Intergovernmental Panel on Climate Change (IPCC) represents this consensus.¹⁷ According to the IPCC, human activities, particularly the burning of fossil fuels such as coal and petroleum, have added measurably to the natural background levels of GHGs in the atmosphere, which in turn has contributed to rising global temperatures.¹⁸

The IPCC estimates that the Earth's surface temperature increased by about 1 degree Fahrenheit during the past century, with much of that warming occurring during the past two decades. The hottest 22 years on record have occurred since 1980; the hottest 10 years on record have all occurred since 1990; and 2005 was the hottest year ever recorded. According to the IPCC, most of the observed warming over the last 50 years is likely due to increased GHG concentrations attributable to human activities (see Figure 2-1 below).¹⁹

¹⁶ On September 29, 2005, many CCAG members participated in an informal background briefing on the causes and impacts of climate change presented by Dr. Andrew Comrie, Professor of Atmospheric Sciences, University of Arizona.

See <http://www.azclimatechange.us/ewebeditpro/items/O40F7043.pdf>

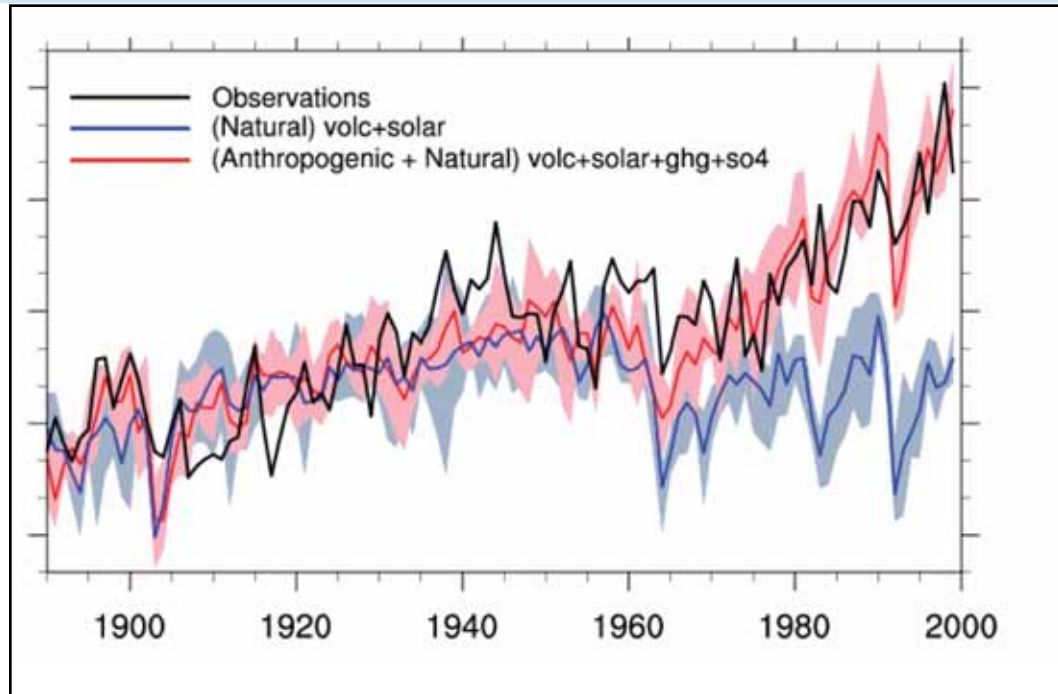
¹⁷ The IPCC is composed of thousands of scientists (including several from Arizona, such as Dr. Jonathan Overpeck, Professor of Geosciences, University of Arizona, and director of the University's Institute for the Study of Planet Earth) representing the parties to the United Nations Framework Convention on Climate Change (UNFCCC), and was formed to provide assessments of climate science, impacts, and mitigation policy to the parties to the UNFCCC every five years.

See <http://www.ipcc.ch>.

¹⁸ IPCC, Third Assessment Report (2001) www.ipcc.ch.

¹⁹ IPCC, Third Assessment Report (2001) The IPCC's Fourth Assessment Report is due in 2007. The National Academy of Sciences affirmed the IPCC conclusions in its 2001 report titled "Climate Change Science: An Analysis of Some Key Questions," <http://newton.nap.edu/catalog/10139.html>.

**Figure 2-1 Observed Temperatures and Two Simulations:
Natural vs. Anthropogenic Plus Natural²⁰**



(Figure courtesy of Dr. Gerald Meehl, National Center for Atmospheric Research.)

Future increases in global temperature are projected to occur with increased atmospheric GHG concentrations unless action is taken to reduce total annual GHG emissions. According to the IPCC, worldwide consequences of increased temperatures due to the build-up of GHGs in the atmosphere are likely to include increased warming of the earth, and enhanced heat stress, natural and human water system needs, melting glaciers and ice caps, sea level rise, increased severe weather events, flooded coastal and lowland communities, more frequent and intense tropical storms and hurricanes, expanded drought, expansion of tropical disease risk, and other serious occurrences.²¹

²⁰ IPCC scientists use climate models to simulate the observed temperature changes over the last century attributable to atmospheric “forcings,” both natural and anthropogenic (a forcing can be a warming or cooling effect).

Figure 2-1 compares the results for two simulations:

- (1) The blue line shows a simulation of natural forcing (solar variation and volcanic activity).
- (2) The red line shows the simulation of natural forcing plus anthropogenic forcing, i.e., GHG gases and sulfate aerosols (which have a cooling effect).

Actual temperature observations are shown in a black line representing deviations from the average of temperatures from 1890-1999.

²¹ IPCC, Third Assessment Report (2001)

Impacts in Arizona and the West

Over the past 50 years, the climate in the western United States has warmed on average by 1.4 degrees Fahrenheit. IPCC climate models predict that further June to August temperature increases of 3.6 to 9.0 degrees Fahrenheit are possible by 2040 to 2069 for western North America,²² while the most extreme warming scenario currently considered possible suggests that annual mean temperatures in the southwestern United States could increase potentially by up to 14 degrees Fahrenheit before the end of the century.²³ A warmer climate could mean less winter snowfall, more winter rain and a faster, earlier snowmelt in Arizona's mountains.

Higher temperatures and increased evaporation also could lower reservoir levels, lake levels, and stream flows in the summer. Lower stream flows could concentrate pollutant levels and increase salinity, a critical water quality problem in Arizona. Less water would be available to support irrigation, hydropower production, public and industrial supply, fish and wildlife habitat, and recreation. More winter rain, coupled with more rapid snowmelt, could contribute to winter and spring flooding. Meanwhile, less spring and summer aquifer recharge could exacerbate already-declining water levels in parts of the state that depend on groundwater withdrawals for irrigation and municipal supply. With continued population growth, water demand could outpace water supply in areas of the State.

Even conservative estimates of climate change predict significant potential impacts on the Colorado River system by the end of this century due to decreased snowfall and snow pack and increased evaporation, including a 15% reduction in annual runoff; a 40% decrease in basin storage; and a decline in hydroelectric power production to 45 to 56% of the historical average. The date of peak spring runoff could continue to advance, coming more than a month earlier in many Western rivers by the century's end.²⁴

Further, climate change could reduce Arizona's forested areas by 15 to 30%, with hotter, drier weather conditions increasing the already-high potential for more frequent, intense wildfires that threaten both forests and property.²⁵ Milder, drier winters could also increase the likelihood of insect outbreaks and wildfires that result from the accumulation of dead wood on the forest floor.

Arizona is already experiencing the effects of a hotter, drier climate. Due in part to a decade-long drought and warmer temperatures, Arizona's fire season began earlier (in February) this year (2006) than ever before. Moreover, the two worst wildfires in Arizona history have occurred in just the last few years:

²² Professor Steven Running, Numerical Terradynamic Simulation Group, University of Montana; published July 6, 2006 in ScienceXpress, the online version of the journal Science; 10.1126/science.1130370.

²³ Stainforth et al., Nature, Vol 433, 27 January 2005; www.nature.com/nature.

²⁴ From presentation of Dr. Andrew Comrie, Professor of Atmospheric Sciences, University of Arizona, to the CCAG. See <http://www.azclimatechange.us/ewebeditpro/items/O40F7043.pdf>

²⁵ U.S. Environmental Protection Agency Fact Sheet 236-F-98-007c, "Climate Change and Arizona" [http://yosemite.epa.gov/OAR/globalwarming.nsf/UniqueKeyLookup/SHSU5BNJMV/\\$File/az_impct.pdf](http://yosemite.epa.gov/OAR/globalwarming.nsf/UniqueKeyLookup/SHSU5BNJMV/$File/az_impct.pdf)

the Rodeo-Chediski fire in 2002, which consumed nearly 500,000 acres; and the Cave Creek Complex fire in 2005, which burned nearly 250,000 acres.²⁶ The drought and warmer winter temperatures also have contributed to bark beetle infestations in the State's forests, killing thousands of pine trees and adding to the already-severe fire risk. The State's two driest years in more than a century occurred in 2002 and 2006, respectively, and coincided with the two lowest levels of run-off ever recorded due to decreased snowfall. The 2006 spring runoff season, which measures snowmelt from January through May, provided just 121,000 acre-feet of water this year (2006), as compared to 665,000 acre-feet normally.²⁷

Climate change could likewise significantly alter Arizona's agricultural crop production, which is heavily dependent on irrigation.²⁸ Cotton yields could decline by 5 to 11% and wheat yields by as much as 70% as temperatures rise beyond the tolerance levels for the crop, particularly with reduced water availability. Livestock production, which accounts for about half of the State's annual agriculture industry, could also suffer, as livestock tend to gain less weight in hotter, drier conditions and when pasture yields decline, limiting forage.²⁹ The potential increased susceptibility of crops and livestock caused by these stressors, combined with reduced die-back of pests and diseases resulting from milder winters, could exacerbate these impacts.

A changing climate also could exacerbate Arizona's air pollution problems. During the winter of 2005-06, the Phoenix metropolitan area suffered a record-breaking 143 consecutive days without measurable precipitation, which contributed to unprecedented levels of particulate matter pollution (referred to as PM10) in the area. Between November 1, 2005 and March 15, 2006, the Phoenix metropolitan area exceeded the federal standard for PM10 on 30 days, and the Arizona Department of Environmental Quality (ADEQ) issued 25 High Pollution Advisories, more than in the previous decade combined. Increased temperatures also could contribute to increased ozone concentrations in the Phoenix metropolitan area during summer months.

²⁶ A July 6, 2006 study published in ScienceXpress, the online version of the journal Science, linked climate change to larger, longer-lasting wildfires in the Western United States and found that the worst fires (1,000 acres or more) occurred in years with warmer springs and earlier snowmelts. More acreage and larger fires burned in the West between 1987 and 2003 than in the previous 16-year span. See "Warming and Earlier Spring Increases Western U.S. Forest Wildfire Activity" <http://www.sciencemag.org/cgi/rapidpdf/1128834.pdf>. Dr. Thomas Swetnam of the University of Arizona's Tree Ring Research Laboratory, a CCAG member, was a co-author of the study.

²⁷ Arizona Republic, June 16, 2006.

²⁸ U.S. Environmental Protection Agency Fact Sheet 236-F-98-007c, "Climate Change and Arizona" [http://yosemite.epa.gov/OAR/globalwarming.nsf/UniqueKeyLookup/SHSU5BNJMV/\\$File/az_impct.pdf](http://yosemite.epa.gov/OAR/globalwarming.nsf/UniqueKeyLookup/SHSU5BNJMV/$File/az_impct.pdf)

²⁹ Ibid.

CHAPTER 3 GREENHOUSE GAS EMISSIONS INVENTORY AND REFERENCE CASE PROJECTIONS 1990-2020

Executive Order 2005-02 directed the Climate Change Advisory Group (CCAG) to prepare an inventory of Arizona's greenhouse gas (GHG) emissions and a projection of future emissions. The Center for Climate Strategies (CCS) prepared a draft document for this purpose for the first CCAG meeting, and CCAG members reviewed the methodology, assumptions, and conclusions in subsequent meetings. The Technical Work Groups did the same for the portions of the document relevant to their sectors. At their December meeting the CCAG members unanimously approved the final document, *Arizona Greenhouse Gas Emissions Inventory and Reference Case Projections, 1990-2020* (hereafter, the *Inventory and Projections*, Appendix D to the Action Plan).

The *Inventory and Projections* provides historical GHG emissions estimates for the years 1990 through 2003³⁰ using a set of generally-accepted principles and guidelines for state GHG emissions and relying to the extent possible on Arizona-specific data and inputs.³¹ The reference case projections to 2020 are based on a compilation of various existing Arizona and regional projections of electricity generation, fuel use, and other GHG emitting activities, along with a set of simple, transparent assumptions described later in this chapter.

The *Inventory and Projections* covers the six types of gases included in the U.S. Greenhouse Gas Inventory: carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF₆). Emissions of these greenhouse gases are presented using a common metric, CO₂ equivalence (CO₂e), which indicates the relative contribution of each gas to global average radiative forcing³² on a Global Warming Potential (GWP) weighted basis. In addition, black carbon (soot/smoke particles) and organic carbon aerosols (used in a variety of commercial and consumer products) could have a significant climate impact, with black carbon having a particularly powerful warming impact. However, because the science is less certain on the relative magnitude of this impact, and because there are as yet no widely-accepted GWP weights to enable comparison with greenhouse gases, these black and organic carbon emissions are not integrated in the CO₂ equivalent emissions estimates provided in the main GHG inventory and projection figures presented here.

³⁰ For some sectors and sources, historical data are only available through 2000-2002.

³¹ The Arizona Department of Environmental Quality (ADEQ) prepared a preliminary GHG inventory assessment, which provided a starting point for this analysis.

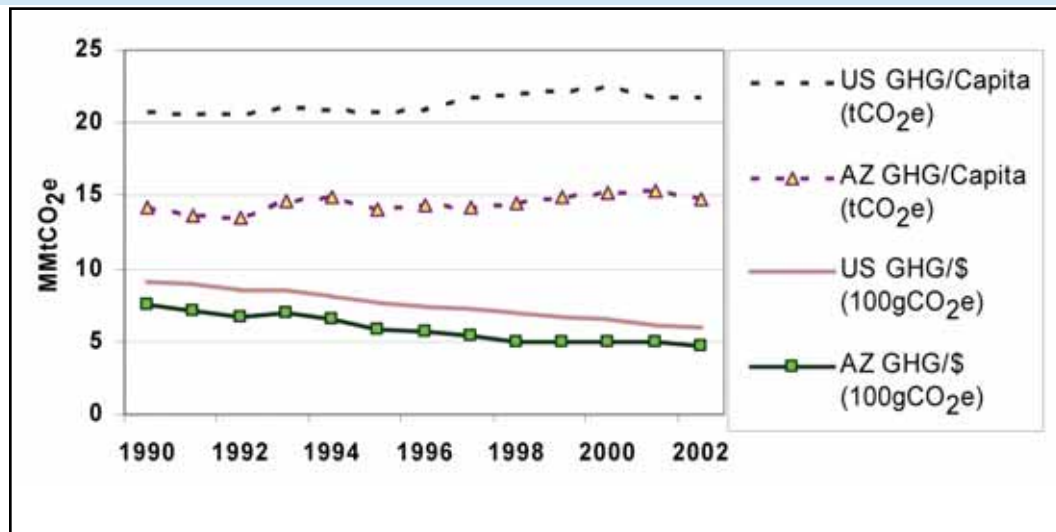
³² A change in the net radiative energy (incoming solar radiation and outgoing infrared radiation) of the global Earth-atmosphere system is termed a radiative forcing. Positive radiative forcings warm the Earth's surface and lower atmosphere; negative radiative forcings cool them.

Arizona Greenhouse Gas (GHG) Emissions: Sources and Trends

In 2000, Arizona accounted for approximately 82.3 million metric tons³³ (MMt) of net carbon dioxide equivalent (CO₂e) emissions, an amount equal to 1.2% of total U.S. GHG emissions³⁴. Arizona GHG emissions are rising rapidly compared with the nation as a whole, driven by the rapid pace of Arizona's population and economic growth. Arizona GHG emissions were up nearly 40% from 1990 to 2000, while national emissions rose by 23% during this period.³⁵

On a per capita basis, Arizonans emit about 14 tCO₂e, 36% less than the national average of 22 tCO₂e per capita. Lower per capita emissions are due in part to Arizona's mild climate, and also to the State's less emissions-intensive economic base.³⁶ Figure 3-1 illustrates the State's lower emissions per capita and per unit of economic output. It also shows that like the nation as a whole, per capita emissions have remained fairly flat, while economic growth outpaced emissions growth throughout the 1990-2002 period. During the 1990s, emissions per unit of gross product dropped by 29% nationally, and by 33% in Arizona.

Figure 3-1 Arizona and U.S. GHG Emissions, Per Capita and Per Unit Gross Product (2000 Dollars)



MMtCO₂e – million metric tons carbon dioxide equivalent

tCO₂e – metric tons carbon dioxide equivalent

100gCO₂e – 100 grams carbon dioxide equivalent

³³ All GHG emissions are reported here in metric tons.

³⁴ United States emissions estimates are drawn from Climate Analysis Indicators Tool (CAIT) version 1.5. (Washington, DC: World Resources Institute, 2003). Available at: <http://cait.wri.org>.

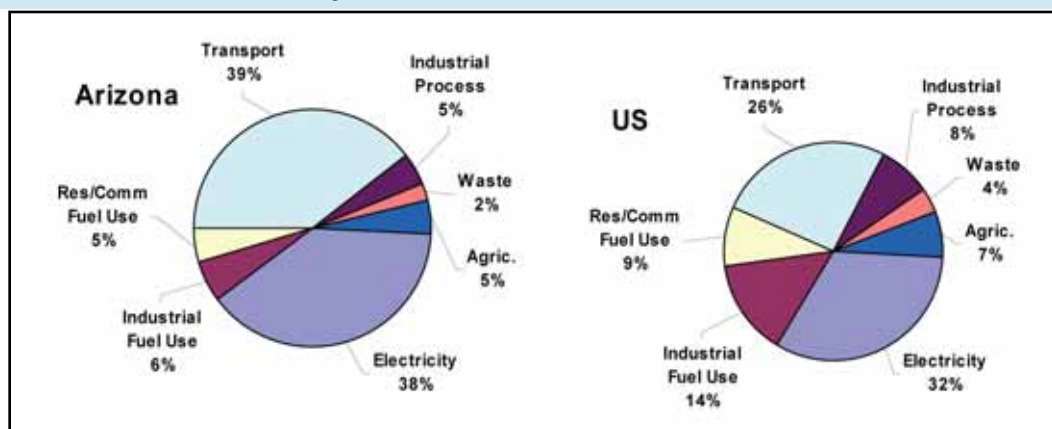
³⁵ During the 1990s, population grew by 39% in Arizona compared with 13% nationally. Furthermore, Arizona's economy grew faster on a per capita basis (up 63% vs. 52% nationally).

³⁶ Arizona's economy has a lower share of emissions-intensive industrial and agricultural activities, such as steel production, petroleum refining, or dairy farming. Furthermore, while cooling demands are significant, the emissions associated with air conditioning are lower on average than those for space heating in the rest of the country.

Electricity use and transportation are the State's principal GHG emissions sources. Together, the combustion of fossil fuels in these two sectors accounts for nearly 80% of Arizona's gross GHG emissions, as shown in Figure 3-2.³⁷ The remaining use of fossil fuels – natural gas, oil products, and coal – in the residential, commercial, and industrial (RCI) sectors constitutes another 11% of State emissions.

Agricultural activities such as manure management, fertilizer use, and livestock (enteric fermentation) result in methane and nitrous oxide emissions that account for another 5% of State GHG emissions. Industrial process emissions also comprise about 5% of State GHG emissions today, and these emissions are rising rapidly due to the increasing use of hydrofluorocarbons (HFC) as substitutes for ozone-depleting chlorofluorocarbons.³⁸ Other industrial processes emissions result from perfluorocarbon (PFC) use in semiconductor manufacturing, carbon dioxide released during cement and lime production, and methane released by natural gas systems and coal mines. Landfills and wastewater management facilities produce methane and nitrous oxide emissions accounting for the remaining 2% of current State emissions; these emissions have declined slightly in recent years as landfill gas is increasingly captured and flared or used for energy purposes.

Figure 3-2 Gross GHG Emissions by Sector, 2000, Arizona and U.S.



Gross emissions estimates do not include the effects of carbon sinks; i.e., the net carbon sequestered in, or released from, soils and vegetation. Recent U.S. Forest Service (USFS) estimates suggest that Arizona forests and the use of forest products sequestered on average about 7 MMtCO₂e per year from 1985 to 2002. Much of this increase appears to have occurred during a period when the formal definition of forestland under Forest Inventory and Analysis (FIA) surveys was liberalized from a minimum 10% forest cover to 5% cover requirements. As a result, refined estimates regarding total statewide biomass sequestration may result in significant changes to current estimates as discussed below and should be the focus of further analysis. The *Inventory and Projections* reports *net* GHG emissions – which include the above sequestration estimates – separately from the *gross* GHG emissions.

³⁷ Gross emissions estimates only include those sources with positive emissions. Carbon sequestration in soils and vegetation is included in net emissions estimates.

³⁸ Chlorofluorocarbons (CFCs) are also potent greenhouse gases. However, they are not included in GHG estimates because of concerns related to implementation of the Montreal Protocol. See Appendix D.

A Closer Look at the Two Major Sources: Electricity and Transportation

As shown in Figure 3-2, electricity use accounts for nearly 40% of Arizona's gross GHG emissions, or about 35 MMtCO_{2e}, slightly higher than the national share of emissions from electricity production (32%).³⁹ On a per capita basis, in contrast, Arizona emits slightly less in terms of greenhouse gases (7 tCO_{2e}/capita vs. 8 tCO_{2e}/capita nationally) due to electricity. The average Arizonan uses about the same amount of electricity as the average US resident (12,000 kWh per person per year), but Arizona electricity has lower emissions than the national average.⁴⁰ Arizona gets slightly less electricity from coal (46% vs. 52% nationally in 2000) and more from low-emitting sources, such as nuclear, hydro, and renewables (44% vs. 29% nationally in 2000).

During the 1990s, Arizona electricity demand grew at a rate of 4% per year, while electricity emissions grew 3.3% annually, reflecting a decline in emissions per kWh. This decline was due largely to the rapid growth of new natural gas generation, and to a lesser extent, increases in nuclear generation.

It is important to note that these electricity emissions estimates reflect the *GHG emissions associated with the electricity sources used to meet Arizona demands*, corresponding to a consumption-based approach to emissions accounting. Another way to look at electricity emissions is to consider the *GHG emissions produced by electricity generation facilities in the State*. For many years, Arizona power plants have tended to produce considerably more electricity than is consumed in the State – in the year 2000, for example, Arizona produced 23% more electricity than it used, exporting on a net basis to consumers in nearby states. As a result, in 2000, emissions associated with electricity production (44.5 MMtCO_{2e}) were considerably higher than those associated with electricity use (34.5 MMtCO_{2e}).⁴¹

While the *Inventory and Projections* presents both the emissions from electricity production and use, unless otherwise indicated, tables, figures, and totals here reflect electricity use emissions. The consumption-based approach can better reflect the emissions (and emissions reductions) associated with activities occurring in the State, particularly with respect to electricity use (and efficiency improvements), and is thus particularly useful in a policy-making context. Under this approach, emissions associated with electricity exported to other states would need to be covered in those states' accounts in order to avoid double counting or exclusions. (Indeed, California, Oregon, and Washington are currently considering such an approach.)

Like electricity emissions, GHG emissions in Arizona from transportation fuel use have risen steadily since 1990 at an average rate of slightly over 3%

³⁹ Unlike for Arizona, for the U.S. as a whole, there is relatively little difference between the emissions from electricity use and emissions from electricity production, as the U.S. imports only about 1% of its electricity, and exports far less.

⁴⁰ In 2000, electricity generation in Arizona emitted 1107 lbCO_{2e} (0.50tCO_{2e}) per MWh; the analysis assumes the same emission rate for electricity delivered to Arizona consumers. In 2000, electricity generation in the US averaged 1321 lbCO_{2e} (0.60tCO_{2e}) per MWh.

⁴¹ Estimating the emissions associated with electricity use requires an understanding of the electricity sources (both in-state and out-of-state) used by utilities to meet consumer loads. The current estimate reflects some simple assumptions described in the *Inventory and Projections* (Appendix D).

annually. Gasoline-powered vehicles account for about 65% of transportation GHG emissions. Diesel vehicles account for another 20%, air travel for roughly 10%, and the remainder of transportation emissions come from natural gas and liquefied petroleum gas (LPG) vehicles. As the result of Arizona's rapid expansion and an increase in vehicle miles traveled (VMT) during the 1990s (from 35 billion VMT in 1990 to 50 billion VMT in 2000), gasoline use has grown at a rate of 3.2% annually.⁴² Meanwhile, diesel use has risen 6.5% annually, suggesting an even more rapid growth in freight movement within the State.

With respect to black carbon emissions, the transportation sector is the largest contributor. Transportation sources such as on-road diesel vehicles contributed 59% of Arizona's black carbon (BC) emissions in 2002. Other important BC emissions sectors include non-road diesel engines (18%; e.g., generators, construction equipment) and railroad engines (about 11%). Coal-fired electricity generating units contributed another 6%.

Reference Case Projections

Relying on U.S. Department of Energy (USDOE) and Arizona agency projections of electricity and fuel use, and other assumptions noted below, the *Inventory and Projections* makes a forecast of GHG emissions through 2020.⁴³ It assumes a continuation of current trends and reflects, to the extent possible, announced plans (e.g., power plant construction and retirement) and the implementation of recently enacted policies. One such policy is the Environmental Portfolio Standard, which currently requires investor-owned utilities to provide 1.1% of the electricity sales from renewable sources by 2012, and could result in emissions savings of slightly over 0.2 MMtCO₂e by 2012.

Figure 3-3 illustrates the results of the reference case projection in terms of gross GHG emissions. Corresponding numerical results are shown at the bottom of Table 3-1 under the four different emissions accounting approaches considered here: consumption basis, production basis, gross, and net. Under the gross, consumption-basis approach – i.e., excluding emissions associated with net electricity exports – Arizona GHG emissions climb to 160 MMtCO₂e by 2020, 80% above 2000 levels and 143% above 1990 levels. Assuming current estimates for forest sequestration (6.7 MMtCO₂e) continue through 2020, net emissions are lower than gross emissions, but the relative increase is greater.

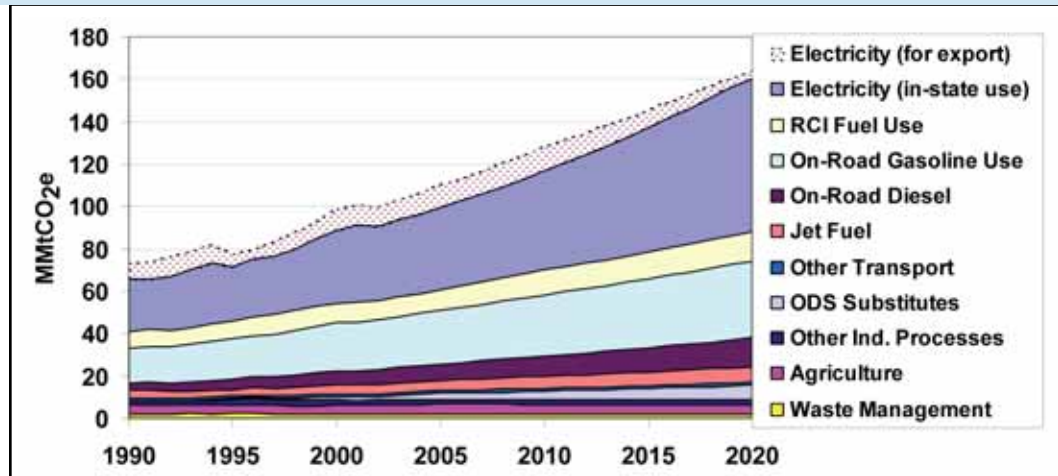
The percentage increases in emissions relative to historical levels are slightly lower under a production-based approach, i.e., one that includes all emissions associated with in-state electricity production. Under the gross emissions case, 2020 production-based emissions are 75% above 2000 levels and 123% above 1990 levels. This difference results from the assumption – based on estimates from the Arizona Corporation Commission and USDOE – that Arizona electricity sales will grow slightly faster than electricity generation from 2010 onwards.

⁴² Based on U.S. Energy Information Agency data for the year 2000, Arizona gasoline use is also slightly below the national average (1.1 vs. 1.3 gallons per person per day). www.eia.doe.gov.

⁴³ Historical data run through 2001 to 2003 depending on the emissions source.

Electricity and gasoline use are projected to be the largest contributors to future emissions growth, as shown in Figure 3-4. Other major sources of emissions growth include freight transport (diesel), fuel use in buildings and industry (RCI), hydrofluorocarbons (HFCs) used in place of ozone-depleting substances (ODS), and air travel.

Figure 3-3 Gross GHG Emissions by Sector, 1990-2020: Historical and Projected

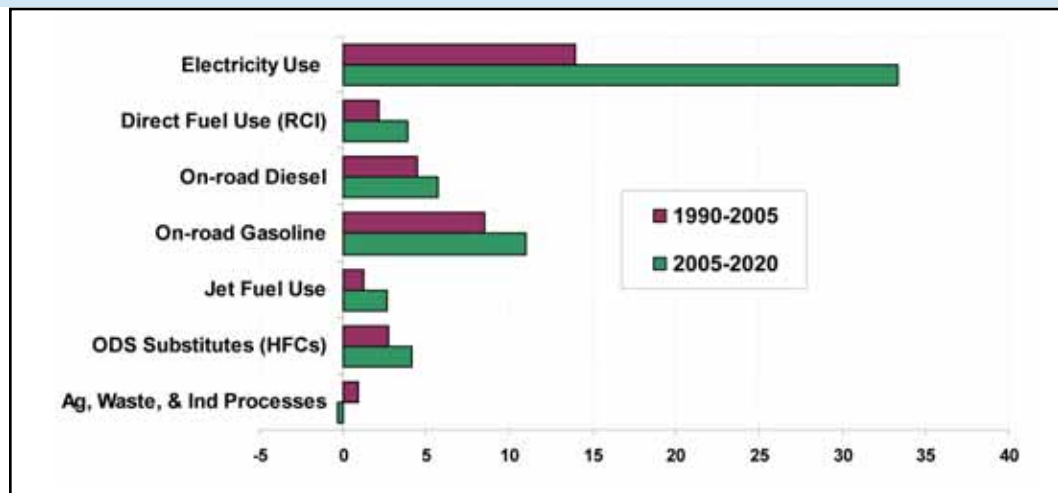


* This chart does not show net carbon sinks (forestry and land use) which average slightly over 10 MMtCO₂e/year.

RCI – Residential, Industrial, and Commercial

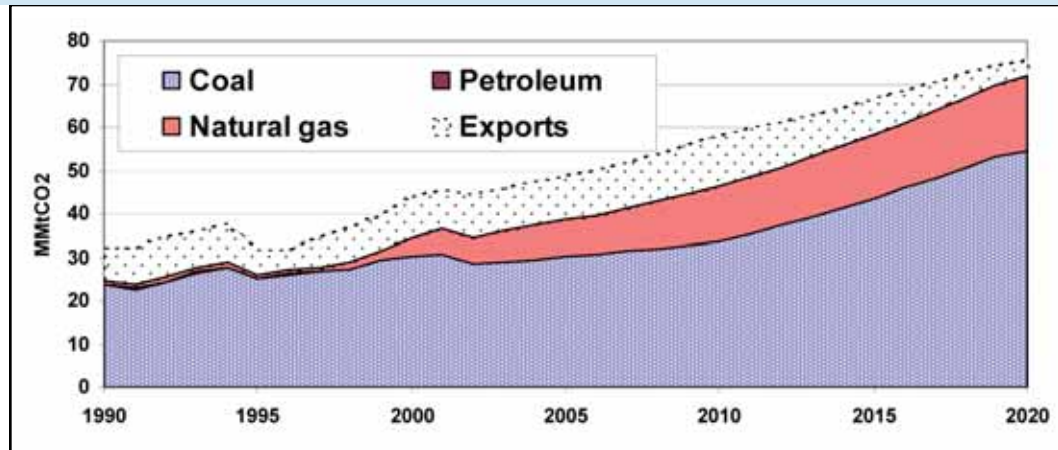
ODS – Ozone-Depleting Substances

Figure 3-4 Contributions to Emissions Growth, 1990-2020: Reference Case Projections (MMtCO₂e)



The particularly steep increase in electricity use emissions is due not only to the assumption that electricity use will continue to grow rapidly, but also that natural gas prices will continue to rise, and the mix of new generation will shift heavily towards coal after 2010, as depicted in Figure 3-5.

Figure 3-5 CO₂ Emissions from Electricity Production in Arizona, by Fuel Source (Includes All In-State Emissions)



Overall, the projected rate of emissions growth is 3% per year from the year 2000 onward, well below anticipated levels of economic growth (4.9% per year), but nonetheless significant. As illustrated in Figure 3-6, emissions track population growth fairly closely until the latter half of this decade, after which they begin to rise more rapidly. The increase in per capita emissions after 2010 appears largely as the result of four factors:

- 1) electricity growth at a rate faster than population growth
- 2) increasing reliance on coal-based generation
- 3) on-road vehicle emissions, particularly freight traffic growing faster than population
- 4) increasing hydrofluorocarbon emissions in refrigeration, air conditioning, and other applications.

For nearly all other sources, with the exception of natural gas use in residential, commercial, and industrial sectors, emissions are projected to grow at a pace slower than State population.

Figure 3-6 Historical and Projected GHG Emissions, GSP, and Population (Indexed to 1990 Value)

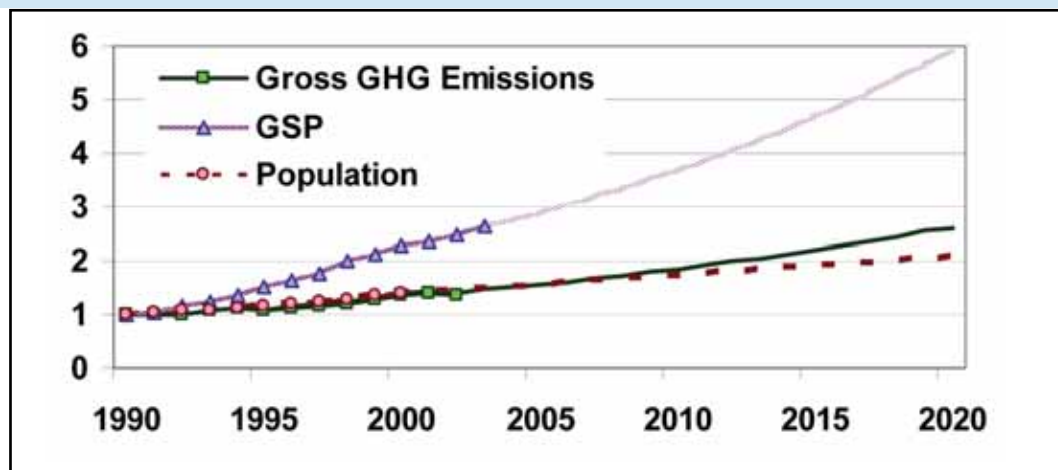


Table 3-1 Historical and Reference Case GHG Emissions, 1990-2020, by Source⁴⁴

(Million Metric Tons CO ₂ e)	1990	2000	2010	2020	Explanatory Notes for Projections
Energy Use (CO₂, CH₄, N₂O)	57.9	78.8	103.6	144.6	
Electricity Use	24.9	34.5	46.6	72.2	
Electricity Production (in-state)	32.3	44.5	58.4	75.8	Total emissions for in-state power plants
Coal	30.9	39.2	42.4	57.5	See electric sector assumptions
Natural Gas	1.3	5.1	15.9	18.3	in Appendix H
Oil	0.1	0.2	0.0	0.0	
Net Electricity Exports	-7.4	-10.0	-11.8	-3.6	
Res/Comm/Ind (RCI)	7.7	9.3	11.6	13.8	
Coal	1.2	1.5	1.8	1.9	Based on USDOE regional projections
Natural Gas	4.2	4.7	5.7	7.2	Based on USDOE regional projections
Oil	2.2	3.0	4.1	4.6	Based on USDOE regional projections
Wood (CH ₄ and N ₂ O)	0.1	0.1	0.1	0.1	Assumes no change after 2003
Transportation	25.3	35.0	45.4	58.6	
On-road Gasoline	16.8	22.8	28.9	36.3	VMT from MoveAZ, constant energy/VMT
On-road Diesel	3.5	6.5	9.5	13.6	VMT from MoveAZ, constant energy/VMT
Jet Fuel and Aviation Gasoline	3.5	4.3	5.7	7.4	Based on USDOE regional projections
Natural Gas (pipeline use)	1.4	1.1	1.2	1.2	constant at 2002 levels
Other	0.2	0.2	0.1	0.1	Based on USDOE regional projections
Industrial Processes	1.9	4.1	6.3	9.1	
ODS Substitutes	0.0	1.4	4.0	6.9	Based on national projections (USEPA)
PFCs in Semi-conductor Ind.	0.4	1.0	0.5	0.3	Based on national projections (USEPA)
SF ₆ from Electric Utilities	0.5	0.3	0.2	0.1	Based on national projections (USEPA)
Cement & Other Industry	0.6	1.0	0.9	1.0	Increases with state population
Methane from Oil & Gas Systems	0.4	0.4	0.6	0.8	Increases with natural gas use
Methane from Coal Mining	0.1	0.1	0.1	0.1	Assumes no change after 2003
Agriculture, Land Use, Forestry	-2.6	-2.5	-2.1	-2.1	
Agriculture (CH ₄ & N ₂ O)	4.1	4.2	4.7	4.7	Assumes (for now) no change after 2002
Soils and Forest Sinks	-6.7	-6.7	-6.7	-6.7	Subject to considerable uncertainty
Waste Management	2.1	1.9	2.0	1.9	
Solid Waste Management	1.7	1.3	1.4	1.1	Based on national projections (USEPA)
Wastewater Management	0.4	0.5	0.7	0.8	Increases with state population
Total Emissions - Consumption-Basis (Excluding Emissions from Net Electricity Exports)					
Gross (excluding sinks)	66.0	89.0	116.6	160.3	
increase relative to 1990		35%	77%	143%	
increase relative to 2000			31%	80%	
Net (including sinks)	59.3	82.3	109.9	153.5	
increase relative to 1990		39%	85%	159%	
increase relative to 2000			34%	87%	
Total Emissions - Production-Basis (Including All In-State Electricity Generation)					
Gross (excluding sinks)	73.5	99.0	128.4	163.9	
increase relative to 1990		35%	75%	123%	
increase relative to 2000			30%	66%	
Net (including sinks)	66.7	92.3	121.6	157.2	
increase relative to 1990		38%	82%	135%	
increase relative to 2000			32%	70%	

⁴⁴ These emissions estimates do not include black carbon and organic carbon contributions. These emissions are difficult to convert into CO₂ equivalents, given the lack of commonly accepted GWPs. Available research provides the basis for some initial GWP estimates, as discussed in Appendix D. Application of these GWPs suggests that Arizona black and organic carbon emissions may have accounted for 3 to 6 MMtCO₂e emissions in 2002. These figures also do not take into account the projected effects of recent energy efficiency related actions for the RCI sectors adopted by the State. With these actions, Arizona's GHG emissions are projected to be roughly 147 MMtCO₂e net, including sinks, in 2020, instead of 153.5 MMtCO₂e.

Key Uncertainties

The strong growth in GHG emissions forecast here is driven largely by economic, demographic, and land use trends (including growth patterns and transportation system impacts), all of which are subject to uncertainty. Table 3-2 presents some of the major assumptions used in this report. Population estimates are based on official projections from the Arizona Department of Economic Security (DES). These projections, however, are widely recognized as outdated (based on assumptions circa 1997). Population growth has been more rapid than these projections would indicate, and the DES projections are currently under revision and might lead to even higher GHG growth projections.⁴⁵

Table 3-2 Key Annual Growth Rates, Historical and Projected

Parameter	Historical		Projected	Sources/Uses
	1980-1990	1990-2000	2000-2020	
Population*	3.1%	3.4%	72.0%	U.S. Census Bureau for historic, AZ Department of Economic Security for projection
GSP	4.1%	6.3%	4.9%	(not used for projections)
Employment*	3.9%	2.9%	2.5%	AZ DOT's MoveAZ report for historic, AZ Department of Economic Security for projection
Electricity sales	4.5%	4.0%	3.6%	EIA SEDS for historic, RCI TWG for projections
Personal Vehicle Miles Traveled*	n/a	n/a	2.4%	Bureau of Transport Statistics for historic, AZ DOT's MoveAZ for projections
Freight Vehicle Miles Traveled*	n/a	n/a	3.7%	Bureau of Transport Statistics for historic, AZ DOT's MoveAZ for projections

* Population, employment and vehicle miles traveled (VMT) projections for Arizona were used together with USDOE's Annual Energy Outlook 2005 projections of changes in fuel use on a per capita, per employee, and per VMT, as relevant for each sector. For instance, growth in Arizona residential natural gas use is calculated as the Arizona population growth times the change in per capita Arizona natural gas use for the Mountain region. Arizona population growth is also used as the driver of growth in cement production, soda ash consumption, solid waste generation, and wastewater generation.

In addition, the reference case does not include an analysis of future agriculture emissions, which might change significantly if water scarcity, commodity programs, and trade agreements, among other factors, induce major shifts among crops and livestock grown in the State.

⁴⁵ If the projected growth rates are higher than currently projected (2.0%), then some emissions projections could rise. However, it is important to note that several of the key drivers for this analysis, such as growth in electricity growth and passenger VMT, are already higher than the projected population, and may implicitly reflect population projections higher than the official forecast.

Two other areas may be subject to significant uncertainty, not simply because the future is hard to predict, but because of limited data availability and scientific understanding:

- **Terrestrial carbon emissions and sinks.** The net forest and land use sequestration estimates noted above are based on recent improvements to U.S. Forest Service (USFS) carbon stock inventory data that have changed data collection and interpretation during the period of analysis. For instance, during the Forest Inventory and Analysis (FIA) survey periods used for FORCARB2⁴⁶ estimates, the definition of Arizona forestland changed from a minimum forest cover requirement of 10%, to a minimum of 5%. As a result, grasslands may or may not be included in these estimates, depending on their level of tree stocking. Follow up work by CCS and the TWG with the USFS suggested that rangeland carbon fluxes are not likely to significantly affect the final results of the forest carbon inventory and forecast.⁴⁷

Second, what the USFS defines as forest area in Arizona has increased by 14% since 1985, when it totaled 4.25 million hectares. This addition appears to account for much of the net gain in carbon stock in the USFS estimates (offsetting a decrease in carbon stock per hectare from 1996 to 2002) and may or may not be attributable to the change in the definition of forestland and the addition of lands at between 5% and 10% forest cover. However, further analysis of data and conferrals with the USFS indicated that further quantification of these changes between inventory periods is unlikely to significantly change current inventory or forecast estimates.

- **Black carbon and other aerosol emissions.** Emissions of aerosols, particularly black carbon from fossil fuel and biomass combustion, could have potentially significant impacts in terms radiative forcing (i.e., climate impacts). Methodologies for conversion of black carbon mass estimates and projections to global warming potential involve significant uncertainty at present. Best available methods for estimating black carbon emissions and their carbon dioxide equivalent are provided in a supplement to Appendix D, along with a preliminary inventory for Arizona for the year 2002. These results are not integrated in either the CO₂ equivalent emissions estimates provided in the main GHG emissions inventory and forecast or the projections presented here.

⁴⁶ FORCARB is the original USFS model estimate of carbon in forests. FORCARB2 is the second version of this model.

⁴⁷ However, the carbon cycle for rangelands is not well understood, and has not been included in current surveys.

CHAPTER 4 GOALS AND CROSS-CUTTING ISSUES

Overview of Cross-Cutting Issues

Some issues considered by the CCAG apply broadly across multiple sectors and are therefore better addressed as “cross-cutting” issues across all sectors rather than assigned to any individual sector. This set includes GHG reduction goals, emissions reporting, GHG emission reduction registries, public education and outreach, and adaptation. The Cross Cutting Issues Technical Work Group (TWG) developed policy options for each of these issues.

Key Challenges and Opportunities

Cross cutting issues bring forth key challenges in addition to the CCAG’s recommended goal. Notable among them, GHG reporting and registry programs will be far more effective if applied on a broad regional or national basis rather than through separate, state-by-state implementation. Beyond the usual differences in states’ perspectives, a further challenge lies in the fact that states are at much different stages of the learning curve with respect to these and other climate actions.

Overview of Policy Recommendations

After carefully considering Arizona’s extraordinary growth rate, overall emissions reduction feasibility, and goals established in other jurisdictions, the CCAG identified a GHG emission reduction goal that is aggressive, yet achievable. The CCAG recommends that a comprehensive effort be undertaken to develop policy options and recommendations for adapting to these conditions.

A thorough GHG emissions reporting program is essential for better understanding mitigation obstacles and opportunities, as well as for measuring future progress. A GHG registry will help recognize and share accomplishments and also protect entities by quantitatively recording early GHG reduction accomplishments. Public awareness of climate change is the cornerstone of public acceptance of the need for concerted climate action because climate impacts are already affecting Arizona dramatically.

All of the following recommendations received the unanimous support of the CCAG.

CCAG Cross-Cutting (CC) All Sectors Policy Descriptions

The Cross-Cutting sector includes policies and measures that apply across the board to all sectors and activities. Cross-cutting recommendations typically enable or support emissions mitigation activities and/or other opportunities. Fully detailed descriptions of the individual Cross-Cutting sector policy options as presented to and approved by the CCAG can be found in Appendix F.

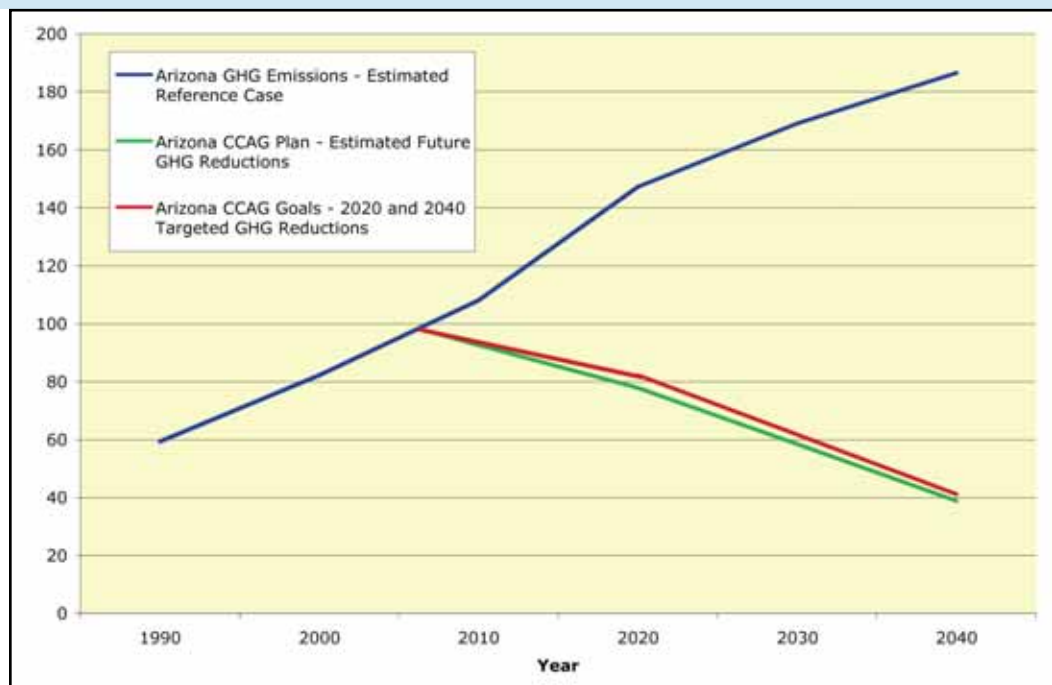
State GHG Reduction Goal (CC-1)

The CCAG recommends that Arizona establish a statewide GHG reduction target to lower GHG emissions to the 2000 level by 2020, with an additional 50% reduction below the 2000 level by 2040. In lieu of establishing a specific target for 2010, the CCAG also strongly recommends the early and aggressive implementation of the recommendations in this report, along with a corresponding set of incentives to promote early adoption.

As the reference case forecast in Figure 4-1 illustrates, Arizona's extraordinary growth in population and economic activity is expected to generate very high percentage growth in carbon emissions compared to other states. Early and aggressive action in Arizona is thus crucial to slowing – and ultimately reducing – carbon emissions.

The recommended goal for reductions in Arizona's GHG emissions reflects the CCAG's policy options recommendations. In fact, the CCAG's recommended policy options, if fully implemented, could reduce GHG emissions in Arizona by several million metric tons more than the amounts called for in the recommended goal.

Figure 4-1 1990-2040 GHG Emissions: Reference Case Forecast, CCAG Goal, and Estimated Cumulative Reductions with CCAG Options



State Greenhouse Gas Reporting (CC-2)

Measurement and public reporting of GHG emissions at a statewide, sector, or sub-sector level are important to support tracking and management of emissions. GHG reporting can help sources identify emission reduction opportunities and reduce potential risks associated with possible future GHG mandates by “starting up the learning curve.” Tracking and reporting of GHG emissions will also help in the construction of periodic state GHG inventories.

GHG reporting is a key precursor for sources to participate in voluntary GHG reduction programs, opportunities for recognition, a GHG emission reduction registry, and to secure “baseline protection.” Further, GHG reporting

is an opportunity for the state to influence reporting practices throughout the region and nation, and to build consistency with other reporting programs. Subject to consistently rigorous quantification, GHG reporting should not be constrained to particular sectors, sources, or approaches in order to encourage GHG mitigation activities from all quarters.

The CCAG recommends implementing a reporting mechanism that includes the following key elements:

- Phasing in mandatory GHG reporting by sectors as rigorous, standardized quantification protocols, base data, and tools become available and responsible parties become clear; allowing for voluntary reporting before mandatory reporting applies; and allowing the state itself to be a participant, reporting emissions associated with its own activities and the programs it implements.
- Applying to all source types (e.g., combustion, processes, vehicles, etc.) but using common sense regarding de minimis emissions.
- Having a goal of reporting “organization-wide emissions within Arizona” but doing so with greatest possible “granularity” to facilitate baseline protection (e.g., the “rolling up” of facility and field emissions reports in a reporting database would provide organization totals in Arizona).
- Reporting annually on a calendar year basis for all six traditional GHGs and, to the extent possible, black carbon.
- Requiring reporting of direct emissions, phasing in reporting of indirect emissions associated with purchased power and heat, and allowing voluntary reporting of other indirect emissions.
- Maximizing consistency with other state and federal reporting programs.
- Verifying emissions reports through self-certification and ADEQ spot-checks, adding third-party verification for registry purposes.
- Allowing for appropriate public transparency of reported emissions, and allowing voluntary project-based emissions reporting when properly quantified.

Suggestions for specific design elements of an effective GHG reporting program are included in Appendix F.

State Greenhouse Gas Registry (CC-3)

Measurement and recording of GHG emissions reductions at a macro- or micro-scale level in a central repository with a “transaction ledger” capacity to support tracking, management, and “ownership” of emission reductions as well as to encourage GHG reductions, to enable potential recognition, baseline protection, and/or the crediting of actions by implementing programs and parties in relation to possible emissions reduction goals, and to provide a mechanism for regional, multi-state, and cross-border cooperation. Subject to consistently rigorous quantification, registration of GHG reductions should not be constrained to particular sectors, sources, or approaches in order to encourage GHG mitigation activities from all quarters.

The CCAG recommends that the State implement a registry mechanism with the following key elements:

- Geographic applicability at least at the statewide level and as broadly (i.e., regionally or nationally) as possible.
- Allowing sources to start as far back chronologically as good data exists, as affirmed by third-party verification, and allowing registration of project-based reductions or “offsets” that are equally rigorously quantified.
- Incorporating adequate safeguards to ensure that reductions are not double-counted by multiple registry participants; providing appropriate transparency; and allowing the state itself to be a participant, registering GHG reductions associated with its programs, direct activities, or efforts.
- Striving for maximum consistency with other state, regional, and/or national efforts, greatest flexibility as GHG mitigation approaches evolve; and providing guidance to assist participants.

Suggestions for specific design elements of an appropriate GHG registry are included in Appendix F.

State Climate Action Education and Outreach (CC-4)

Public education and outreach are vitally important to foster a broad awareness of climate change issues and effects (including co-benefits, such as clean air and public health) among the state’s citizens and to engage them in actions to reduce GHG emissions. Such efforts should seek to integrate with and build upon existing outreach efforts involving climate change and related issues in the state. Ultimately, public education and outreach will be the foundation for the long-term success of all the mitigation actions proposed by the CCAG as well as those which may evolve in the future.

The CCAG recommends that the state undertake climate change education and outreach activities directed toward, but not limited to, the following audiences:

- Policymakers (e.g., legislators, regulators, executive branch, agencies) – because implementation of climate actions hinges on policymakers’ approval.
- Younger generations – by integrating climate change issues into educational curricula, post-secondary degree programs, and professional licensing programs.
- Community leaders and community-based organizations (e.g., businesses, institutions, municipalities, service clubs, social and affinity groups, non-governmental organizations, etc.) – in order to recognize leadership, share success stories and role models, and expand climate involvement and participation in climate change issues.
- The general public – to increase awareness and engage citizens in climate actions in their personal and professional lives.

One concept proposed by a CCAG member would be to create an “extension agent” position to assist in proliferating best practices among builders, homeowners, businesses, farmers and others. Further suggestions for specific activities are included in Appendix F.

State Climate Change Adaptation Strategy (CC-5)

Because of the build-up in the atmosphere of greenhouse gases that already has occurred, Arizona will experience the effects of climate change for years to come, even if immediate action is taken to reduce future GHG emissions. As such, it is essential that the state develop a strategy to identify and manage the projected impacts of ongoing climate change.

While taking action to reduce GHG emissions in Arizona, the CCAG recommends that a comprehensive state climate change adaptation strategy be developed and implemented. The strategy should include time- and program-based goals, characterization of the potential risks and costs of inaction, and the potential costs, benefits, and co-benefits associated with specific policy and program actions and time periods. Further, the strategy should outline actions to be taken to respond to existing climate change impacts and to coordinate these actions with response plans and efforts that are underway or may be contemplated at other agencies or organizations or through other initiatives. Such impacts include the concerns outlined Executive Order 2005-02 (i.e., prolonged drought, severe forest fires, warmer temperatures, increased snowmelt, and reduced snow pack) as well as other serious issues, including risks to public health.

The Governor may wish to consider appointing a task force or advisory group to develop recommendations for the state climate change adaptation strategy. Moreover, the Governor should direct state agencies and other appropriate institutions to identify and characterize potential current and future risks in Arizona to human, natural and economic systems, including potential risks to water resources, temperature sensitive populations and systems, energy systems, transportation systems, vital infrastructure and public facilities, and natural lands (e.g., forests, rangelands, and farmland).

Adaptation measures that also help mitigate GHG emissions should be given priority in the state climate change adaptation strategy, particularly water use conservation and efficiency, forest and agriculture conservation and management, energy production and use, facility siting and management (including residential), infrastructure development, and efficient transportation and land use systems. These actions should be linked to implementation of other specific recommendations of the CCAG to the greatest extent possible.

CHAPTER 5 RCI AND WASTE MANAGEMENT

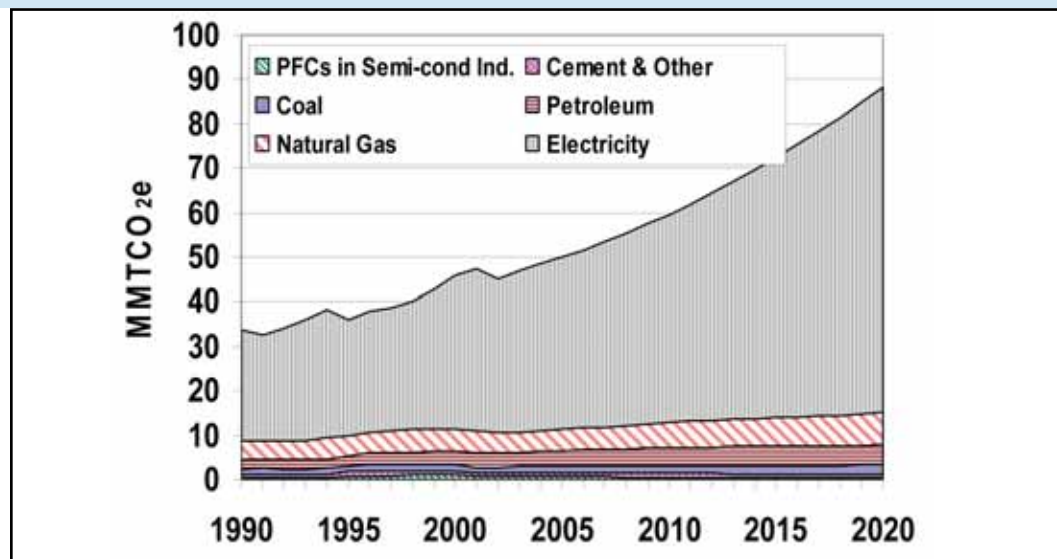
Overview of Greenhouse Gas Emissions

The residential, commercial, and industrial (RCI) sectors are directly responsible for only about one-tenth of Arizona's current GHG emissions (11.3 MMtCO₂e in 2000). Direct emissions result principally from the on-site combustion of natural gas, oil, and coal, the release of CO₂ and fluorinated gases (HFCs, PFCs) during industrial processing (largely cement and semi-conductors), and the leakage of HFCs from refrigeration and related equipment.⁴⁸

Considering only the direct emissions that occur within buildings and industries, however, ignores the fact that nearly all electricity sold in the state is consumed as the result of residential, commercial, and industrial activity. If the emissions associated with producing this electricity are considered, RCI activities are associated with about half of the state's GHG emissions. Arizona's future GHG emissions therefore will depend heavily on future trends in the consumption of electricity and other fuels in these sectors.

Figure 5-1 shows historical and projected RCI GHG emissions by fuel and source, and illustrates the large fraction of RCI emissions associated with electricity use. RCI emissions associated with electricity and natural gas use are expected to double from 2000 from 2020, and are likely to account for over half of the State's emissions growth during this period.⁴⁹

Figure 5-1 Historical and Projected Residential Commercial and Industrial (RCI) Greenhouse Gas (GHG) Emissions, 1990 to 2020



⁴⁸ RCI fuel use accounted for 9.3 MMtCO₂e in GHG emissions in 2000, while industrial process emissions, largely from cement production and the use of perfluorocarbons in the semi-conductor industry, accounted for 2.0 MMtCO₂e. Emissions due to leakage of HFC refrigerants from appliances and equipment in the RCI sector have not been estimated.

⁴⁹ The exception is process emissions from the semi-conductor industry, which are expected to decline significantly due to voluntary efforts.

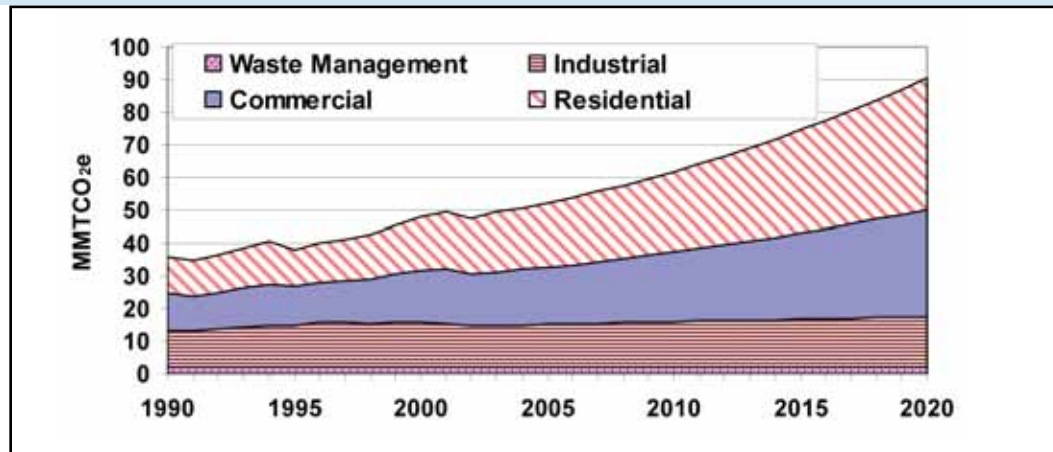
Table 5-1 shows estimated historical and projected emissions from solid waste management and wastewater treatment. Emissions from waste management consist largely of methane leaking from landfills, while emissions from wastewater treatment include both methane and nitrous oxide. These emissions, in terms of carbon equivalents, are relatively minor compared to overall RCI emissions, yielding 2010 and 2020 estimated emissions equal to 2 to 3% of RCI emissions.

Table 5-1 Summary of Estimated Historical and Projected Emissions from Waste and Wastewater Management in Arizona

(Million Metric Tons CO ₂ equivalent)	1990	2000	2010	2020
Waste Management	2.1	1.9	2.0	1.9
Solid Waste Management	1.7	1.3	1.4	1.1
Wastewater Management	0.4	0.5	0.7	0.8

Until recently, overall emissions associated with residential, commercial, and industrial activity have been roughly equivalent across the three sectors. Rapid population growth and increasing emphasis on the commercial sector as the engine for the state's economy suggests, however, that over the coming decades the residential and commercial sectors will, under business as usual conditions, come to dominate in terms of emissions. Manufacturing activity is expected to continue to grow at a rate of about 1.8% per year, though this growth is likely to be offset by continuing declines in overall energy intensity due to energy efficiency gains and structural shifts to less energy-intensive industries.⁵⁰

Figure 5-2 1990-2020 GHG Emissions by Sectors



⁵⁰ Projections of manufacturing activity (employment growth) are based on estimates from the Arizona Department of Economic Security. By contrast, non-manufacturing employment is projected to grow at an annual rate of 2.6%. Declines in energy intensity are based on projections by the U.S. Department of Energy (Annual Energy Outlook 2005).

Key Challenges and Opportunities

The principal means to reduce RCI emissions include improving energy efficiency, substituting electricity and natural gas with lower-emission energy resources (e.g., solar water heating), and various strategies to decrease the emissions associated with electricity production (see Energy Supply). The state's rapid growth and limited pursuit of energy efficiency to date offers particularly strong opportunities to reduce emissions through programs and initiatives to improve the efficiency of buildings, appliances, and industrial practices. At the same time, fast growth places pressure on communities and businesses to make swift decisions, and can shorten their time horizons for recouping investments. A key challenge lies in the design and implementation of strategies that overcome these barriers and thus ensure new buildings and industries take full advantage of opportunities to reduce energy use and emissions.

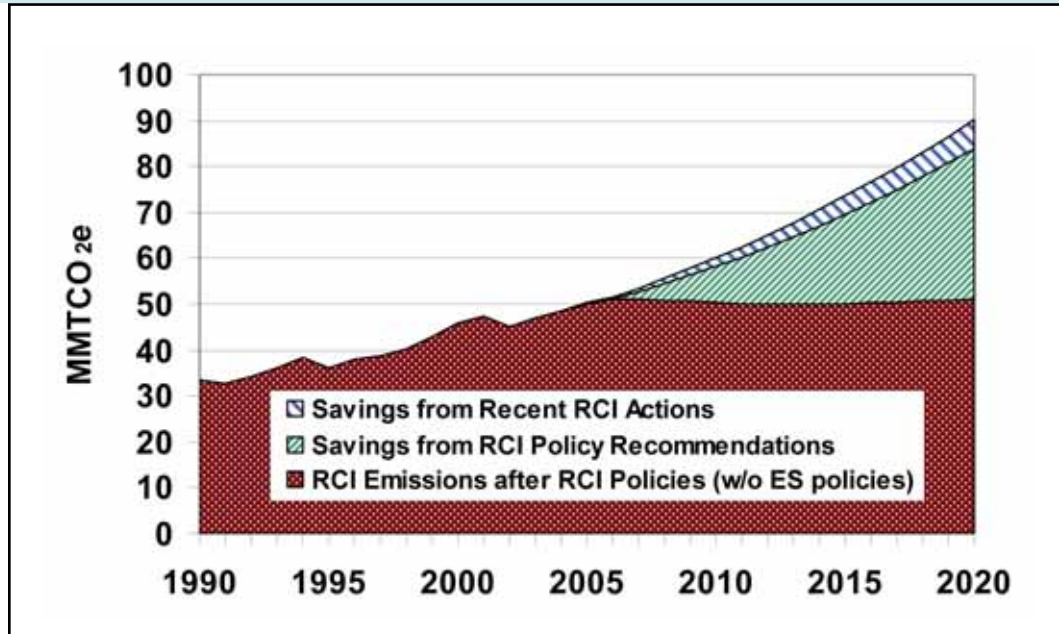
Arizona's business, tribal, government, and citizen representatives have recently taken major steps in this direction. Adopted in 2003, the state's government building energy goals are a nationally-recognized example of leadership-by-example. The state universities have recently installed state-of-the-art combined-heat-and-power facilities, and have completed extensive Energy Saving Performance Contracts. Together with several other states, Arizona adopted state appliance efficiency standards in 2005, which in part provided the impetus for federal adoption in the 2005 Federal Energy Bill. In the past year, the state's electric and gas utilities have made significant new commitments to increase their energy efficiency programs. And the state's semiconductor industry has committed to major reductions of PFC emissions; Intel Corporation, for example, has reduced its PFC emissions in Arizona by a factor of 4 over the past 3-4 years. While an indication of the growing momentum for improving efficiency and reducing emissions, these actions only begin to tap the overall potential of the state to slow its growth of energy use and GHG emissions.

Emissions from solid waste management practices can be addressed through the implementation of more aggressive recycling and waste reduction programs. Programs to reduce water use in the municipal, agricultural, and industrial sectors can yield further savings by reducing the energy required to pump water from place to place.

Overview of Policy Recommendations and Estimated Impacts

The CCAG recommends a set of ten (10) policy options for the residential, commercial, and industrial sectors, plus two (2) options focused on waste and water management, that offer the potential for major economic benefits and emissions savings. As summarized in Figure 5-3, these 12 policy recommendations could lead to emissions savings from reference case projections of 31 MMtCO₂e per year by 2020 and cumulative savings of over 220 MMtCO₂e from 2006 through 2020. The weighted average cost of saved carbon from the policy options for which quantitative estimates of both costs and savings were prepared was minus \$30 per metric ton of CO₂ equivalent, meaning

Figure 5-3 Impact of Policy Recommendations on RCI Emissions



that there is a net savings to the Arizona economy in implementing these options. Most emissions savings from the RCI options are in the form of reduced carbon dioxide emissions, with relatively minor reductions of emissions of other greenhouse gases (principally methane and nitrous oxide) produced via leakage and/or combustion of fuels.

The estimated impacts of the RCI and solid waste/water management policies recommended by the CCAG are shown in Table 5-2. Also shown in Table 5-2 are the results of several policies that have either been recently implemented or will be implemented as a result of earlier State policies. These “Savings from Recent RCI Actions” are not accounted for in the reference inventory and forecast, but contribute to overall emissions reduction along with savings from the CCAG-recommended measures. The combination of savings from recent actions and CCAG policies are, in the RCI sectors, estimated to approximately equal projected reference case growth in emissions from 2006 through 2020.

The CCAG policy recommendations described below result not only in significant emissions and costs savings, but offer a host of additional benefits as well. These benefits include (but are by no means limited to) reduction in spending on energy by homeowners and businesses, contributing to local economic development, reduced local air pollution, reduced need for electricity supply facilities, and, for example, for building improvement measures, improvements in comfort and convenience.

In order for the RCI policy options recommended by the CCAG to yield the levels of savings described here, the options must be implemented in a timely, aggressive, and thorough manner. This means, for example, not only putting the policies themselves in place, but also attending to the development of “supporting policies” that are needed to help make the recommended options effective. Improved building codes will not be optimally effective, for example, without training of contractors, builders, architects, financial institutions,

Table 5-2 Summary of Results

RESIDENTIAL, COMMERCIAL, INDUSTRIAL (RCI) AND WASTE MANAGEMENT						
	CCAG Policy Option	2010 Annual GHG Reduction (MMtCO₂e)	2020 Annual GHG Reduction (MMtCO₂e)	2007-2020 Cumulative Reduction (MMtCO₂e)	Cost or Cost Savings Per Ton GHG Removed (\$/tCO₂e)	Level of CCAG Support
RCI-1	Demand-Side Efficiency Goals, Funds, Incentives, and Programs	3.1	15.1	103	-\$36	Unanimous
RCI-2	State Leadership Programs	0.04	0.4	3	-\$4	Unanimous
RCI-3	Appliance Standards	0.2	1.0	7	-\$66	Unanimous
RCI-4	Building Standards/Codes for Smart Growth	0.3	2.2	14	-\$18	Unanimous
RCI-5	“Beyond Code” Building Design Incentives and Programs for Smart Growth	0.2	3.1	18	-\$17	Unanimous
RCI-6	Distributed Generation Combined Heat and Power	0.4	2.7	16	-\$25	Unanimous
RCI-7	Distributed Generation Renewable Energy Applications	0.1	2.1	10	\$31	Unanimous
RCI-8	Electricity Pricing Strategies	1.1	1.5	16	-\$63	Unanimous
RCI-9	Mitigating High Global Warming Potential (GWP) Gas Emissions (HFCs, SFCs, PFCs)	Not available				Unanimous
RCI-10	Demand-Side Fuel Switching	0.1	1.2	7	Not available	Unanimous
RCI-12	Solid Waste Management	2.2	3.7	36	Not available	Unanimous
RCI-13	Water Use and Wastewater Management	0.2	0.8	6	Not available	Unanimous
Total all options, adjusted for overlap and interaction		7.5	31.1	222		

and building inspectors, among others, in the methods and benefits of efficient building design. Regulatory policies that provide incentives and lower disincentives for the adoption of consumer-sited combined heat and power and renewable electricity generation are also among the supporting policies crucial to the success of the RCI options recommended by the CCAG. The CCAG's work indicates that there are considerable benefits to both the environment and to consumers from adoption of the policy options offered, but careful, comprehensive, and detailed planning and implementation, as well as consistent support, of these policies will be required if these benefits are to be achieved.

CCAG RCI and Waste Management (RCI) Sector Policy Descriptions

The Residential, Commercial, Industrial and Waste Management Sectors include emissions reduction opportunities related to improving energy (and water) use efficiency, using lower GHG energy sources, and enhancing waste management practices. Fully detailed descriptions of the individual RCI policy options as presented to and approved by the CCAG can be found in the Appendix G.

Demand-Side Efficiency Goals, Funds, Incentives, and Programs (RCI-1)

The CCAG recommends the setting of energy savings goals for electricity and natural gas, and the implementation of the policy, program, and funding mechanisms that are needed to achieve these goals. These goals, incentives, and programs are intended to work in tandem with other strategies under consideration by the RCI and ES sectors. Suggested energy savings goals are as follows:

- Electricity (energy savings target): 5% savings by 2010, 15% savings by 2020.⁵¹
- Natural gas (utility spending target): ramp up to spending 1.5% of gas utility revenues on energy efficiency programs by 2015 pursuant to Arizona Corporation Commission (ACC) decoupling of gas sales and revenue. Further decisions by the ACC to decouple gas sales and revenues are viewed as central to achieving this target.

Possible implementation options include public benefit charges, tariff riders, enabling legislation, and/or regulatory directives. These and other options can be augmented, where applicable by state and national tax incentives for energy efficient equipment. Indeed, an evolving and flexible mix of these policy mechanisms may be needed to achieve the efficiency goals described here.

Supporting activities may be important elements in the success of energy efficiency strategies, and could include consumer education and outreach programs (including, for example, enhanced State Energy Office and university-based energy-efficiency extension services), and market transformation programs and organizations. Activities in support of energy efficiency could also include decoupling utility sales and revenues and creating performance incentives that reward utilities for implementing effective demand-side

⁵¹ These savings targets would be for electricity sales (MWh), and would reflect cumulative (from today), verified savings as a percentage of those years' (projected) loads, starting from the time of policy adoption.

management (DSM) programs. Furthermore, the CCAG recommends the inclusion of energy efficiency resource in an integrated resource planning (IRP) process, which can enable the overall most efficient and cost-effective delivery of energy services.

State Leadership Programs (RCI-2)

The CCAG recommends that state and local governments undertake “Lead by Example” activities to achieve energy cost savings and promote clean energy technologies by the public and private sectors.

Specific recommendations include:

- Extending state building energy savings goal (A.R.S. §34-451) to include a further 15% reduction in energy use per square foot in state buildings from 2011 to 2020, along with purchasing of EnergyStar equipment.
- Standards for new state buildings, with possible design parameters including recommendations for new buildings to be better than code or LEED⁵² (or similar) energy efficiency requirements, such as those recommended by the Arizona Working Group on Renewable Energy and Energy Efficiency and by the Energy Efficiency Task Force of the Western Governors Association Clean and Diversified Energy Advisory Committee (WGA CDEAC) (see also Option RCI-5), as well as mechanisms to support the state in achieving its building energy efficiency goals.
- Green procurement strategies, such as installation of renewable energy systems as additional backup services in emergency services buildings, and efforts to promote or require the purchase by state buildings of 5% of their building energy needs from renewable sources (over a phased-in period) by 2012, increasing to 10% by 2020.
- The promotion of new combined heat and power (CHP) facilities in State buildings, recent examples of which are the facilities in place and under construction at Arizona State University and the University of Arizona (approximately 35 MW total), and the expansion of existing performance contracting law to require life cycle analysis for CHP in State lease-purchase construction.

The full policy option description provided in Appendix G acknowledges numerous programs and policies currently in place in Arizona and includes additional specific recommendations.

Appliance Standards (RCI-3)

Appliance efficiency standards reduce the market cost of energy efficiency improvements by incorporating technological advances into base appliance models, thereby creating economies of scale. Appliance efficiency standards can be implemented at the state level for appliances not covered by federal standards. Arizona and other states recently adopted state level appliance efficiency standards covering several appliances.

⁵² The Leadership in Energy and Environmental Design (LEED) certification process includes, but is not limited to, energy-efficiency specifications for buildings. Other building energy-efficiency guidelines may also be applicable.

The CCAG recommends implementation of state appliance efficiency standards for appliances not covered by federal standards or where higher-than-federal standard efficiency requirements are appropriate.

More specifically, the CCAG calls for the State to:

- Advocate for stronger federal appliance efficiency standards where such standards are technically feasible and economically justified.
- For those appliances not likely to be covered by federal efforts, pursue efficiency standards already adopted by California and/or other states.
- Where possible, consider encouraging local manufacturing of high-efficiency appliances and equipment when adopting state standards.

Building Standards/Codes for Smart Growth (RCI-4)

The CCAG recommends that improved and increasingly stringent energy efficiency codes for Arizona be adopted and implemented.

Building energy codes specify minimum energy efficiency requirements for new buildings or for existing buildings undergoing major renovations. Given Arizona's growth and the long lifetime of buildings, the current and future building codes will have a considerable impact on future energy use in buildings, and on related greenhouse gas emissions. Specifically, the CCAG recommends that:

- Arizona should either establish a statewide code or strongly encourage local jurisdictions to adopt and maintain state-of-the-art codes. Adoption is targeted for 2007, with codes in force in early 2008, but with the recognition that some municipalities in Arizona may implement energy efficiency codes later than others.
- Arizona and/or local jurisdictions should adopt the 2004 International Energy Conservation Code (IECC), to the extent that adoption has not already occurred. Also, Arizona and/or local jurisdictions should consider adopting innovative features of California's latest Title 24 building energy codes, such as lighting efficiency requirements in new homes.
- Arizona and local jurisdictions should update energy codes regularly. A three-year cycle could be timed to coincide with release of the national model codes.
- Revised building codes for Arizona as a whole and for local jurisdictions should be prepared with the involvement of local chapters of code organizations to assist in obtaining support for and compliance with the new policies. All buildings should be covered, including manufactured homes, and local building inspectors should enforce compliance with codes. Inspectors need to be properly trained in new elements of the codes.

"Beyond Code" Building Design Incentives and Programs for Smart Growth (RCI-5)

The CCAG recommends that building energy performance standards be implemented in State-funded and other (such as local) government buildings. It also recommends promotion of similar standards for use in other buildings,

such that new buildings achieve high standards of energy efficiency, and existing buildings are renovated or retrofitted to yield significant energy efficiency improvements. Specifically, this policy option includes:

- Implementation of the energy-efficiency elements of LEED (Leadership in Energy and Environmental Design) standards/certifications and/or other “green building” certifications and/or measured or modeled building energy performance criteria to specify building energy performance standards.
- A performance standard for State-owned or state-leased buildings to demonstrate the feasibility of not only achieving the minimum code requirements but also significantly exceeding code requirements.
- A requirement that State-owned or leased facilities use life-cycle costing, including full consideration of future energy costs, in the selection and implementation of building designs and components (including energy-using equipment such as heating, ventilation and air conditioning systems) for both new and renovated space, or for the selection of replacement components. Further, following life-cycle cost analysis, require that the most cost-effective design/equipment/component options be chosen.
- Financial or tax incentives for non-public and non-state public buildings (such as municipal buildings) to improve their energy performance beyond that required by existing codes.

Distributed Generation/Combined Heat and Power (RCI-6)

Distributed generation with clean combined heat and power (DG/CHP) systems improves the overall efficiency of fuel use as well as electricity system benefits. The CCAG recommends that the implementation of DG/CHP systems should be encouraged through a combination of regulatory changes and incentive programs. CHP systems of 10 MW or smaller (or of equivalent mechanical power) would be covered, and policies in place by the end of 2006, and in force thereafter, with periodic review as needed. Regulatory changes and incentives should be designed to enable a significant fraction of Arizona's estimated remaining CHP potential to be realized. The full policy description for RCI-6, as provided in Appendix G, notes possible funding mechanisms and regulatory standards that could be considered.

Distributed Generation/Renewable Energy Applications (RCI-7)

Customer-sited distributed generation powered by renewable energy sources provides electricity system benefits such as avoided capital investment and avoided transmission and distribution losses, while also displacing fossil-fueled generation and thus reducing greenhouse gas emissions. Customer-sited renewable distributed generation can include solar photovoltaic systems, wind power systems, biogas and landfill gas-fired systems, geothermal generation systems, and systems fueled with biomass wastes or biomass collected or grown as fuel.

The CCAG proposes that Arizona promote the increased use of renewable distributed generation in Arizona through a combination of regulatory changes and incentives.

Policies to encourage and accelerate the implementation of customer-sited renewable distributed generation include direct incentives for system purchase, market incentives (including “net metering”) related to the pricing of electricity output by renewable distributed generation, state goals or directives, and favorable rules for interconnecting renewable generation systems with the electricity grid.

Non-electric renewable energy applications also covered by this policy include solar water heat and solar space heat and cooling. It is suggested that Arizona should, at a minimum, set as its target the addition of customer-sited distributed renewable generation consistent with the overall generation capacity by year goals for renewable distributed generation in the West as expressed in the WGA CDEAC reports.

Electricity Pricing Strategies (RCI-8)

As with other energy and non-energy commodities, the pricing of electricity—including electricity from the grid used by consumers and electricity generated on the consumers’ premises flowing to the grid—can have a significant impact on consumers’ usage decisions. Proper and clear electricity tariffs and price signals can provide significant encouragement to distributed generation, energy conservation (in many forms), and reduction of electricity use during times of peak electricity demand.

Creating such tariff structures may involve restructuring tariffs to provide incentives for “shoulder” and peak usage period demand reductions—for example, through implementation of time-of-use energy charges—as well as setting net metering or other rules for sales from distributed generation to the grid that provide appropriate credit for the electricity generated during periods of high power demand. Changes in tariff structures are also needed that revise the balance between energy and demand charges and change the way that demand charges are fixed.

The CCAG recommends that changes in Arizona electricity pricing and tariffs be designed to provide improved incentives for end-users to adjust the timing of energy use so as to reduce greenhouse gas emissions as much as possible. The implementation of inverted block rates, where higher tariffs are charged once electricity use per household (for example) reaches a threshold level each month, is also recommended.

Mitigating High Global Warming Potential Gas Emissions (RCI-9)

The CCAG recommends a combination of voluntary agreements with industries and new specifications for key equipment to reduce the emissions of process gases that have high global warming potential.⁵³ In particular, the CCAG suggests consideration of specifications and possible voluntary incentives

⁵³ Based on the current AZ emissions inventory and projection, GHG emissions from hydrofluorocarbons (HFCs) could grow from about 1 MMtCO₂e or <1% of Arizona GHG emissions in 2000 to over 7 MMtCO₂e or about 5% of state emissions by 2020. Most HFC emissions are expected to result from leaks in mobile air conditioning and refrigeration applications. Other sources of high Global Warming Potential (GWP) gases, which include the emission of perfluorocarbons (PFCs) and HFCs and from semiconductor manufacture and leakage of sulfur hexafluoride (SF₆) from electricity distribution equipment, contribute less to state emissions, and these emissions are expected to decline based on existing emission reduction efforts, such as the semiconductor industry’s voluntary worldwide agreement.

for new commercial refrigeration equipment, such as the specifications currently under consideration by the California Air Resources Board. The specifications would: a) promote the use of low global warming potential (GWP) refrigerants in refrigerators in retail food stores, restaurants, and refrigerated transport vehicles (trucks and railcars); and/or b) require or provide incentives that centralized systems with large refrigerant charges and long distribution lines be avoided in favor of systems that use much less refrigerant and lack long distribution lines.

The CCAG further recommends that the Governor explore working with California and other states in addressing HFC emissions from refrigeration systems. Maintaining momentum of voluntary industry-government partnerships (such as the semi-conductor industry agreement) should also be a high priority.

Demand-Side Fuel Switching (RCI-10)

The CCAG recommends the adoption of options for encouraging consumers to switch to the use of less carbon-intensive fuels to provide key energy services. Fuel switching opportunities can include using natural gas in the place of electricity for thermal end-uses, natural gas in the place of coal for key industrial end-uses, biomass fuels in the place of electricity or natural gas for thermal end-uses, and solar thermal energy in the place of electricity or natural gas for thermal end-uses.

The CCAG recommends a two-part approach to promote demand-side fuel switching. Phase I consists of efforts to promote switching from high-carbon fuels to lower-carbon fuels (such as from oil or coal to natural gas). Phase II targets inducing consumers to switch to “low or zero carbon” fuels by offering incentives to do so. In particular: a) the promotion of solar water heating through a combination of incentives and targeted research, and b) the substitution of biodiesel for diesel in commercial and industrial equipment, are recommended.

Solid Waste Management (RCI-12)

The CCAG recommends pursuing several options to increase recycling and reduce waste generation in order to limit greenhouse gas emissions associated with landfill methane generation and with the production of raw materials. In 2005, over 3 million residents in 39 Arizona communities had access to residential curbside recycling, representing slightly over 50% of the state’s population. To further increase the diversion of waste from landfill and the amount of materials recycled, the State should aim to:

- Ensure that curbside recycling programs are provided in all communities over 50,000 in population;
- Increase the penetration of recycling programs in multi-family dwellings;
- Create new recycling programs for the commercial sector;
- Provide incentives for the recycling of construction materials;
- Develop markets for recycled materials;
- Increase average statewide participation/recovery rates for all existing recycling programs;
- Develop a statewide recycling goal.

Implementation options to increase recycling and reduce waste generation may include the following: expanded ADEQ Waste Reduction Assistance (WRA) grants; mandatory source separation and recycling laws or ordinances in urban areas; tax breaks or other incentives to make recycling financially attractive for private commercial sector waste haulers; full recycling as a contract requirement for state facilities; government purchasing requirements for recycled content of items purchased (paper, carpets, etc.); a waste education campaign, aiming at waste reuse and reduction, and targeting greenhouse gas reductions; and general awareness building, such as working with community leaders to appreciate benefits and cost-effectiveness of curbside recycling.

Water Use and Wastewater Management (RCI-13)

Arizona currently uses about 7.2 million acre-feet (MAF) of water, an estimated 78%⁵⁴ of which is delivered to agricultural consumers, 18% to municipal consumers, and the remainder to industrial users. A significant amount of energy is used to pump this water from underground aquifers (3.6 MAF), from the Colorado River (2.6 MAF), and other sources (1.2 MAF), and to treat it in wastewater facilities after it is used. The CCAG has the following five recommendations:

- Accelerate investment in water use efficiency. Elements may include implementing best management practices and efficient water management practices, and providing incentives for implementation of water management improvement measures. Consideration should also be given to developing a statewide water and wastewater savings plan, based on a thorough assessment of water and wastewater options in all water using sectors.
- Increase the energy efficiency of all water and wastewater treatment operations, and develop long-term programs to better mesh with the long-term investments in water and wastewater infrastructure. Two specific suggestions with respect to improving pump efficiency are detailed in the full policy description for RCI-13 provided in Appendix G.
- Increase energy production by water and wastewater agencies from renewable sources such as in-conduit hydropower generation and biogas production from sewage sludge.
- Encourage and create incentives for technologies with the capability to reduce water use associated with power generation.
- Ensure that power plants use the best management practices and economically feasible technology available to conserve water (via siting, evaluation, permitting, or other processes).

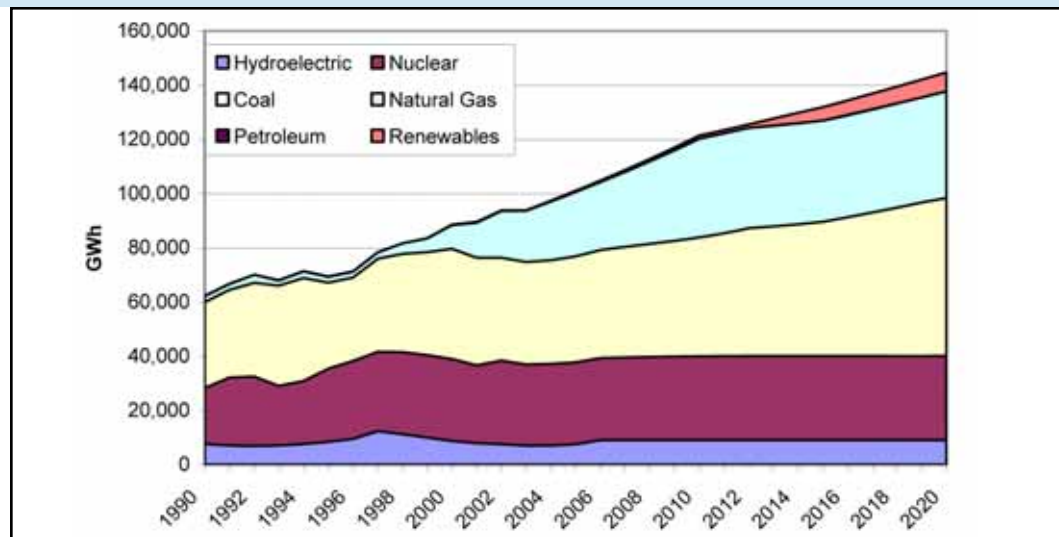
⁵⁴ Arizona Department of Water Resources statistic, July 2006.

CHAPTER 6: ENERGY SUPPLY

Overview of Greenhouse Gas Emissions

Arizona's historical sources of electricity generation by fuel type are shown in Figure 6-1, with projections to the year 2020.⁵⁵ Natural gas generation has grown considerably during the past decade, while coal, nuclear, and hydro generation have stayed relatively constant. Based on the CCAG reference case forecast, natural gas will continue to dominate new generation through 2010, at which point coal assumes an increasing market share, reflecting that natural gas prices may continue to rise.

Figure 6-1 Electricity Generated by Arizona Power Plants, 1990-2020⁵⁶

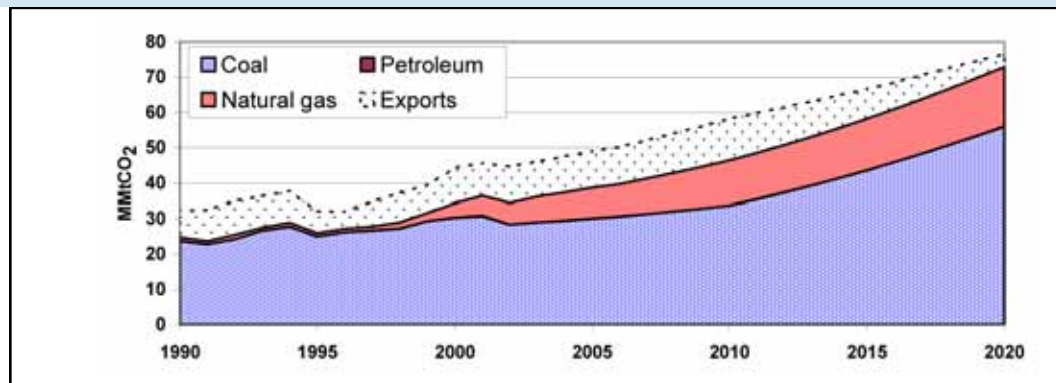


Electricity emissions are estimated both on a consumption basis (i.e., accounting for the GHG emissions associated with electricity consumed within the State) and on a production basis (i.e., based on the GHG emissions associated with electricity produced within Arizona, much of which is currently exported). Figure 6-2 shows the GHG emissions associated with electricity consumption and exports, based on the assumptions mentioned above. From 1990 to 2000, electricity sales in the state grew by about 4% per year, with CO₂ emissions growing at roughly 3% per year in this period. Emissions grew more slowly than electricity sales because the share of natural gas generation increased while the coal share decreased. The decreasing share of coal led to a slight decrease in CO₂ emissions per MWh generated (1,142 lb CO₂/MWh in 1990 to 1,107 lb CO₂/MWh in 2000). From 2000 to 2020, emissions associated with electricity use are projected to grow at 3.8% per year, as the fraction of coal generation increases, especially after 2010.

⁵⁵ Values are based on the assumptions described in Appendix D, *Final Arizona Greenhouse Gas Inventory and Reference Case Projections, 1990-2020*.

⁵⁶ This same data and graphic are also presented in Figure 6-4 herein as the "Reference Case Electricity Supply by Fuel Type" for purposes of comparison with the projected impact of the CCAG's recommended policy options on electricity generation fuel supply.

Figure 6-2 Historical and Projected CO₂ Emissions Associated with Electricity Use (Consumption-Basis) and Exports, 1990-2020



Key Challenges and Opportunities

The principal challenge in addressing GHG emissions from Arizona’s electricity sector is the State’s extraordinary growth rate, specifically the accompanying increase in baseload demand expected over the next 15 years, coupled with natural gas price uncertainty. Absent any carbon policy, the least-cost choice for new baseload capacity in the 2010 to 2020 timeframe is expected to be pulverized coal. Commercial scale applications of advanced coal technologies like integrated gasification combined cycle (IGCC) with carbon capture and storage are currently under development in many states (including Arizona) with commercial operation anticipated between 2011 and 2014. These advanced coal technologies offer the opportunity for the implementation of low carbon policies. If low carbon policies are implemented, advanced coal technologies like IGCC will likely be less costly (in terms of electricity produced) than pulverized coal, albeit at a cost higher than today’s cost for pulverized coal.

Arizona’s most plentiful renewable resource, of course, is solar energy, and the State has a significant leadership opportunity in the commercialization of solar technologies. Solar photovoltaic (PV) is commercial in certain applications, particularly for peak shaving and for off-grid applications, but requires cost-effective storage technology in order to provide baseload power. Concentrating solar power (CSP) is an emerging technology on the cusp of commercialization. Some CSP technologies can dispatch electricity for six or more hours after sundown, providing power for all but the lowest demand hours. Arizona has untapped, but limited, wind resources. Wind’s intermittency inhibits its value for baseload capacity, but wind can provide baseload power if wind facilities are carefully planned at multiple sites and coupled with backup combustion turbines.

Arizona may also face unusual challenges in reducing electric sector GHG emissions as a result of the nature of its electric power industry. Generating stations in Arizona are subject to substantially different oversight regimes depending on whether they are regulated by the Arizona Corporation Commission (e.g., APS, Tucson Electric), overseen by independently elected board (e.g., the Salt River Project), or are located on tribal lands (e.g., the Four Corners and Navajo generating stations). This disparity may make broad adoption of some of the CCAG’s recommendations more difficult.

Overview of Policy Recommendations and Estimated Impacts

The CCAG recommends a set of eight policy options for the Energy Supply (ES) sector that offer the potential for significant emission reductions. Of these policies, three (ES-3, Direct Renewable Energy Support; ES-9, Reduce Barriers to Renewables and Clean Distributed Generation; and ES-11, Pricing Strategies) are quantified under the RCI sector. These results are noted in Table 6-1 below, but they are not included in the Energy Supply sector totals in order to avoid double-counting. The CCAG has recommended ES-4, GHG Cap and Trade, as a policy option that Arizona should explore at the regional or national level. The estimates in Table 6-1 are based on modeling of a national cap and trade program and the likely impact on only Arizona's power sector. The CCAG has recommended an economy-wide cap and trade program, but the estimates do not include any projected reductions from sectors other than the power sector. Values for the range of results are shown. ES-10, Metering Strategies, is an enabling policy for greater penetration of clean distributed generation and energy efficiency technologies. The reductions attributable to this greater penetration are quantified under other CCAG policy options.

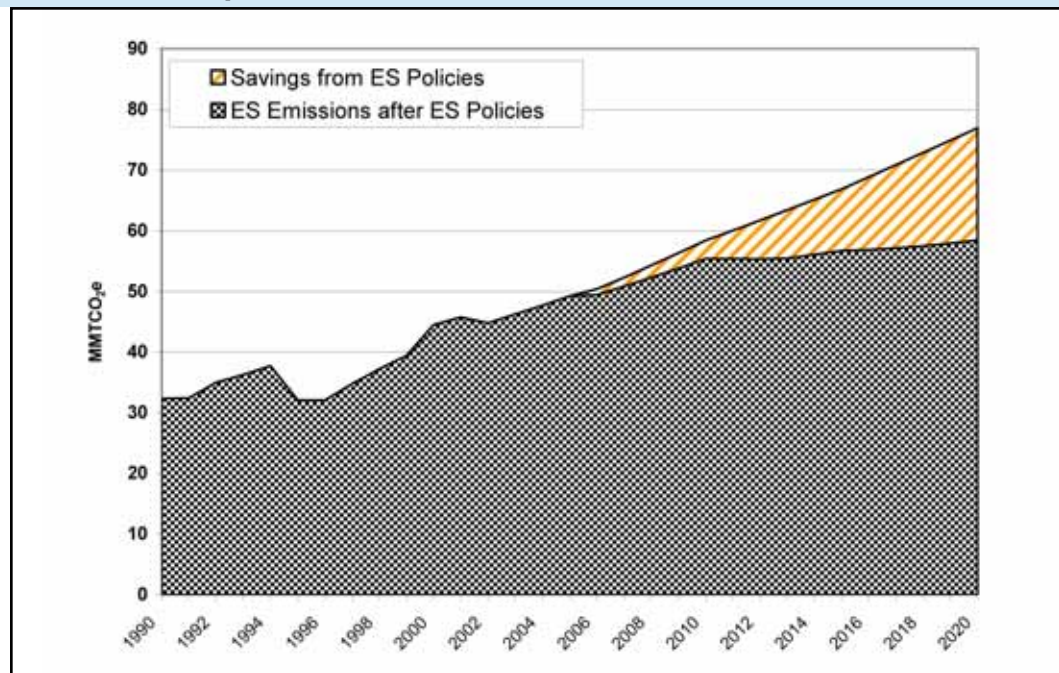
Three policies are quantified as Energy Supply options that Arizona can implement on its own, including ES-1, Environmental Portfolio Standard/Renewable Energy Standard and Tariff; ES-6, Carbon Intensity Targets; and ES-12, Integrated Resource Planning. Because the purpose of ES-12 would largely be accomplished by (i.e., overlap with) the activities that would be undertaken to satisfy ES-1 and ES-6, only the results from ES-1 and ES-6 are included in the totals in Table 6-1. (The results of ES-12 are indicated in the Table, but not counted in the totals in order to avoid double-counting.) Further, because either ES-1 or ES-6 would exhaust all available wind, biomass, and geothermal generation capacity within Arizona, GHG reductions from these resources are included only in ES-6 in order to avoid double-counting.⁵⁷

If implemented as part of a comprehensive package of the CCAG's recommendations, ES-1 and ES-6 would need to be evaluated with respect to the reference case electricity demand forecast in order to take into account the fact that other measures (e.g., energy efficiency and distributed generation) would reduce the demand for grid electricity generation. Because the GHG reductions associated with ES-1 and ES-6 are directly related to total MWhs generated, GHG reductions for ES-1 and ES-6, in this situation, would have to be adjusted downward to reflect this lower demand. Specifically, GHG reductions achieved by the ES policies would have to be reduced by the same percentage as the RCI policies reduced grid electricity generation in order to approximate the combined results of ES and RCI policies. See the Appendix H for further information.

⁵⁷ ES-6 was chosen for relative ease of calculation; wind, biomass, and geothermal could have been included in ES-1 instead.

Figure 6-3 shows the impact of ES-1 and ES-6 on GHG emission projections in Arizona.

Figure 6-3 Impact of Policy Recommendations on Energy Supply (ES) GHG Emissions Compared to Reference Case



The individual CCAG policy recommendations described briefly below (and in more detail in Appendix H) provide substantial GHG emission reductions, and when combined with the options recommended jointly by Energy Supply and RCI, substantial cost savings and additional benefits as well. These benefits include (but are not limited to) reduced need for electric generation facilities, reduced local air pollution, greater energy reliability and security, and greater contribution to local economic development, including the creation of jobs in rural communities and job-needy areas due to the development of alternative energy opportunities (i.e., biomass, biofuels and wind) in these areas. It is estimated that a 50 MMgal/year ethanol plant in Arizona would yield approximately 70 full-time positions, with additional job creation resulting from the production and processing of feedstocks used in production of ethanol. Given the estimates for ethanol production assumed in this Action Plan, 14 plants would be required by 2020 resulting in nearly 1,000 new jobs in rural Arizona.

Implementing the policies recommended by the CCAG to reduce carbon emissions associated with electric generation, increase renewable energy, and enhance energy efficiency would have a profound effect on the character of Arizona's future energy supply sector. This is evident in the contrast between Figure 6-4, the reference case, and Figure 6-5, which reflects the carbon-intensity-reducing and demand-reducing policies recommended by the CCAG from the ES and RCI sectors.

Figure 6-4 Reference Case Electricity Supply by Fuel Type

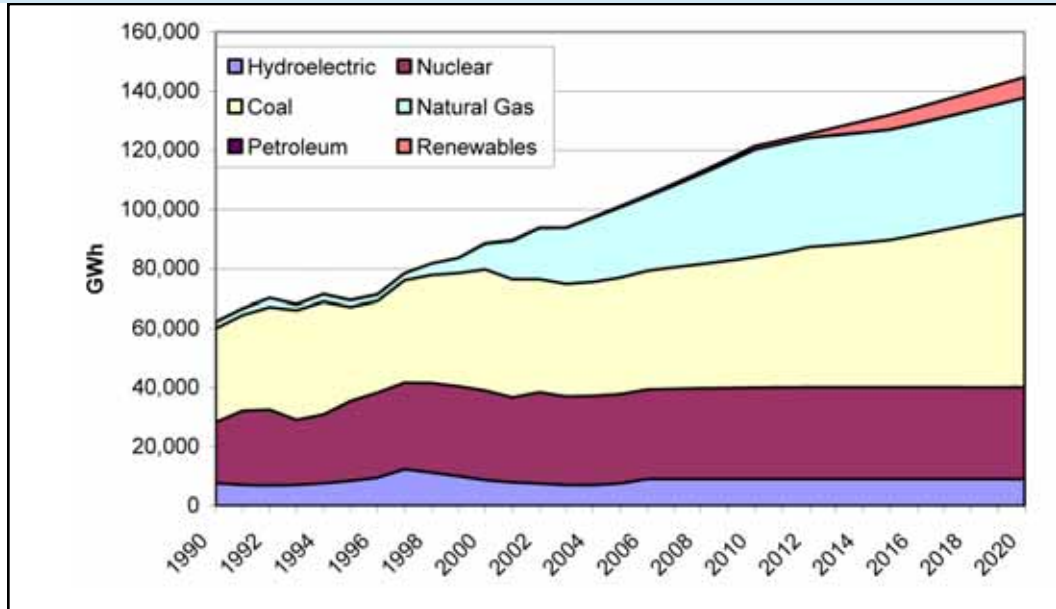
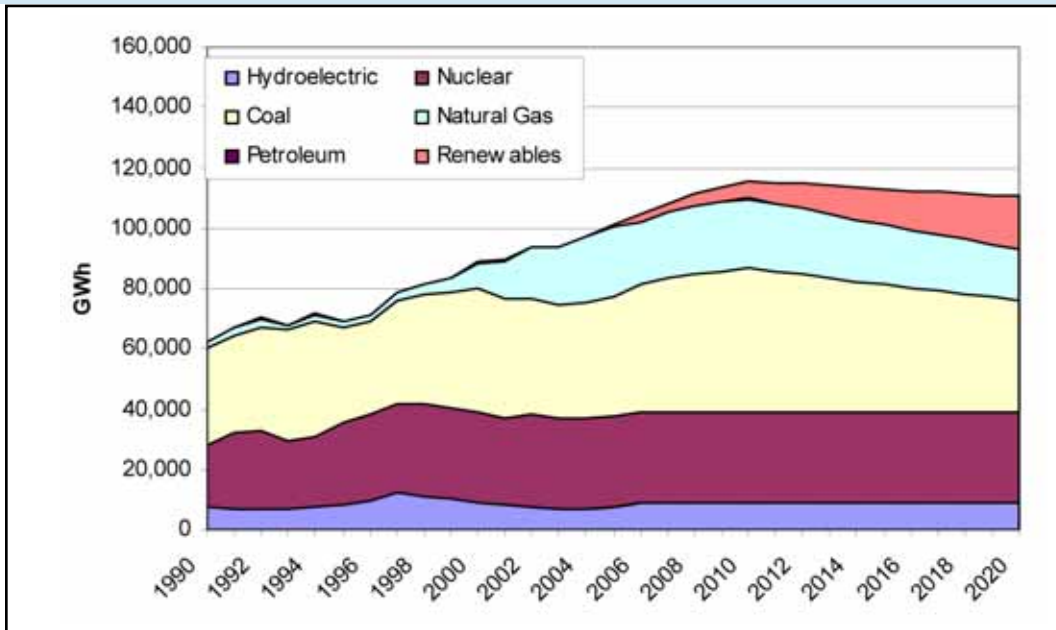


Figure 6-5 Policy Case Electricity Supply by Fuel Type (Reflecting CCAG ES and RCI Recommendations)



Not directly evident from the above figures is the fact that the dramatic expansion of renewables would be accompanied by a corresponding increase in the number of jobs in Arizona associated with this expansion. This would be paid for in large measure by the corresponding reduction in imports to Arizona of fossil fuels.

The CCAG's Energy Supply recommendations will not provide the levels of savings indicated here, of course, unless they are implemented in a timely, aggressive and effective manner, along with corresponding enabling policies. Careful, comprehensive, and consistent regulatory policies to reduce barriers and provide incentives for the adoption of consumer-sited combined heat and

power, waste energy recovery, and renewable electricity generation will be crucial to the success of these and several RCI policy options recommended by the CCAG. Similarly, public education and outreach, and institutional incentives such as GHG reporting and registry programs – also recommended by the CCAG – will be essential for maximum effectiveness.

Table 6-1 CCAG Recommended Policy Options, By Sector

ENERGY SUPPLY (ES)						
	CCAG Policy Option	2010 Annual GHG Reduction (MMtCO₂e)	2020 Annual GHG Reduction (MMtCO₂e)	2007-2020 Cumulative Reduction (MMtCO₂e)	Cost or Cost Savings Per Ton GHG Removed (\$/tCO₂e)	Level of CCAG Support
ES-1	Environmental Portfolio Standard/Renewable Energy Standard and Tariff	4.2	16.4	116.0	\$6	Majority
ES-3	Direct Renewable Energy Support (including Tax Credits and Incentives, R&D, and siting/zoning)	This option is quantified under RCI-7, Distributed Generation / Renewable Energy Applications. Values are shown below for completeness, but not included in cumulative totals to prevent double-counting.				Unanimous
		0.1	2.1	10.0	\$31	
ES-4	National or Regional GHG Cap and Trade	These estimates are based on modeling of a national cap-and-trade policy and the likely impact on Arizona's power sector. The values presented here show the range of results for GHG reductions and costs.				Unanimous
		- 0.28– 0.18	2.0– 18.5	7 - 88	\$7 - \$19	
ES-6	Carbon Intensity Targets	0.0	14.0	70.4	\$44	Majority
ES-9	Reduce Barriers to Renewables and Clean Distributed Generation	This option is quantified under RCI-6, Distributed Generation / Combined Heat and Power. Values are shown below for completeness, but not included in cumulative totals to prevent double-counting.				Unanimous
		0.4	2.7	16.0	-\$25	
ES-10	Metering Strategies	ES-10 is an enabling policy for RCI-6 and RCI-7; its quantification is incorporated as part of those options.				Unanimous
ES-11	Pricing Strategies	This option is quantified under RCI-8, Electricity Pricing Strategies. Values are shown below for completeness, but not included in cumulative totals to prevent double-counting.				Unanimous
		1.1	1.5	16.0	-\$63	
ES-12	Integrated Resource Planning	This option overlaps substantially with ES-6, Carbon Intensity Targets. Values are shown below for completeness, but not included in cumulative totals to prevent double-counting.				Unanimous
		0.1	5.4	28.0	-\$2	
Total All Options, Adjusted for overlap and interaction		3.0	17.9	120.6		Note: Total includes only ES-1 and ES-6.

CCAG Energy Supply (ES) Sector Policy Descriptions

The Energy Supply sector includes emissions and mitigation opportunities related to electrical energy supply options, including the generation, transmission, and distribution of electricity, whether generated through the combustion of fossil fuels or by renewable energy sources, and whether generated in a centralized power station supplying the grid or by distributed generation facilities. Arizona has relatively little oil and gas production, so the CCAG has made no recommendations concerning the oil and gas energy supply options.

Fully detailed descriptions of the individual Energy Supply policy options as presented to and approved by the CCAG can be found in Appendix H.

Environmental Portfolio Standard /Renewable Energy Standard and Tariff (ES-1)

An environmental portfolio standard (EPS) is a requirement that utilities must supply a certain percentage of electricity from environmentally-friendly sources. An EPS differs from a Renewable Portfolio Standard (RPS) in that an EPS can include more options than renewables for meeting the requirement. Utilities can meet their requirements by purchasing or generating environmentally-friendly electricity or by purchasing clean energy credits. By giving utilities the flexibility to purchase clean energy credits, a market in these credits will emerge that will provide an incentive to companies that are best able to generate clean energy, either through energy efficiency or renewables.

The CCAG initially considered four option scenarios as variations of the changes that the Arizona Corporation Commission (ACC) is expected to make to the State's existing EPS. The EPS, of course, applies only to ACC-jurisdictional utilities. Major aspects of the anticipated ACC changes include:

- RPS of 5% in 2015, 15% in 2025.
- Starting in 2007, 5% of this total renewable requirement must be from distributed renewables, increasing to 30% by 2011 and remaining at 30% in future years.
- Renewable Energy Credit (REC) trading is allowed, provided that all other associated attributes are retired when applying RECs to the annual renewable energy requirement.
- Out-of-state resources can be used provided that the necessary transmission rights are obtained and used.

The CCAG narrowed the list of options from four to two:

- ES-1a(1): The ACC's likely changes to the EPS, with the Salt River Project (SRP) continuing with its sustainable resource program. (SRP plans to supply 15% of energy for retail sales with renewable or demand-side sources by 2025.)
- ES-1c: A more aggressive alternative proposal, applicable to all utilities in the state (not just ACC-jurisdictional utilities) starting with the 1% RPS in 2005 and increasing 1% each year to 26% in 2025, and allowing out-of-state renewables and REC trading.

The CCAG recognized that the ACC has related proceedings underway and believes that approval of the ACC's current rule-making effort would provide significant GHG emissions reductions. The CCAG recommended the more aggressive alternative (ES-1c) because of its cost-effectiveness and significant emissions reductions.

Direct Renewable Energy Support (ES-3)

The purpose of this suite of policies is to encourage investment in renewables by providing direct financial incentives and by removing siting and zoning barriers to renewable energy facilities. Development of new renewable technologies is also encouraged through research and development funding. Direct renewable energy support can take many forms including:

- 1) direct subsidies for purchasing/selling renewable technologies given to the buyer/seller;
- 2) tax credits or exemptions for purchasing/selling renewable technologies given to the buyer/seller;
- 3) tax credits or exemptions for operating renewable energy facilities;
- 4) feed-in tariffs, which are direct payments to renewable generators for each kWh of electricity generated from a qualifying renewable facility;
- 5) tax credits for each kWh generated from a qualifying renewable facility.

This option is closely related to RCI-7, Distributed Generation / Renewable Energy Applications, and is quantified under that option.

Greenhouse Gas Cap and Trade Program (ES-4)

A cap and trade system is a market mechanism in which CO₂ emissions are limited or capped at a specified level, and those participating in the system can trade allowances (where each allowance represents one ton of CO₂ emissions) in order to lower overall costs of compliance. For every ton of CO₂ released, an emitter must hold an allowance. The total number of allowances issued or allocated represents the cap. The government can give allowances away for free to those participating in the cap and trade system (or even to those who are not) using many different approaches (e.g., based on generation output, based on historical emissions, etc.), or it can auction them, or use a hybrid approach. Participants can range from a small group within a single sector to the entire economy, and the program can be implemented on "upstream" sources (where fuel is extracted or imported) or "downstream" sources (where fuel is consumed).

The CCAG recommendation is to encourage the Governor to explore development of a regional or national, economy-wide cap and trade program.

Carbon Intensity Targets (ES-6)

Rather than a fixed cap on carbon emissions, a carbon intensity target is a limit on the ratio of carbon emissions to a measure of output. Absolute emissions can increase as output increases. Measures of output are clear for some sectors like electricity generation (i.e., MWh), but are less clear for sectors where outputs vary widely (e.g., manufacturing). One measure of output for

such sectors could be dollars equal to the value of the output. The CCAG's recommendation reflects consideration of a mandatory carbon intensity target for Arizona beginning in 2010 (i.e., set equivalent to carbon intensity in 2010) and declining by 3% each year through 2025. The annual carbon intensity target would be translated into a cap, and trading would be allowed under that cap.

Reduce Barriers to Renewables and Clean Distributed Generation (ES-9)

By removing barriers to renewables and clean distributed generation (DG), more clean generation can come into the energy supply mix, displacing fossil fueled generation and thereby reducing CO₂ emissions. The CCAG's recommendation proposes to remove barriers by standardizing interconnection policies; improving procurement policies (e.g., state power purchases, loading order requirements, long-term contracting with clean DG, etc.); and requiring environmental disclosure, among other approaches. This option is closely related to RCI-6, Distributed Generation/Combined Heat and Power, and is quantified under that option.

Metering Strategies (ES-10)

There are two common metering strategies and policies: net metering and advanced metering. Net metering is a policy that allows owners of grid-connected distributed generation (i.e., generating units on the customer side of the meter) to generate excess electricity and sell it back to the grid, effectively "turning the meter backward." This policy allows for low transaction costs (e.g., by avoiding the need to negotiate individual contracts for the sale of electricity back to the utility) and is attractive to distributed generation (DG) owners because they are compensated equal to the full cost of purchased electricity (i.e., the sum of wholesale generation, transmission and distribution, and utility administration costs), rather than just the utility's avoided costs.

Advanced metering technology allows electricity consumers much greater opportunity to manage their electricity consumption. For example, consumers could set their meter to turn off air conditioning during the day while they are away. Coupled with pricing strategies whereby prices reflect actual costs, advanced metering could be set to automatically reduce power demand by turning off lights or appliances during peak times when the price reaches a threshold set by the consumer. Advanced metering could be encouraged by subsidizing or requiring their installation.

The CCAG approved this policy option as a recommendation, but because it is more of an enabling policy (for clean, distributed generation) than a reduction policy per se, it was not quantified for GHG reduction potential or cost effectiveness. It is an enabling policy for RCI-6 and RCI-7, which are quantified.

Pricing Strategies (ES-11)

Pricing strategies can take many forms including: (a) real-time pricing in which utility customer rates are not fixed, but reflect the varying costs that utilities themselves pay for power (which vary substantially during the day and over the seasons); (b) "time-of-use" rates which are fixed rates for different

times of the day and/or for different seasons; (c) “increasing block” rates whereby unit prices rise as consumption increases; (d) green pricing whereby customers are given the opportunity to purchase electricity with a renewable or cleaner mix than the standard supply mix offered by the utility; and (e) taking advantage of advanced metering to allow electricity consumers far greater opportunity to manage their electricity consumption to reduce use and cost.

The CCAG approved this option as a recommendation, but decided not to quantify it because of uncertainties surrounding it (e.g., load-shifting under time-of-use rates would reduce costs but could actually increase GHG emissions). However, this option is closely related to RCI-8, Electricity Pricing Strategies, which is quantified.

Integrated Resource Planning (ES-12)

Integrated Resource Planning (IRP) is a process that diverges from traditional utility least-cost planning. Rather than focusing only on supply-side options to meet a forecasted growth in electricity demand, IRP also incorporates demand-side technology and policy options to meet the anticipated future demand. Demand-side measures include energy efficiency, distributed generation, waste energy recovery, and peak-shaving measures. Typically, IRP also takes into account a broader array of costs, including environmental and social costs.

IRP is an involved, iterative process that, by its nature as a bottom-up planning methodology for individual utilities, does not lend itself to setting broad implementation levels per se. An emissions value, or “shadow price”, can be specified for use in the IRP planning process, however. In making decisions about which resources to use to satisfy future energy demand, utilities would be required to apply this shadow price as a CO₂ adder in the course of their evaluation of technologies and options. Utilities would not actually be required to pay the shadow price.

The CCAG’s analysis and recommendation reflects a shadow price of \$15 per ton of CO₂ emitted to approximate the results of an IRP process.

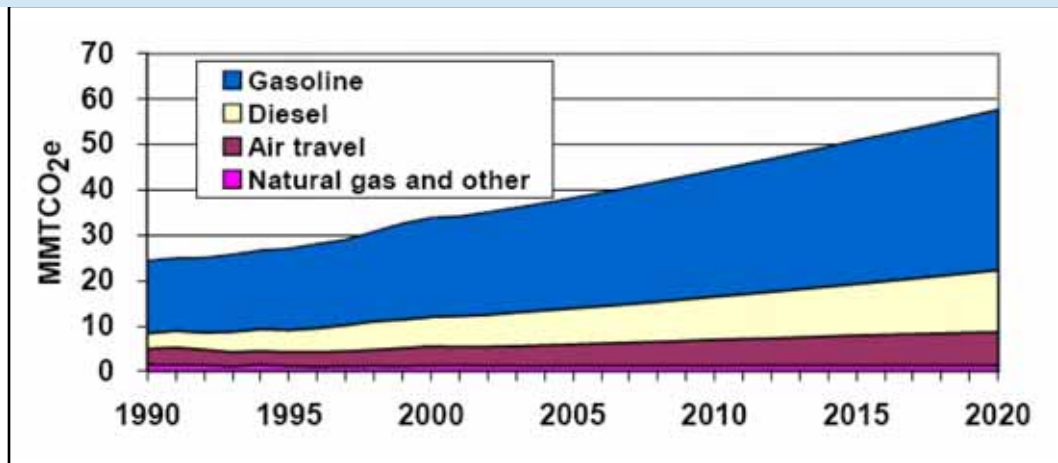
CHAPTER 7: TRANSPORTATION AND LAND USE

Overview of Greenhouse Gas Emissions

The transportation sector is a major source of GHG emissions in Arizona – currently accounting for about 40% of Arizona’s gross GHG emissions. The transportation technologies and fuels used are key determinants of those emissions, along with population, economic growth, and various land use policies that all affect the demand for transportation services. GHG emissions from the transportation sector totaled about 35 MMtCO₂e in 2000. Carbon dioxide accounts for about 97% of transportation GHG emissions from fuel use; much of the remaining 3% is due to nitrous oxide emissions from gasoline engines.

Figure 7-1 shows historical and projected Transportation and Land Use (TLU) GHG emissions by fuel and source, and illustrates their rapid growth. TLU emissions are expected to more than double from 1990 to 2020. Arizona studies suggest on-road vehicle miles traveled (VMT) will continue to grow faster than the population, and rapid growth in freight VMT is also expected, reflecting continued economic growth and cross-border trade.

Figure 7-1 Historical and Projected TLU GHG Emissions, from 1990 to 2020



Key Challenges and Opportunities

The principal means to reduce TLU emissions include improving vehicle fuel efficiency, substituting gasoline and diesel with lower-emission fuels, modal switches to lower-emission means of travel, and various strategies to decrease the growth in fuel use and VMT.

In Arizona and in the nation as a whole, vehicle fuel efficiency has improved little since the late 1980s, yet many studies have documented the potential for substantial increases consistent with maintaining vehicle size and performance. The use of biofuels with lower GHG emissions is growing in

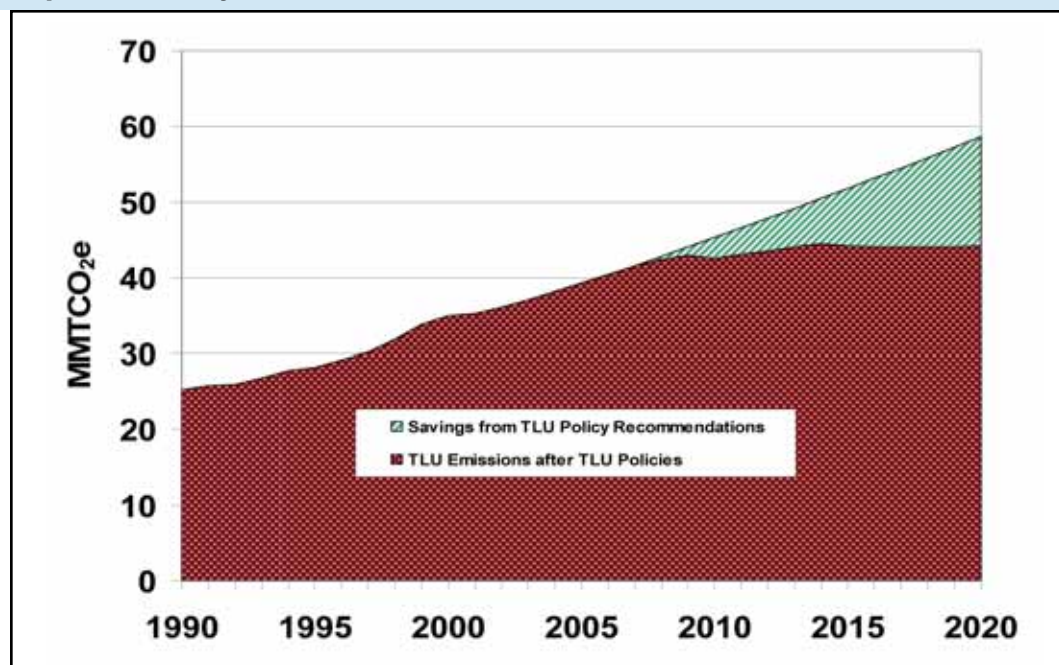
Arizona, but many obstacles remain in the way of large market penetration. Arizona also has taken some steps to increase transit options and encouraging Smart Growth.

Overview of Policy Recommendations and Estimated Impacts

The CCAG recommends a set of 13 policy options for the TLU sector that offer the potential for major GHG emissions reductions from the reference projection. As summarized in Table 7-1, these 13 policy recommendations could lead to emissions savings from reference case projections of 14.5 MMtCO₂e per year by 2020 and cumulative savings of 91 MMtCO₂e from 2007 through 2020. The weighted average cost of saved carbon from the policy options for which quantitative estimates of both costs and savings were prepared was minus \$32 per metric ton of CO₂ equivalent, meaning that there is a net savings to the Arizona economy in implementing these options.

The estimated impacts of the TLU policies recommended by the CCAG are shown in Figure 7-2. Aggressive implementation of these policies could keep TLU emissions growth relatively flat, increasing only to about 44 MMtCO₂e in 2020.

Figure7-2 Impact of Policy Recommendations on TLU Emissions



The CCAG policy recommendations described briefly here (and in more detail in Appendix I) result not only in the significant emissions and costs savings, but offer a host of additional benefits as well. These benefits include (but are by no means limited to) reduced local air pollution, more livable, healthy communities, and economic development and job growth from in-state biofuel production.

In order for the TLU policy options recommended by the CCAG to yield the levels of savings described here, the options must be implemented in a timely, aggressive, and thorough manner. Notably, the State Clean Car Program

for light-duty vehicles (TLU-1) accounts for a large portion of the reductions in this sector (e.g., more than 5 of the 16 MMtCO₂e of reductions in the year 2020). This option must clear several hurdles before Arizona or any other state can adopt it, including EPA approval of the original California Clean Car Program (that other states can then opt into) and a court challenge to the underlying notion of regulation of GHG emissions from vehicles. If, for any reason, Arizona is not able to implement the Clean Car Program, other options could play a larger role. For example, Hybrid Promotion and Incentives (TLU-7) and Feebates (TLU-8) would improve fuel efficiency. A multi-state approach

Table 7-1 CCAG Recommended Policy Options, By Sector

TRANSPORTATION AND LAND USE (TLU)						
	CCAG Policy Option	2010 Annual GHG Reduction (MMtCO₂e)	2020 Annual GHG Reduction (MMtCO₂e)	2007-2020 Cumulative Reduction (MMtCO₂e)	Cost or Cost Savings Per Ton GHG Removed (\$/tCO₂e)	Level of CCAG Support
TLU-1	State Clean Car Program	0.3	5.6	32.5	-\$90	Unanimous
TLU-2	Smart Growth Bundle of Options	1.5	4.0	26.7	\$0 (Net Savings)	Unanimous
TLU-3	Promoting Multimodal Transit	Not available (included in TLU-2)				Unanimous
TLU-4	Reduction of Vehicle Idling	0.7	1.3	11.8	-\$22	Unanimous
TLU-5	Standards for Alternative Fuels	Not available (enabling policy for TLU-12 and A-3)				Unanimous
TLU-7	Hybrid Promotion and Incentives	Not available (include in TLU-1)				Unanimous
TLU-8	Feebates	Not available				Super-Majority
TLU-9	Pay-As-You-Drive Insurance	0.0	2.8	12.3	\$0 (Zero net cost)	Unanimous
TLU-10	Low Rolling Resistance Tires and Tire Inflation	0.0	0.8	4.8	Not available	Unanimous
TLU-11	Accelerated Replacement/Retirement of High-Emitting Diesel Fleet	0.2	0.03	1.2	Not available	Unanimous
TLU-12	Biodiesel Implementation	0.1	1.1	6.2	\$0 (Zero net cost)	Unanimous
TLU-13	State Lead-By-Example (via Procurement and Smart Way)	0.03	0.04	0.4	\$0	Unanimous
TLU-14	60 mph Speed Limit for Commercial Trucks	0.3	0.5	5.2	\$35	Super-Majority
Total all options adjusted for overlap and interaction		3.1	14.5	91.0		

to feebates is recommended here because of the drawbacks of Arizona (or any state) acting alone in this area.

To be most effective, Smart Growth (TLU-2) will require change at every level of government, and as such will be most effective with focused leadership by the State, including training, outreach, and technical assistance to local governments.

Transit-Oriented Development (TLU-3), as well, will require integrated action by state, regional, and local governments. The State can lead by ensuring that state investments support regional and local smart growth, by both how and where it makes those investments. Finally, TLU-2 and TLU-3 are mutually supportive, and implementing one will increase the benefits generated by the other.

CCAG Transportation and Land Use (TLU) Sector Policy Descriptions

The TLU sector includes emissions and mitigation opportunities related to vehicle technologies, fuel choices, transit options, and demand for transportation services. Fully detailed descriptions of the individual TLU policy options as presented to and approved by the CCAG can be found in Appendix I.

State Clean Car Program (TLU-1)

Arizona should adopt the State Clean Car Program in order to reduce GHG emissions from new light-duty vehicles. The standards, which must still be approved by US EPA, would take effect in model year 2011 (calendar year 2010). Other Clean Car Program elements include standards requiring reductions in smog- and soot-forming pollutants, and promoting introduction of very low-emitting technologies into new vehicles.

New cars and light trucks in all states must comply with Federal emission standards, and, generally speaking, states have the choice of adopting a stronger set of standards applicable in California.

Eleven (11) states already have adopted the Clean Car Program standards: California, Connecticut, Maine, Massachusetts, New Jersey, New York, Oregon, Pennsylvania, Rhode Island, Vermont and Washington.

Smart Growth Bundle of Options (TLU-2)

Arizona should implement a bundle of options to reduce GHG emissions driven by land use practices and policies. The options include:

- *Infill, increased density and brownfield redevelopment:* Shifting housing and commercial development toward location efficient sites, such as brownfields and infill parcels, and away from location inefficient sites, such as greenfields, reduces overall travel demand and expand lower emitting mode choices. Brownfields are commercial or industrial properties that are abandoned or are not being fully used because of actual or perceived environmental contamination. These properties have potential for redevelopment, but the uncertainty and risk of environmental liability and the cost of investigation and cleanup keep them from being redeveloped. Brownfields can be former industrial properties, abandoned gas stations,

vacant warehouses, or former dry-cleaning establishments. Redevelopment of these contaminated properties creates jobs, revitalizes neighborhoods, increases property and sales tax revenues, decreases urban sprawl, and reduces potential health risks to the local community. Infill development and increased density can also revitalize neighborhoods, increase tax revenues, and decrease urban sprawl.

- *Transit-oriented development*: Enables shifts to lower emitting modes by building compact, mixed-use development around transit stops so that people can meet daily needs by foot, bicycle, or transit.
- *Smart growth*: Smart growth allows for mixed land uses with a range of housing opportunities and multiple transportation options including pedestrian/bike access. State actions to support smart growth include planning, modeling, and regulatory tools that support location efficient growth; and making State-funded investments in smart growth communities that are proximate to household amenities (such as jobs, shopping, school, services, entertainment, etc.) as opposed to growth in areas that are not proximate and require greater travel distance and have less mode choice.
- *Targeted open space protection*: Includes programs designed to protect and conserve State lands and other open spaces, and develop and improve neighborhood, community, and regional parks in ways that encourage location efficient growth and broader mode choice.

Multi-Modal Transit Options (TLU-3)

Arizona should enable and support multimodal transit and promote shifts in passenger transportation mode choice (auto, bus, rail, bike, pedestrian, etc.) to lower emitting choices. This includes: making optimal use of Community Multi-scale Air Quality (CMAQ) funds; expanding transit infrastructure (rail, bus, bus rapid transit [BRT]); improving transit service, promoting and marketing transit (including tax-free and employer-paid commuter benefits); improving bike and pedestrian infrastructure; exploring commuter rail using existing rail corridors; considering re-establishing train service between Phoenix and Tucson; reviewing all proposed transportation projects for multi-modal flexibility (e.g., add BRT or light rail if feasible); and conducting research into new transportation technologies and urban planning techniques.

Reduction of Vehicle Idling (TLU-4)

Arizona should implement policies to reduce idling from diesel and gasoline heavy-duty vehicles, buses, and other vehicles through the combination of a Statewide anti-idling ordinance and by promoting and expanding the use of technologies that reduce heavy-duty vehicle idling. These technologies include: automatic engine shut down/start up system controls; direct fired heaters (for providing heat only); auxiliary power units; and truck stop electrification. The goal of this policy is to implement a Statewide vehicle idling restriction rule that can be enforced and that minimizes allowable exemptions, in place by 2008, with plans for providing the necessary resources for enforcing the ordinance. The policy also aims to develop and pilot truck stop electrification programs. The policy target is an overall reduction in idling of 80% by 2010 and 100% by 2020.

This policy would be implemented through the following primary mechanisms: information and outreach to provide information indicating when and where idling is prohibited, and indicating the benefits of reducing idling, including fuel savings, toxic emission reductions, and GHG reductions; technical assistance for coordination with anti-idling product manufacturers; funding mechanisms to partially fund idling technology loan grants; a well-defined anti-idling ordinance; and a phased enforcement program.

Standards for Alternative Fuels (TLU-5)

Arizona should promote more widespread acceptance of alternative fuels by developing and enforcing a State standard for neat biodiesel (B100), biodiesel blends, and ethanol blends to ensure fuel quality and good vehicle performance. For biodiesel blends, the biofuel portion and the petroleum diesel portions of the fuel are separately regulated through ASTM standards;⁵⁸ however, no standard is currently in place for the blended biodiesel. Similarly, for ethanol blends, E85 and the gasoline portion of ethanol blends are regulated by ASTM standards.

Arizona recently passed legislation in 2006 (House Bill 2590) that regulates biodiesel blends and E85 blends. The base gasoline for ethanol blends must meet the standards for gasoline sold in that area. This measure should now focus on enforcement of the standard to ensure that fuel taxes are being paid and that blenders are registered with the State. To reduce fraud, the measure should ensure fuel that is delivered is as advertised, and eliminate consumer problems. Enforcement of this standard would be led by the Arizona Department of Weights and Measures. Certain exemptions might be acceptable (e.g., a school district blending biodiesel for use in its own school buses and not for outside sale).

Through the National Energy Act, growth in alternative fuels is expected in the near term. This measure will ensure that these alternative fuels sold in Arizona meet quality standards. This measure would also be broadened to include other alternative fuels that may be sold in Arizona.

Hybrid Promotion and Incentives (TLU-7)

Arizona should adopt a combination of public education and information efforts with financial incentives to promote the sales of light-duty vehicles with hybrid gasoline-electric power trains. This could include reduction in fees and taxes and giving preferential infrastructure access to hybrids on carpool lanes or metered parking spaces.

Hybrid promotion and incentive programs should be implemented from the time period between the near-term years when production is limited and the medium-to-long term years when expansion of production capabilities makes it more likely that promotion and incentive policies will have a significant effect on consumer choices. The State needs to study further the level and design of incentives necessary to achieve the goal set forth here.

In the near term (2006-2008), the hybrid vehicle sales are constrained on the producer side by an inability of automobile manufacturers to keep up with already existing consumer demand. In the medium-to-long term (2009 forward

⁵⁸ American Society for Testing and Materials (ASTM).

for Arizona), automobile manufacturers are likely to increase production capabilities for hybrid power train vehicles, and provide consumers with many more choices of hybrid cars. As a result, hybrid promotion and incentive programs are likely to have some incremental positive net effect on consumer purchase behavior.

Feebates (TLU-8)

Arizona should initiate a cost-shared, multi-state study of “feebate” program benefits and costs. At a minimum, the effort should include California and New Mexico. Feebates would provide incentives for reduce GHG emissions by creating:

- 1) fees on relatively high emissions/lower fuel economy vehicles and
- 2) rebates or tax credits on low emissions/higher fuel economy vehicles.

A multi-state approach is useful because of drawbacks in a single state adopting feebates in isolation.

Pay-As-You-Drive Insurance (TLU-9)

Arizona should authorize insurance companies to offer “Pay-As-You-Drive” (PAYD) auto coverage, under which a portion of auto insurance premiums are linked to miles driven (while the remaining portion remains a “fixed cost” as under current practice). Arizona should promote a PAYD pilot program in 2008, evaluate the results, and, if successful, promote this form of auto insurance.

Assuming this pilot is successful, market penetration could increase to 100% by 2020. This could happen either through competitive pressure (i.e., increasing numbers of companies offer it in order to stay competitive) or through a change in State policy mandating PAYD insurance at some point after it has been shown to work.

PAYD insurance has been promoted by a variety of groups for reasons that include emissions reduction and safety (through decreased driving), and fairness (by changing insurance costs to more closely track the portion of individuals' risk that is created by miles driven).

Low Rolling Resistance (LRR) Tires and Tire Inflation (TLU-10)

Arizona should establish minimum energy efficiency standards for replacement tires and require that greater information about high-efficiency “low-rolling resistance” (LRR) replacement tires be made available to consumers at the point of sale. Arizona should also promote proper inflation of tires by consumers to improve mileage and reduce emissions.

Manufacturers currently use LRR tires on new vehicles, but they are not easily available to consumers as replacement tires. When installing original equipment tires, carmakers use low rolling resistance tires as a way to contribute to meeting the federal automobile fuel economy (CAFE) standards. When replacing the original tires, consumers often purchase less efficient tires. Currently, tire manufacturers and retailers are not required to provide information about the fuel efficiency of replacement tires. In addition, there is no current minimum standard for fuel efficiency that all replacement tires must meet. A

combination of minimum standards and better consumer information could lead to a gain in fuel efficiency of about 3%. Improperly inflated tires decrease fuel efficiency and result in greater GHG emissions. Properly inflated tires will improve mileage, decrease fuel consumption and reduce GHG emissions.

Accelerated Replacement/Retirement of High-Emitting Diesel Fleet (TLU-11)

Arizona should reduce GHG black carbon emissions from heavy-duty diesel vehicles by developing and implementing an incentives program in Arizona to accelerate the replacement and/or retirement of the highest-emitting diesel vehicles.

Starting with the 2007 model year, the federal emission standards for new heavy-duty diesel vehicles will be improved. In conjunction with these more stringent emission standards, the sulfur content of diesel fuel is being lowered from 500 parts per million (ppm) to 15 ppm. These measures will combine to significantly reduce GHG black carbon emissions from heavy-duty diesel trucks and buses. However, a large number of older, more-polluting diesel vehicles will remain in the fleet. This measure is aimed at developing methods to incentivize the owners of these older vehicles to retire their vehicles early and replace them with vehicles meeting the 2007 emission standards.

The goal of this policy is to target 25% of vehicles from model years 1990 through 2006 (e.g., vehicles that still have over four years of expected useful life and do not meet the 2007 emission standards) for early retirement/replacement.

Biodiesel Implementation (TLU-12)

Arizona should increase market penetration of biodiesel fuels sold within the State. (Ethanol-related reductions are accounted for in the agriculture sector.) The State should conduct a review of any technical impediments to biodiesel use, and, if these are not significant, proceed to policies and measures that significantly increase biodiesel use and substitution for conventional diesel fuel. This program should be targeted to applications with the greatest likelihood of success and with a certainty of obtaining significant GHG emission reductions. This measure will help to ensure that Arizona is actively pursuing and meeting or exceeding the alternative fuel penetration goals specified in the Energy Security Act of 2005.

The goal of this program is to achieve a 75% penetration of B2 by 2010 (e.g., 1.5% total penetration of biodiesel). The State should review the program success by 2015 and determine whether further penetration of biodiesel fuel is desirable. This review should take into consideration the interactions of biodiesel blends with the ultra-low sulfur diesel to be sold nationally by 2010 and the technologies used to meet the new diesel vehicle emission standards starting in 2007. If the program is determined to be successful at that point and if biodiesel supply is not an issue, a goal of 50% penetration of B20 by 2020 (e.g., 10% total penetration of biodiesel) should be set.

Implementation mechanisms for this measure should include information on the benefits and potential performance issues associated with using biodiesel fuels; voluntary agreements targeting certain fleet segments with good likelihood of success in this program; a possible biodiesel use requirement

for fuel vendors; and an early pilot program for State diesel vehicles to begin using B10 or B20.⁵⁹

State Lead-By-Example via Vehicle Procurement and SmartWay (TLU-13)

Arizona state agencies should “lead by example” by enacting procurement policies and/or joining the EPA SmartWay program to achieve a lower-emitting vehicle fleet for the State. There are numerous activities Arizona could pursue to participate fully in enacting procurement policies or programs such as SmartWay. For example:

- State agencies with vehicle fleets could sign on as SmartWay carrier partners. They would then measure their environmental performance with the FLEET model and come up with a plan to improve that performance. The partnership provides information and suggested strategies to improve fuel economy and environmental performance of vehicle fleets.
- State agencies that buy transportation services, or ship goods could sign on as SmartWay shippers. As shipper partners, state agencies would seek to select SmartWay partners when they purchase the services of carriers. One way that the State could help would be to add SmartWay certification to the list of factors that they may consider when selecting carriers. Alternatively, they could just encourage the carriers that they do business with to join the partnership. Shippers can also implement direct strategies, for instance developing no-idle policies for their loading areas.
- State agencies could sign onto SmartWay as affiliates. As affiliates, they would help to distribute information on the program to interested parties. This could be as easy as putting a link on their web site, or it could involve a more active role.
- State agencies should purchase only vehicles that are hybrids, meet low-GHG emission standards, or use E-85, biofuels or other low-GHG alternative fuels.
- The State also should set a goal for replacement of the State vehicle fleet, so that by a date certain (e.g., 2010), all State vehicles shall be hybrids, meet low-GHG emission standards, or use E-85, biofuels or other low-GHG alternative fuels.


60 mph Speed Limit for Commercial Trucks (TLU-14)

Arizona should reduce the speed limit for commercial trucks to 60 mph on Arizona highways and freeways. Enforcement of this measure should begin by 2008, with a goal of reducing the portion of Class 8⁶⁰ diesel truck traffic currently traveling above speeds of 60 mph on interstates, freeways, and major arterials by 50 percent.

This measure would primarily be implemented by requiring all interstates, freeways, and major arterials in the State to be signed with a maximum speed of 60 mph for Class 8 commercial trucks. Additionally, significant enforcement resources will be needed for this measure to achieve the expected reductions.

⁵⁹ Legislation adopted in 2006 allows fleets required to meet alternative fuel conversions to get credit for biodiesel consumption. See www.azleg.gov/legtext/47leg/2r/laws/0388.htm.

⁶⁰ Class 8 commercial trucks are those above 33,000 lb gross vehicle weight rating. They are primarily trucks that pull one or more trailers of freight (i.e., the typical “18-wheeler”).



Education and outreach would also be needed to provide information to the trucking industry and the general public emphasizing the fuel economy benefits and resulting GHG emission reductions that are obtained when reducing speeds from 70 mph to 60 mph. The associated fuel cost savings and increased safety effects of this measure should also be emphasized.

CHAPTER 8 AGRICULTURE AND FORESTRY

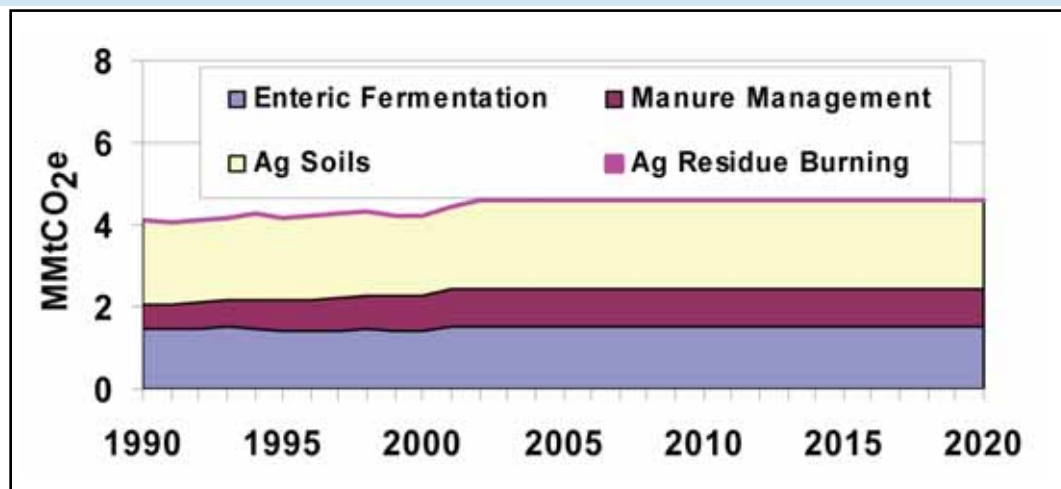
Overview of Greenhouse Gas Emissions

The agriculture and forestry (AF) sectors are directly responsible for only a small amount of Arizona's current GHG emissions. Net emissions are -2.4 MMtCO₂e in 2000, reflecting 4.2 MMtCO₂e emitted by the agricultural sector and a forestry sink of -6.7 MMtCO₂e. Agriculture emissions include methane (CH₄) and nitrous oxide (N₂O) emissions from enteric fermentation, manure management, agriculture soils, and agriculture residue burning. Emissions from agriculture soils account for the largest portion (about 50%) of agricultural emissions; this category includes N₂O emissions resulting from activities that increase nitrogen in the soil, including fertilizer (synthetic, organic, and livestock) application and production of nitrogen fixing crops. Other important agricultural sources are methane emissions from enteric fermentation in cattle and manure management at dairies.

Forestland emissions refer to the net CO₂ flux⁶¹ from forested lands in Arizona, which account for about 16% of the state's land area. Recent U.S. Forest Service estimates suggest that Arizona forests and the use of forest products sequestered on average 6.7 MMtCO₂e per year from 1987 to 2002.

Figure 8-1 shows historical and projected AF GHG emissions. The graph shows that no growth in the agricultural sector is assumed beyond 2004. Similarly, for the forestry sector, no change in carbon sequestration rate was assumed beyond 2002.

Figure 8-1 1990-2020 GHG Emissions by Sectors: Agriculture



⁶¹ "Flux" refers to both emissions of CO₂ to the atmosphere and removal (sinks) of CO₂ from the atmosphere.

Opportunities for GHG mitigation in the AF sector involve measures that can reduce emissions within the sector or reduce emissions in other sectors. For example, production of liquid fuels can offset emissions in the transportation sector, while biomass energy can reduce emissions in the energy supply or RCI sectors. The primary opportunities for GHG mitigation are as follows:

- *Production of renewable fuels:* production of renewable fuels, such as ethanol from crops, crop residue, forestry residue or municipal solid waste, can produce significant reductions, when they are used to offset consumption of fossil fuels (gasoline consumption in the transportation sector);
- *Beneficial use of forest biomass:* expanded use of biomass removed from forested areas during treatments to reduce fire risk can achieve GHG benefits by offsetting fossil fuel consumption (either to produce electricity or heat);
- *Control and utilization of CH₄ at dairies:* methane emissions from manure management can be reduced through the use of anaerobic digesters or other technology. The methane captured can then be used to create electricity, steam, or heat to offset fossil fuel use;
- *Protection of forest and agricultural land from conversion to developed use:* by protecting these areas from development, the carbon in above-ground biomass and below-ground soil organic carbon can be maintained and additional emissions of CO₂e to the atmosphere can be avoided; and
- *Restoration of forested lands:* a great deal of forested land has been lost to wildfire and disease in recent years. To the extent that the forests on these lands can be restored, the carbon sequestration potential of the land can also be restored.

Additional opportunities for reducing GHGs include: the use of agricultural residues, such as orchard trimmings and wheat straw, as biomass energy for the production of electricity, steam or heat; and programs to support local farming, which seek to reduce the amount of food trucked for long distances and the associated GHGs.

Key Challenges and Opportunities

In the forestry sector, restoration of forested areas has the potential for GHG benefits (0.1 MMtCO₂e/yr by 2020). However, the CCAG recognizes that restoration projects in many cases could be limited by available precipitation. Additional analysis is needed to identify areas where restoration programs are likely to be successful. Fairly significant GHG benefits were also estimated for utilization of biomass energy from forest treatment projects (to reduce fire risk). These benefits will total nearly 0.7 MMtCO₂e/yr in 2010 and 2020 based on current levels of treatment. Success will be achieved through close cooperation between Arizona, federal agencies (USFS), and private industry to identify biomass resources and effective end uses for the resource. Through recommendation of the option to support development of biomass gasification and combined cycle technology (BGCC), the CCAG recognized the need to promote efficient biomass energy resource utilization.

In the agricultural sector, production of ethanol was found to offer the most substantial GHG reduction potential (range of 0.6 to 4.0 MMtCO₂e/yr depending on the level of production targeted). While the policy recommendation is technology neutral, cellulosic ethanol production offers much larger GHG benefits than starch-based production. Available information on cellulosic production technology was used to estimate the benefits and costs for the policy recommendation. Additional information on the ethanol issues can be found in Appendix J. Combining the agricultural and forestry land protection options, 0.5 MMtCO₂e/yr in GHG savings is estimated to be saved by 2020. To achieve these reductions, the State will need to work closely with local planning agencies, land owners, and non-governmental organizations to identify lands suitable for acquisition/conservation easements and funding mechanisms. Another benefit to these options, which was not quantified, is the reduction in vehicle-miles traveled due to more efficient development patterns.

Overview of Policy Recommendations and Estimated Impacts

The CCAG recommends a set of 11 policy options for the AF sectors. These options are shown in Table 8-1 below. These policy recommendations could lead to emissions savings from reference case projections of nearly 6 MMtCO₂e per year by 2020 and cumulative savings of over 51 MMtCO₂e from 2006 through 2020. The weighted average cost of saved carbon from the policy options for which quantitative estimates of both costs and savings were prepared was \$2 per metric ton of CO₂ equivalent.

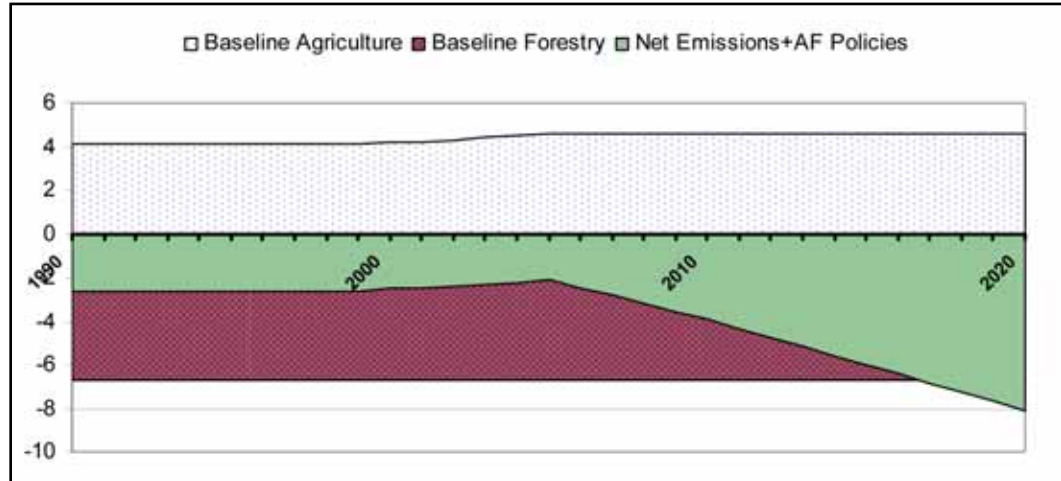
The emissions savings from the AF options are primarily a combination of reduced carbon dioxide and methane emissions. The carbon dioxide reductions come mainly from avoided gasoline or other fossil fuel emissions (e.g., from gasoline offset by ethanol produced within the State or other fossil fuels offset by biomass energy). Emissions are also reduced through forestry measures that protect or enhance Arizona forests in sequestration of carbon dioxide from the atmosphere. Methane emissions are reduced mainly from dairy operations. None of the other GHGs emitted by the AF sectors (e.g., nitrous oxide) are significantly affected by these options.

The estimated impacts of the AF policies recommended by the CCAG are shown in Figure 8-2. As shown in this graph, the effects of the recommended AF policies begin to appear prior to 2010 on the “Net Emissions + AF Policies” line. This line shows historical to 2005 net emissions (agricultural emissions plus forestry sinks) and the subsequent effects of recommended options. The net negative emissions of about -2.4 MMtCO₂e in 2005 begin to decrease to an estimate of -8 MMtCO₂e by 2020.

Table 8-1 CCAG Recommended Policy Options, By Sector

AGRICULTURE (A) AND FORESTRY (F)						
	CCAG Policy Option	2010 Annual GHG Reduction (MMtCO₂e)	2020 Annual GHG Reduction (MMtCO₂e)	2007-2020 Cumulative Reduction (MMtCO₂e)	Cost or Cost Savings Per Ton GHG Removed (\$/tCO₂e)	Level of CCAG Support
A-1	Manure Management – Manure Digesters	0.2	0.5	3.8	\$1	Unanimous
A-2	Biomass Feedstocks for Electricity or Steam Production	0.05	0.1	4.5	-\$8	Unanimous
A-3	Ethanol Production and Use	0.5	4.0	28.0	\$0	Unanimous
A-7	Convert Agricultural Land to Forest or Grassland	Not available				Unanimous
A-8	Reduce Conversion of Farm & Rangelands to Developed Uses	0.1	0.2	1.6	\$65	Unanimous
A-9	Programs to Support Local Farming/Buy Local	0.01	0.02	0.1	\$6	Unanimous
F-1	Forestland Protection from Developed Uses	0.3	0.3	3.7	\$17	Unanimous
F-2	Reforestation/Restoration of Forestland	0.02	0.1	0.6	\$44	Unanimous
F-3a	Forest Ecosystem Management – Residential Lands	0.5	0.5	6.4	-\$21	Unanimous
F-3b	Forest Ecosystem Management – Other Lands	0.2	0.2	2.9	-\$21	Unanimous
F-4	Improved Commercialization of Biomass Gasification and Combined Cycle	Not Quantified				Unanimous
Total all options adjusted for overlap and interaction		1.8	5.9	51		

Figure 8-2 Impact of Policy Recommendations on AF Emissions



Agriculture and Forestry (AF) Sectors Policy Descriptions

The Agriculture and Forestry (AF) Sectors include emissions and mitigation opportunities related to use of biomass energy, protection, and enhancement of forest and agricultural carbon sinks, control of agricultural methane emissions, production of renewable fuels, and reduction of transport emissions from imported agricultural commodities. Fully detailed descriptions of the individual Agriculture and Forestry policy options as presented to and approved by the CCAG can be found in the Technical Appendix.

Manure Management - Manure Digesters (A-1)

Methane emissions from livestock manure should be reduced through the use of manure digesters installed at dairies. Energy from the manure digesters is used to create heat or power, which offsets fossil fuel-based energy production and associated CO₂ and black carbon emissions. The goal is to manage dairy manure using anaerobic digesters and energy capture technology (e.g., electricity generators) covering 15% of the state-wide dairy population by 2010, and then increase this level to 50% of the dairy population by 2020.

Biomass Feedstocks for Electricity or Steam Production (A-2)

Arizona should set a goal of using 20% of available biomass by 2010, and 50% of available agricultural biomass by 2020 to displace fossil fuel usage through the use of agricultural waste (e.g., orchard trimmings, and other crop residue) as a feedstock for electricity or steam production. The CO₂ savings occur as a result of displacing fossil fuel use in the production of electricity or steam. There also would likely be a reduction in black carbon emissions to the extent that coal-based combustion is offset.

Ethanol Production and Use (A-3)

The State should provide incentives for the production of ethanol from crops, agricultural waste, or other materials to offset fossil fuel (gasoline) use.

Different incentive programs will be needed for crop (starch-based) ethanol production versus agricultural waste (cellulosic) ethanol production processes. Cellulosic production technology achieves much greater GHG benefits than starch-based processes and was used to estimate the benefits of this option (starch-based production is estimated to achieve about one-fourth the benefit of cellulosic production).

The CCAG considered three production goal options:

- By 2010, produce enough ethanol to support the use of E10 (10% ethanol by volume in gasoline) year round in areas that currently use it during the winter season (Maricopa, northern Pinal, and Pima counties). This would require the production of 207 MMgal/yr. (Year-round use would more than double the current usage levels of ethanol in Arizona.)
- By 2020, produce enough ethanol to support alignment with the New Mexico CCAG goal of 20% ethanol usage by volume in gasoline by 2012. This would require the production of 858 MMgal/yr in 2020.
- By 2050, produce enough ethanol to support alignment with the New Mexico CCAG goal of 40% ethanol by 2030. This would require production of 3,450 MMgal/yr by 2050.

Note: Production from the new Pinal County facility is included in the forecasted goals.

Convert Agricultural Land to Grassland or Forest (A-7)

Arizona should increase carbon sequestration in the state's agricultural land by converting marginal land used for annual crops to permanent cover, either grassland or forests. The state would determine a goal of converting a number of acres of marginal agricultural land to grassland or forest by 2010, 2020 and 2040. A loss of carbon to the atmosphere from tillage and fallow land would result by converting land to permanent cover. This action would have the effect of increasing soil carbon content and above-ground carbon stocks would also be increased by converting to cover with a greater ability to sequester carbon (i.e., higher biomass).

Reduce Conversion of Farm and Rangelands to Developed Uses (A-8)

The rate at which existing crop and rangelands are converted to developed uses should be reduced. The carbon sequestered in soils and above-ground biomass is higher in crop and rangelands than in developed land uses. The 2010 goal is to reduce the rate of crop and rangeland loss to 20% of the loss rate that occurred from 1982-1997. By 2020, the rate of loss should be lowered to 50% of that loss rate. Agricultural land protection is expected to occur through the promotion of land acquisition or conservation easements.

Programs to Support Local Farming/Buy Local (A-9)

Arizona should promote consumption of locally-produced agricultural commodities, which would offset consumption of commodities transported from other states or countries. It includes the modification, enhancement,

and further development of local farm programs employed in Arizona to reduce transport-related GHG emissions. The goal of this option is to increase consumption of Arizona-grown commodities by 5% by 2010 and another 5% by 2020 (total of 10% offset in 2020).

Forestland Protection from Developed Uses (F-1)

Arizona should reduce the rate at which existing forestlands and forest cover are cleared and converted to developed uses or damaged by development that reduces productivity.

The CCAG proposes that policy initiatives decrease the conversion of forest and woodlands to urban and other developed uses to 50% or less of the rates of loss to these uses during the 1987-1997 period by 2010 and continuing through 2020. A 50% reduction would decrease the conversion rate from 380 acres/year to 190 acres/year. If the rangeland type were assumed to include about 50% pinyon-juniper type, a 50% reduction in conversion rate would decrease the conversion rate of woodlands to urban or developed uses from 8,530 acres/year to 4,260 acres/year.

Reforestation/Restoration of Forestland (F-2)

Arizona should expand forest cover (and associated carbon stocks) by regenerating or establishing forests in areas with little or no forest cover at present.


The CCAG estimated the number of acres of previously forested lands to be restored to their native forested state at 155,000 acres, with a stocking rate of 35 tons of above-ground biomass per acre. Stocking this number of acres at the specified rate from 2008-2020 would result in approximately 26,000 acres regenerated/established by 2010 and 130,000 acres between 2010 and 2020. This equals an average of about 12,000 acres per year.

Forest Ecosystem Management (F-3a & 3b)

Sustainable thinning or biomass reduction from residential forestlands (intended to address fire and forest health issues) should be managed so that harvested biomass is directed to wood products and renewable energy instead of open burning or decay. F-3a is directed at residential lands (the wildland-urban interface or WUI) and F-3b is directed at non-WUI areas.

Most efforts to reduce biomass in residential forests and woodlands for forest health/sustainability and wildfire suppression include some emphasis on using the extracted woody biomass for wood products and/or energy production, rather than eliminating these materials through open burning, or storage or decay off site. The CCAG recommends placing a greater emphasis on wood products and/or energy production, through appropriate mechanisms, incentives, etc. More specifically, the CCAG recommends:

- Using 50% or more of biomass extracted from residential lands for wood products and/or energy production by 2010 and continuing through 2020.
- Accelerating current and planned fuels treatments in Arizona so that all high priority areas (e.g., in wild land urban interface) are treated by 2015.



The Governor's Forest Health Oversight Council and Forest Health Advisory Council should review forest management practices and policies aimed at GHG reduction and carbon sequestration.

Improved Commercialization of Biomass Combustion, Gasification and Combined Cycle (F-4)

Carbon savings occur when biomass energy combustion processes are converted from conventional technology to new technologies with greater thermal efficiency and reduced emissions with lower pollution outputs. Arizona should accelerate the rate of technology development and market deployment of biomass combustion, gasification, and combined cycle (BGCC) technologies. The State should set a goal of 10 megawatts of biomass energy between 2006 and 2010, and an additional 25 megawatts between 2010 and 2020 (or the equivalent amount of new biomass thermal energy).



**APPENDIX A:
EXECUTIVE ORDER 2005-02**

Executive Order 2005-02

Climate Change Advisory Group

WHEREAS, the Western Governors Association has recognized that, “Climate variability has impacted the West in recent years, including very significant droughts across much of the region;” and

WHEREAS, Arizona and other Western States have particular concerns about the impacts of climate change and climate variability on our environment, including the potential for prolonged drought, severe forest fires, warmer temperatures, increased snowmelt, reduced snow pack and other effects; and

WHEREAS, the Western Governors Association has recognized that, “The failure to take appropriate actions to address global climate change risks economic, environmental and societal damage;” and

WHEREAS, scientific consensus has developed that increasing emissions of carbon dioxide (CO₂), methane and other greenhouse gases released to the atmosphere are affecting the Earth’s climate; and

WHEREAS, there is growing interest in the United States in state-level actions to address the effects of climate change and greenhouse gas emissions; and

WHEREAS, a number of states are addressing climate change and greenhouse gas emissions on an individual and/or regional basis, including through the West Coast Governor’s Climate Change Initiative, the Regional Greenhouse Gas Initiative and other collaborations; and

WHEREAS, actions to reduce greenhouse gas emissions, including increasing energy efficiency, conserving natural resources and developing renewable energy sources, may have multiple benefits including economic development, job creation, cost savings, and improved air quality; and

WHEREAS, a stakeholder process to address climate change and greenhouse gas emissions in Arizona can build upon the work of, and further address issues raised by, the Energy Efficiency/Renewable Energy Working Group, the Essential Services Task Force, the Forest Health Advisory and Forest Health Oversight Councils, the Drought Task Force, the Governor’s Efficiency Review and other efforts of the State;

NOW THEREFORE, I, Janet Napolitano, Governor of the State of Arizona, by virtue of the powers vested in me by the Constitution and laws of this State, do hereby order the following actions to address climate change and greenhouse gas emissions in Arizona:

1. The Climate Change Advisory Group is established and charged with the development of recommendations to the Governor to reduce greenhouse gas emissions in Arizona, recognizing Arizona’s interests in continued growth, economic development and energy security.

2. The Climate Change Advisory Group shall be organized and coordinated by the Arizona Department of Environmental Quality.
3. The Climate Change Advisory Group shall not exceed 36 members each of whom shall be appointed by, and serve at the pleasure of the Governor. Commission members should represent the scope and diversity that this issue holds for Arizona. They should include representatives from some or all of the following sectors:
 - A. Electric Power Generation
 - B. Fossil Fuel Industry
 - C. Manufacturing/Mining
 - D. Agriculture/Forestry
 - E. Construction/Building
 - F. Tourism/Recreation
 - G. Health Care
 - H. Non-Governmental Organizations
 - I. Indian Tribes
 - J. State and Local Government
 - K. General Public
4. The Climate Change Advisory Group shall produce an inventory of greenhouse gas emissions in Arizona and their sources by June 30, 2005.
5. The Climate Change Advisory Group shall produce a Climate Change Action Plan with recommendations for reducing greenhouse gas emissions in Arizona, to be submitted to the Governor by June 30, 2006.

IN WITNESS WHEREOF, I have hereunto set my hand and caused to be affixed the Great Seal of the State of Arizona.


GOVERNOR

DONE at the Capitol in Phoenix on this 2 day of February in the Year Two Thousand Five and of the independence of the United States of America the Two Hundred Twenty-Ninth.

ATTEST:


SECRETARY OF STATE





**APPENDIX B:
DESCRIPTION OF THE CCAG PROCESS**



Description of the CCAG Process

The Arizona Climate Change Advisory Group (CCAG) process is based on successful planning templates developed for recent, comprehensive state climate change action plans and adapted specifically to Arizona. The Center for Climate Strategies (CCS, www.climatestrategies.us) was formed to assist states with the development and implementation of climate change mitigation plans and policies based on experience with many climate change plans and related policy processes. The Arizona CCAG process is designed to address multiparty, multi-issue, science intensive, consensus-building issues inherent to comprehensive climate policy action plans. It combines techniques used successfully in Alternative Dispute Resolution, Community Collaborative Based Decision Making, and Strategic Planning.

Purpose and Goals

The purpose and goals of the CCAG are expressed in Executive Order 2005-02, and include:

- Formation of the CCAG
- Development of recommendations for a comprehensive Arizona Climate Change Mitigation Action Plan
- Development of comprehensive greenhouse gas (GHG) emissions inventories and reference case projections for all sectors
- Transmittal of a final report with stakeholder recommendations to the Governor

Process Design

Activities of the CCAG process will be:

- Stepwise: The process will iterate to consensus and require continuity among participants. Stakeholder and technical work group participants will be expected to regularly attend meetings. Alternates should attend as needed due to schedule conflicts, but not as regular replacements.
- Fact based: Technical analysis and policy design will be achieved through preliminary and joint fact-finding and, ultimately, joint policy development by stakeholders and technical work groups assisted by a facilitation and technical consulting team.

- Consensus driven: The state will seek but not mandate consensus through this process, and final decisions by stakeholders will be made through agreed upon decision criteria and voting procedures that allow a full expression of viewpoints.
- Self-determined: The process starts with no pre-commitments to particular policies. Priorities for analysis and final recommendations will be self-determined through informed judgments by stakeholders and working groups.
- Informal and nonbinding: The process will be advisory and nonbinding to the state to provide public input for potential future policy decisions. It is structured as an informal consensus building effort to provide a full opportunity for stakeholders to make voluntary decisions on recommended policies.
- Transparent: The processes will be transparent. Policy options will include clear design parameters such as levels, timing, coverage, and implementation mechanism. Technical analyses will include clear disclosure of data, methods, sources and assumptions. All proceedings will be posted to the project website, www.azclimatechange.us.
- Inclusive: The process will include stakeholders, work group participants, and opportunities for public input in accordance with the Arizona Open Meetings Law.
- Flexible: Throughout the process the facilitation team will check with participants and the state on progress and any potential need for revision. Any proposed changes will be shared openly with the group.

Key steps and parameters of the process include the following:

- Stakeholder and technical work groups will explore solutions in all sectors, including: energy supply; commercial, industrial and residential; transportation and land use; agriculture and forestry; and waste management.
- The process will start with examination of a compendium of related policy actions undertaken in Arizona as well as other states and regions, with adaptation and initial prioritization for Arizona based on stakeholder preference.
- Mitigation of all GHG's will be examined, including carbon dioxide, methane, nitrous oxide, synthetic gases and, potentially, black carbon. Units will be expressed in carbon dioxide equivalents (CO₂e).
- Historical emissions inventories and reference case projections will be developed for years 1990-2020.
- Recommendations for action will cover future time periods of 2010, 2020 and, potentially, a third period beyond to be determined.
- Recommendations may include state level action as well as multi-state regional actions, as well as applicable voluntary and mandatory approaches.
- Recommendations will include both quantified and non-quantified actions, with emphasis on numerical analysis of GHG reduction potential and cost effectiveness for as many options as possible under available funding and project timetables. Secondary impacts and ancillary issues will be evaluated on a case-by-case basis pending stakeholder input.
- Stakeholder discussions will iterate to consensus and explore alternative policy designs and additional analysis as needed to reach final consensus, with assistance from the facilitation team and work groups.

- The final report will document CCAG recommendations and views on each policy option, including alternative views as needed.

Facilitator Guidelines

As a part of its role as evaluative facilitator, CCS voluntarily abides by the model standards of conduct by the American Arbitration Association, American Bar Association, and Association For Conflict Resolution as applicable to the advisory process as an informal, consensus building initiative.

Participant Guidelines

Stakeholders and technical work group members are expected to follow certain codes of conduct during the process, including:

- Attendance at all meetings to provide continuity to the stepwise process. Alternates may be named when absolutely necessary but may not serve as regular replacements for designated CCAG members or vote on behalf of CCAG members.
- Active involvement in proposals and evaluations is needed to fully support the process of joint policy development.
- Good faith participation and full support of the process is needed to respond to the Governor's request for comprehensive policy recommendations.
- In exchanging information and views, CCAG members should make fact based offers and statements, and refrain from personal criticisms.
- Do not represent the state or stakeholders in contacts with the media.

Timing

The first stakeholder meeting is scheduled for July 14, 2005, with six stakeholder meetings to be held from July 2005 to June 2006. Interim working group conference calls will be held between stakeholder meetings as needed. A draft inventory and projection of state greenhouse gas emissions will be provided to CCAG members for discussion at the July 14 meeting, with a final version produced for approval by the CCAG at its December meeting. The final report with stakeholder recommendations will be transmitted to the Governor by June 30, 2006. See the master schedule for the process for more detail on the timing of specific activities.

Roles and Responsibilities:

Leadership and Management

Governor Janet Napolitano has convened the CCAG through Executive Order 2005-02 and invited stakeholders to participate. ADEQ will organize and coordinate the process. The Center For Climate Strategies (CCS) under the direction of Tom Peterson will provide facilitation and

technical support. CCS will report to ADEQ and provide a final CCAG report to Governor Napolitano.

Stakeholders

A group of stakeholders has been selected by the state to form the CCAG. This group is tasked with developing final recommendations to the Governor with the assistance of technical work groups and an evaluative facilitation team.

Technical Work Groups

Technical work groups will be formed from subgroups of stakeholders, augmented as needed by other technical representatives and experts designated by the state. These groups will cover the following sectors: energy supply, waste energy, transportation and land use, commercial, industrial, residential, agriculture, forestry and cross cutting issues (such as reporting, registries, and education). Technical work groups will be tasked with providing guidance to stakeholders on priorities for analysis, technical analysis and design of options, and potential options for recommendation. They will be advisory to the stakeholder group and will participate in facilitated discussions between stakeholder meetings.

Public Participation

CCAG meetings will be conducted in accordance with the Arizona Open Meetings Law. Meeting notices, advance materials, and minutes of previous proceedings will be made available to the public through the project Web site or other means. Public input may be provided as a part of stakeholder meetings.

Evaluative Facilitation

The stakeholder and technical work group facilitators will serve as neutral and expert parties with the role of facilitating decisions and providing evaluative assistance to assist consensus building. Tom Peterson will serve as facilitator of the stakeholder group and coordinate an experienced technical facilitation and evaluation team. CCAG facilitation responsibilities include:

- Reporting to ADEQ
- Coordination and liaison with agency technical and support staff
- Coordination of technical work group leaders
- Facilitation and management of stakeholder meetings
- Oversight of the facilitation of work group discussions
- Oversight of advisory group documents
- Oversight of editing and production of the final report
- Conducting public meetings as needed

Technical Evaluation

Technical work group leaders will provide facilitation and consulting support to the advisory group to support consensus building. Technical consultants will perform analyses and provide support based on work group and stakeholder input. The team includes work group leaders covering key sectors and other consultants as needed for specialized analysis or additional capacity.

General responsibilities of work group leaders include:

- Assistance to CCAG members and technical work groups with fact finding and policy development
- Development of work group technical plans
- Development of work group agendas, documents, and presentations
- Analysis of policy options and scenarios to advisory group specifications
- Coordination with work group leaders, advisory and work group members, consultants, agency staff and outside technical experts as necessary
- Development of final report language, tables, and graphs

Specific analysis by technical consultants will include:

- GHG emissions inventories and reference case projections for all sectors
- Lists of potential mitigation options and assistance with development of initial priorities for analysis
- Open technical guidance related to policy design, data sources, methods and assumptions for analysis of policy options
- Initial quantification of direct GHG impacts and cost effectiveness, including advanced modeling for sectors, as necessary
- Revisions and alternative design proposals as needed
- Assistance in identifying potential implementation mechanisms and scenarios
- Final quantification of GHG impacts, cost effectiveness, and ancillary issues, including economic modeling, as necessary.

In addition to providing technical consulting team support for policy analysis and development, CCS will manage a project website for use by participants, www.azclimatechange.us. The website will be used for document sharing throughout the process. CCS will be responsible for posting documents and managing the site.

Key Members of the CCS Project Team:

Thomas D. Peterson - Executive Director, The Center For Climate Strategies (CCS), Senior Research Associate, Penn State University; Advisory Group Facilitator

Dr. Karl Hausker – Senior Advisor and Consultant to Enterprising Environmental Solutions Inc. (EESI); CCS Transportation and Land Use Work Group Leader

Maureen Mullen – Senior Chemical Engineer, E.H. Pechan & Associates, Inc.; CCS Transportation Issues Consultant

Michael Lazarus - Senior Scientist, Climate and Energy Program, Tellus Institute; CCS Residential/Commercial/Industrial Work Group Leader

Alison J. Bailie - Associate Scientist, The Tellus Institute, CCS Residential/Commercial/Industrial Work Group Leader

Eric Williams – Consultant to EESI; CCS Energy Supply Work Group Leader

Stephen Roe – Senior Scientist, Director Of California Operations, E. H. Pechan And Associates; CCS Registry and Emissions Modeling Consultant, Agriculture and Forestry Work Group Leader

Kenneth A. Colburn – Consultant to EESI; CCS Cross Cutting Issues Work Group Leader

Wiley Barbour - Executive Director of Environmental Resources Trust (ERT); CCS Registry and Markets Consultant

Dr. Adam Rose - Professor, Department of Geography, Penn State University; CCS Economic Modeling Consultant

For biographies of the CCS team members, please see the CCS Web site at www.climatestrategies.us. For contact information related to advisory group and technical work groups see www.azclimatechange.us.



**APPENDIX C:
LIST OF TECHNICAL WORK GROUP MEMBERS**

Energy Supply Technical Work Group

Stephen Ahearn – Arizona Residential Utility Consumer Office
Sandy Bahr – Sierra Club**
Mike Boyd – Western Wind Energy**
Ken Clark – Arizona Department of Commerce, Energy Office
Roger Clark – Grand Canyon Trust**
Margaret Cook – Gila River Indian Community**
Cosimo De Masi – Tucson Electric Power**
Kara Downey – Arizona Electric Power Cooperative**
Stephen Etsitty – Navajo Nation EPA**
Edward Fox – Pinnacle West/APS**
Richard Hayslip – Salt River Project**
Will Humble – Arizona Department of Health Services
Renz Jennings – Private Citizen/former Arizona Corporation Commissioner
Vince Murphy – Waste Management of Arizona

Residential/Commercial/Industrial Technical Work Group

Susan Culp – Arizona League of Conservation Voters
Kevin Kinsall – Phelps Dodge**
Grady Gammage, Jr. – Gammage and Burnham**
Jeff Homer – General Dynamics**
Glenn McGinnis – Arizona Clean Fuels**
Lisa McNeilly – The Nature Conservancy
Tim Mohin – Intel Corporation**
Don Netko – Freescale Semiconductors**
Amanda Ormond – Grand Canyon Trust
Suzanne Pfister – St. Joseph's Hospital**
Jeff Schlegel – Southwest Energy Efficiency Project**
Sean Seitz – Arizona Solar Energy Industry Association**
Penny Allee Taylor – Southwest Gas**
Richard Tobin – Lewis and Roca**

Transportation and Land Use Technical Work Group

David Berry – Swift Transportation**
Diane Brown – Arizona Public Interest Research Group
Beverly Chenausky – Arizona Department of Transportation
Becky Daggett – Governor's Growing Smarter Council
Rob Elliott – Arizona Raft Adventures**
Kirsten Engel – University of Arizona Law School**
Gina Grey – Western States Petroleum Association
Ursula Kramer – Pima County Department of Environmental Quality**
Willis Martin – Pulte Homes**
George Seitts – Arizona Department of Weights and Measures**
Karen O'Regan – City of Phoenix**
Bill Pfeifer – American Lung Association of Arizona**
Bob Ramirez – Salt River Pima-Maricopa Indian Community**
John Skelley – Arizona Grain
Duane Yantorno – Arizona Department of Weights and Measures

** Member of the Climate Change Advisory Group (CCAG)

Agriculture and Forestry Technical Work Group

Bas Aja – Arizona Cattle Growers' Association
Bob Broscheid – Arizona Game & Fish Department
Sam Campana – Audubon Arizona
Marcia Colquitt – Arizona Department of Agriculture
Jim Crosswhite – Rancher**
Dannion Cuning– Lake Havasu City Convention and Visitors Bureau**
Don Farmer – Arizona Wildlife Federation
Steve Gatewood – Greater Flagstaff Forest Council**
Jim Henness – Farmer**
George Koch – Northern Arizona University
Kirk Rowdabaugh – Arizona State Forester
Robert Shuler – Western Growers Association
Joe Sigg – Arizona Farm Bureau
Karen Smith – Arizona Department of Water Resources
Thomas Swetnam – University of Arizona Tree Ring Research Lab**

Cross Cutting Issues Technical Work Group

Sandy Bahr – Sierra Club **
Roger Clark – Grand Canyon Trust**
Rob Elliot – Arizona Raft Adventures**
Kirsten Engel – University of Arizona**
Stephen Etsitty – Navajo Nation EPA**
Edward Fox – Pinnacle West Capital Corporation/APS**
Richard Hayslip – Salt River Project**
Ursula Kramer – Pima County Dept. of Environmental Quality**
Tim Mohin – Intel Corporation**
Karen O'Regan – City of Phoenix**
Steve Owens – ADEQ**
Jeff Schlegel – Southwest Energy Efficiency Project**
Penny Allee Taylor – Southwest Gas Corporation**

*** Member of the Climate Change Advisory Group (CCAG)*

Other individuals who supported the Technical Work Group processes:

Cindy Coping – Arizona Cattle Growers' Association
Jo Crumbaker – Maricopa County Environmental Services, Air Quality
Jim Denson – Waste Management of Arizona
Mark Ellery – Arizona Department of Commerce, Energy Office
Ken Evans – Phelps Dodge
David Jallo – Arizona Public Service
Gaye Knight – City of Phoenix
Hsin-I Lin – Arizona Department of Health Services
Barbara Lockwood – Arizona Public Service
C.V. Mathai – Arizona Public Service
Brian O'Donnell – Southwest Gas Corporation
Frank Putman – Arizona Department of Water Resources
Mohan Toopal – Arizona Department of Transportation
Kate Whalen – Arizona League of Conservation Voters
Kate Widland – Salt River Project



**APPENDIX D: GREENHOUSE GAS EMISSIONS
INVENTORY AND REFERENCE CASE PROJECTIONS
1990-2020**

**Final Arizona Greenhouse Gas Inventory and
Reference Case Projections
1990-2020**

formally approved by the Arizona CCAG in March 2006

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Acronyms and Key Terms

ACC	Arizona Corporation Commission
ADEQ	Arizona Department of Environmental Quality
AEO2005	US DOE Energy Information Administration's Annual Energy Outlook 2005
AZDOT	Arizona Department of Transportation
BC	Black Carbon*
CH ₄	Methane*
Cl	Chlorine
CO ₂	Carbon Dioxide*
CO ₂ e	Carbon Dioxide equivalent*
DES	Department of Economic Security
EDMS	Emissions Data Management System
EIA	US DOE Energy Information Administration
FIA	Forest Industry Analysis
FORCARB	Original US Forest Service model estimate of carbon in forests
FORCARB2	Second US Forest Service model estimate of carbon in forests
GHG	Greenhouse Gases*
GWP	Global Warming Potential*
HFCs	Hydrofluorocarbons*
IPCC	Intergovernmental Panel on Climate Change*
MMt	Million Metric tons
MOVEAZ	Arizona DOT's Long Range Transportation Plan
MTBE	Methyl Tertiary Butyl Ether
N ₂ O	Nitrous Oxide*
NEI	National Emissions Inventory
NMIM	National Mobile Inventory Model
O ₃	Ozone
OC	Organic Carbon*
ODS	Ozone-Depleting Substances
OM	Organic Material*
PFCs	Perfluorocarbons*
POA	Primary Organic Aerosols
PM	Particulate Matter
RCI	Residential, Commercial, and Industrial

SEDS	State Energy Consumption, Price, and Expenditure Estimates
SF ₆	Sulfur Hexafluoride*
Sinks	Removals of carbon from the atmosphere, with the carbon stored in forests, soils, landfills, wood structures, or other biomass-related products.
t	Metric ton (equivalent to 1.102 short tons)
TWG	Technical Work Group
US DOE	U.S. Department of Energy
US EPA	U.S. Environmental Protection Agency
USFS	U.S. Forest Service
USGS	U.S. Geological Survey
VMT	Vehicle-Miles Traveled
W/m ²	Watts per square meter
WRAP	Western Regional Air Partnership

* See Supplement H for more information on these greenhouse gases.

1. Summary of Preliminary Findings

Introduction

This report, prepared by the Center for Climate Strategies, presents initial estimates of historical and projected Arizona anthropogenic greenhouse gas (GHG) emissions and sinks for the period from 1990 to 2020. These estimates were intended to assist the State, stakeholders, and technical work groups (TWGs) with an understanding of current and possible future Arizona's GHG emissions, and thereby inform the analysis and design of GHG mitigation strategies.

Historical GHG emissions estimates (1990 through 2003)¹ were developed using a set of generally-accepted principles and guidelines for State greenhouse gas emissions, as described in Section 2, relying to the extent possible on Arizona-specific data and inputs.² The initial reference case projections out to 2020 are based on a compilation of various existing Arizona and regional projections of electricity generation, fuel use, and other GHG emitting activities, along with a set of simple, transparent assumptions described later in this report.

This report covers the six types of gases included in the U.S. Greenhouse Gas Inventory: carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF₆). Emissions of these greenhouse gases are presented using a common metric, CO₂ equivalence (CO₂e), which indicates the relative contribution of each gas to global average radiative forcing on a Global Warming Potential (GWP) weighted basis. Supplement H to this report provides a fuller discussion of greenhouse gases and GWPs. Supplement I contains a White Paper on a 2002 base year and reference case emissions inventory of black carbon (BC) and organic carbon (OC) aerosols. Black carbon and organic carbon aerosols could have a significant climate impact, with black carbon having a particularly powerful warming impact. However, because the science is less certain on the relative magnitude of this impact, and because there are as yet no widely-accepted GWPs to enable comparison with greenhouse gases, these black and organic carbon emissions are not integrated in the CO₂ equivalent emissions estimates provided in the main GHG inventory and projection figures presented here.

Arizona Greenhouse Gas Emissions: Sources and Trends

Preliminary analysis suggests that in 2000, Arizona accounted for approximately 80 million metric tons³ (MMt) of *net* carbon dioxide equivalent (CO₂e) emissions, an amount equal to 1.2% of total US GHG emissions.⁴ Arizona GHG emissions are rising rapidly compared with the nation as a whole, driven by the rapid pace of Arizona's population and economic growth. Arizona GHG emissions were up 51% from 1990 to 2000, while national emissions rose by 23% during this period.⁵

¹ For some sectors and sources, historical data is only available through 2000, 2001 or 2002.

² In September 2004, the Arizona Department of Environmental Quality (ADEQ) prepared a preliminary GHG inventory assessment, which provided a starting point for this analysis. This final report was formally approved by the Arizona CCAG in March 2006.

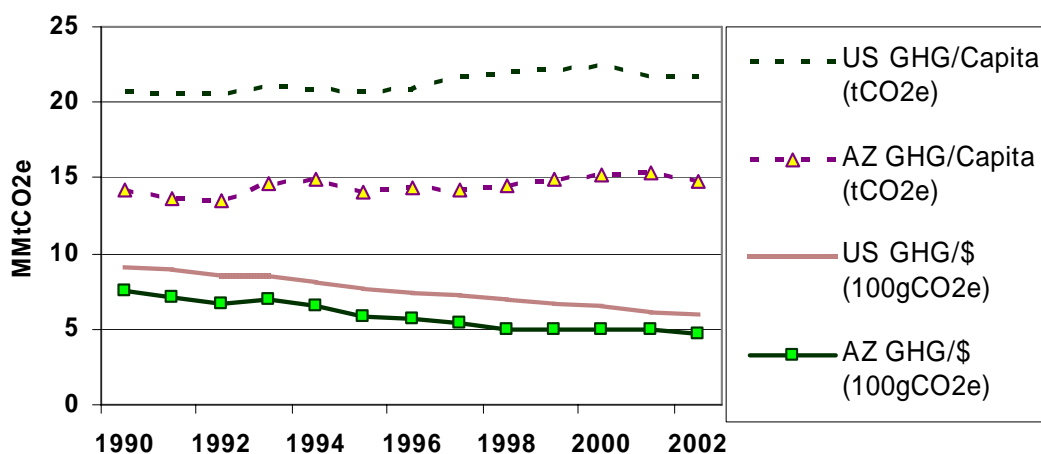
³ All GHG emissions are reported here in metric tons.

⁴ United States emissions estimates are drawn from Climate Analysis Indicators Tool (CAIT) version 1.5. (Washington, DC: World Resources Institute, 2003). Available at: <http://cait.wri.org>.

⁵ During the 1990s, population grew by 39% in Arizona compared with 13% nationally. Furthermore, Arizona's economy grew faster on a per capita basis (up 63% vs. 52% nationally).

On a per capita basis, Arizonans emit about 14 tCO₂e, 36% less than the national average of 22 tCO₂e per capita. Lower per capita emissions are due in part to Arizona's mild climate, and also to the State's less emissions-intensive economic base.⁶ Figure 1 illustrates the State's lower emissions per capita and per unit of economic output. It also shows that, like the nation as a whole, per capita emissions have remained fairly flat, while economic growth outpaced emissions growth throughout the 1990-2002 period. During the 1990s, emissions per unit of gross product dropped by 29% nationally, and by 33% in Arizona.

Figure 1. Arizona and US GHG Emissions, Per Capita and Per Unit Gross Product (2000\$)



Electricity use and transportation are the State's principal GHG emissions sources. Together, the combustion of fossil fuels in these two sectors accounts for nearly 80% of Arizona's gross GHG emissions, as shown in Figure.⁷ The remaining use of fossil fuels — natural gas, oil products, and coal—in the residential, commercial, and industrial (RCI) sectors constitutes another 11% of State emissions.

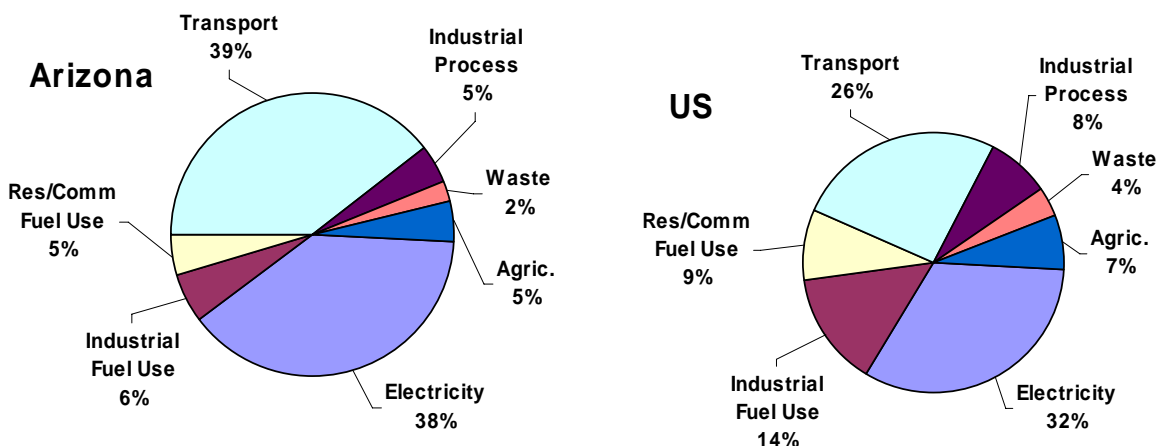
Agricultural activities such as manure management, fertilizer use, and livestock (enteric fermentation) result in methane and nitrous oxide emissions that account for another 5% of State GHG emissions. Industrial process emissions also comprise about 5% of State GHG emissions today, and these emissions are rising rapidly due to the increasing use of hydrofluorocarbons (HFC) as substitutes for ozone-depleting chlorofluorocarbons.⁸ Other industrial processes emissions result from perfluorocarbon (PFC) use in semiconductor manufacture, CO₂ released during cement and lime production, and methane released by natural gas systems, and coal mines. Landfills and wastewater management facilities produce methane and nitrous oxide emissions accounting for the remaining 2% of current State emissions; these emissions have declined slightly in recent years as landfill gas is increasingly captured and flared or used for energy purposes.

⁶ Arizona's economy has a lower share of emissions-intensive industrial and agricultural activities, such as steel production, petroleum refining, or dairy farming. Furthermore, while cooling demands are significant, the emissions associated with air conditioning are lower on average than those for space heating in the rest of the country.

⁷ Gross emissions estimates only include those sources with positive emissions. Carbon sequestration in soils and vegetation is included in net emissions estimates.

⁸ Chlorofluorocarbons (CFCs) are also potent greenhouse gases; however, they are not included in GHG estimates because of concerns related to implementation of the Montreal Protocol. See final Supplement H.

Figure 2. Gross Green House Gas Emissions by Sector, 2000, Arizona and U.S.



Gross emissions estimates do not include the effects of carbon sinks, i.e. the net carbon sequestered in, or released from, soils and vegetation. Recent U.S. Forest Service estimates suggest that Arizona forests and the use of forest products sequestered on average about 7 MMtCO_{2e} per year from 1985 to 2002. Much of this increase appears to have occurred during a period when the formal definition of forestland under Forest Inventory and Analysis (FIA) surveys was liberalized from a minimum 10% forest cover to 5% cover requirements. As a result, refined estimates regarding total statewide biomass sequestration, may result in significant changes to current estimates, but additional reviews of the data suggest the effects are more likely very small. This issue is discussed below and should be the focus of further analysis. (See *Key Uncertainties and Next Steps*). We report *net* GHG emissions – which include the above sequestration estimates – separately from the *gross* GHG emissions.

A Closer Look at the Two Major Sources: Electricity and Transportation

As shown in Figure 2, electricity use accounts for nearly 40% of Arizona's gross GHG emissions, or about 35 MMtCO_{2e}, slightly higher than the national share of emissions from electricity production (32%).⁹ On a per capita basis, in contrast, Arizona emits slightly less in terms of greenhouse gases (7 MMtCO_{2e}/capita vs. 8 MMtCO_{2e}/capita nationally). The average Arizonan uses about the same amount of electricity as the average U.S. resident (12,000 kWh per person per year), but Arizona electricity has lower emissions than the national average.¹⁰ Arizona gets slightly less electricity from coal (46% vs. 52% nationally in 2000) and more from low-emitting sources, such as nuclear, hydro, and other renewables (44% vs. 29% nationally in 2000).

During the 1990s, Arizona electricity demand grew at a rate of 4.0% per year, while electricity emissions grew 3.3% annually, reflecting a decline in emissions per kWh. This decline was due largely to the rapid growth of new natural gas generation, and to a lesser extent increases in nuclear generation.

⁹ Unlike for Arizona, for the U.S. as a whole, there is relatively little difference between the emissions from electricity use and emissions from electricity production, as the U.S. imports only about 1% of its electricity, and exports far less.

¹⁰ In 2000, electricity generation in Arizona emitted 1.107₂ (0.50tCO_{2e}) per MWh; as a placeholder we are presently assuming the same emission rate for electricity delivered to Arizona consumers. In 2000, electricity generation in the U.S. averaged 1321 lbCO_{2e} (0.60tCO_{2e}) per MWh.

It is important to note that these preliminary electricity emissions estimates reflect the *GHG emissions associated with the electricity sources used to meet Arizona demands*, corresponding to a consumption-based approach to emissions accounting (see Section 2). Another way to look at electricity emissions is to consider the *GHG emissions produced by electricity generation facilities in the State*. For many years, Arizona power plants have tended to produce considerably more electricity than is consumed in the State. For example, in the year 2000, Arizona produced 23% more electricity than it used, exporting on a net basis to consumers in nearby states. As a result, in 2000, emissions associated with electricity production (44.5 MMtCO_{2e}) were considerably higher than those associated with electricity use (34.5 MMtCO_{2e}).¹¹

While we estimate both the emissions from electricity production and use, unless otherwise indicated, tables, figures, and totals in this report reflect electricity use emissions. The consumption-based approach can better reflect the emissions (and emissions reductions) associated with activities occurring in the State, particularly with respect to electricity use (and efficiency improvements), and is thus particularly useful in a policy-making context. Under this approach, emissions associated with electricity exported to other states would need to be covered in those states' accounts in order to avoid double-counting or exclusions. (Indeed, California, Oregon, and Washington are currently considering such an approach.)

Like electricity emissions, GHG emissions from transportation fuel use have risen steadily since 1990 at an average rate of slightly over 3% annually. (See Figure 3.) Gasoline-powered vehicles account for about 65% of transportation GHG emissions. Diesel vehicles account for another 20%, air travel for roughly 10%, and the remainder of transportation emissions come from and natural gas and LPG vehicles. As the result of Arizona's rapid expansion and an increase in miles traveled during 1990s (from 35 billion vehicle-miles traveled [VMT] in 1990 to 50 billion VMT in 2000), gasoline use has grown at rate of 3.2% annually.¹² Meanwhile, diesel use has risen 6.5% annually, suggesting an even more rapid growth in freight movement within the State.

With respect to black carbon (BC) emissions, the transportation sector is the largest contributor. Transportation sources such as on-road diesel vehicles contributed 59% of Arizona's black carbon emissions in 2002 (see Supplement I). Other important BC emissions sectors include non-road diesel engines (18%; e.g., generators, construction equipment) and railroad engines (about 11%). Coal-fired electricity generating units contributed another 6%.

Reference Case Projections

Relying on US DOE and Arizona agency projections of electricity and fuel use, and other assumptions noted below, we developed a simple reference case projection of GHG emissions through 2020.¹³ The reference case assumes a continuation of current trends and reflects, to the extent possible, announced plans (e.g. power plant construction and retirement) and the implementation of recently enacted policies. One such policy is the

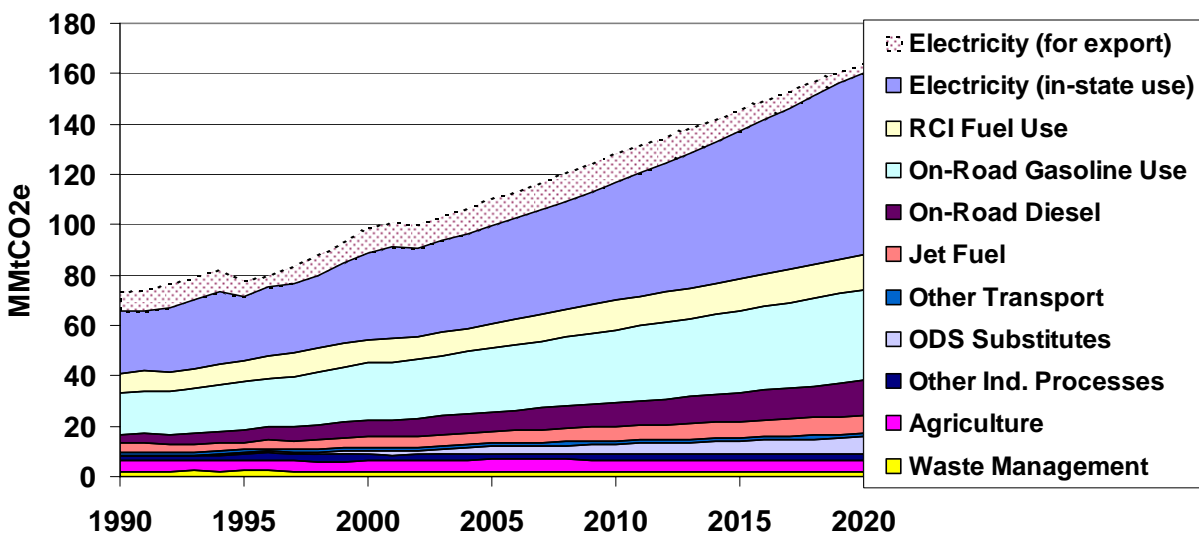
¹¹ Estimating the emissions associated with electricity use requires an understanding of the electricity sources (both in-state and out-of-state) used by utilities to meet consumer loads. The current estimate reflects some very simple assumptions described in the electricity appendix. We are currently collecting data from the State's larger electricity utilities that will help in refining these estimates.

¹² Based on U.S. Energy Information Agency data for the year 2000, Arizona gasoline use is also slightly below the national average (1.1 vs. 1.3 gallons per person per day). www.eia.doe.gov

¹³ Historical data runs through 2001 to 2003 depending on the emissions source.

Environmental Portfolio Standard, which currently requires investor-owned utilities to provide 1.1% of the electricity sales from renewable sources by 2012, and could result in emissions savings of slightly over 0.2 MMtCO₂e by 2012. As base case projections are finalized through collaboration with stakeholders and technical work groups, it will be important to include other existing and planned actions.

Figure 3. Gross GHG Emissions by Sector, 1990–2020: Historical and Projected



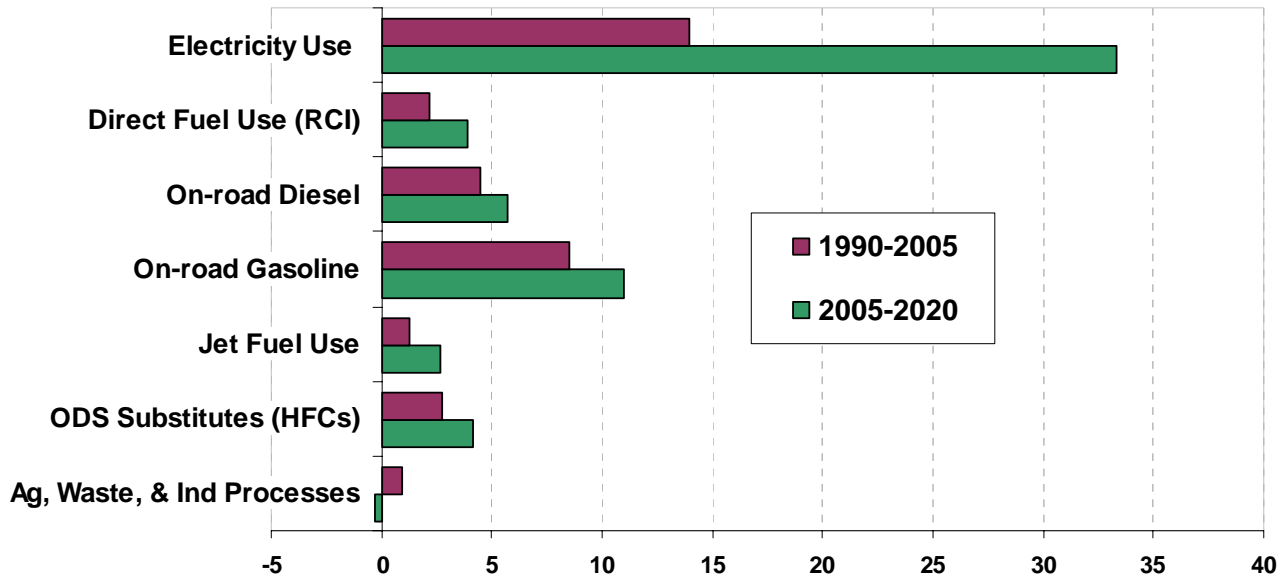
*This chart does not show net carbon sinks (forestry and land use) which average slightly over 10 MMtCO₂e/year.

Figure 4 illustrates the results of the reference case projection in terms of gross GHG emissions; corresponding numerical results are shown at the bottom of TABLE 1, under the four different emissions accounting approaches considered here: consumption basis, production basis, gross, and net. Under the gross, consumption-basis approach—i.e., excluding emissions associated with net electricity exports—Arizona GHG emissions would climb to 160 MMtCO₂e by 2020, 80% above 2000 levels and 143% above 1990 levels. Assuming current estimates for forest sequestration (6.7 MMtCO₂) continue through 2020, net emissions are lower than gross emissions, but the relative increase is greater.

The percentage increases in emissions relative to historical levels are slightly lower under a production-based approach, i.e., one that includes all emissions associated with in-state electricity production. Under the gross emissions case, 2020 production-based emissions are 75% above 2000 levels and 123% above 1990 levels. This difference results from the assumption—based on estimates from the Arizona Corporation Commission and US DOE—that Arizona electricity sales will grow slightly faster than electricity generation from 2010 onwards.

Electricity and gasoline use are projected to be the largest contributors to future emissions growth. Other major sources of emissions growth include freight transport (diesel), fuel use in buildings and industry (RCI), hydrofluorocarbons (HFCs) used in place of ozone-depleting substances (ODS), and air travel.

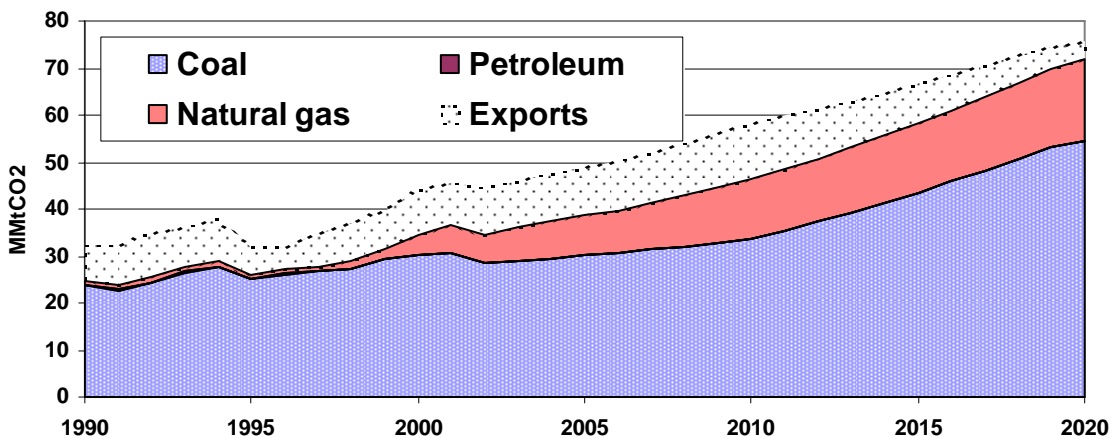
Figure 4. Contributions to Emissions Growth, 1990-2020: Reference Case Projections (MMtCO₂e)



ODS – Ozone Depleting Substance ; HFCs - Hydroflourocarbons

The particularly steep increase in electricity use emissions is due not only to the assumption that electricity use will continue to grow rapidly, but also that natural gas prices will continue to rise, and the mix of new generation will shift heavily towards coal after 2010, as depicted in Figure 5.

Figure 5. CO₂ Emissions from Electricity Production in Arizona, by Fuel Source (Includes All In-State Emissions)



Overall, the projected rate of emissions growth is 3.0% per year from the year 2000 onward, well below anticipated levels of economic growth (4.9% per year), but nonetheless significant. As illustrated in Figure , emissions track population growth fairly closely until the latter half of this decade, after which they begin to rise more rapidly. The increase in per

capita emissions after 2010 appears largely as the result of four factors: 1) electricity growth at a rate faster than population growth, 2) increasing reliance on coal-based generation, 3) freight traffic growing faster than population, and 4) increasing hydrofluorocarbon emissions in refrigeration, air conditioning, and other applications. For nearly all other sources, with the exception of natural gas use in residential, commercial, and industrial sectors, emissions are projected to grow at a pace slower than State population.

Figure 6. Historical and Projected GHG Emissions, GSP, and Population

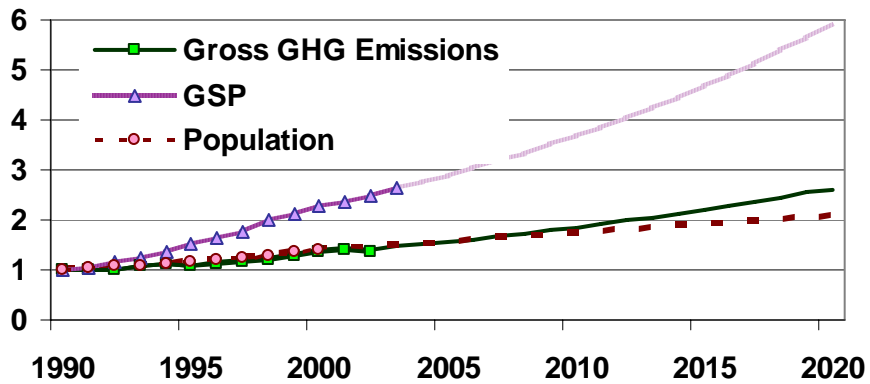


Table 1. Historical and Reference Case GHG Emissions, 1990–2020, by Source

(Million Metric Tons CO _{2e})	1990	2000 ^a	2010	2020	Explanatory Notes for Projections
Energy Use (CO₂, CH₄, N₂O)	57.9	78.8	103.6	144.6	
Electricity Use	24.9	34.5	46.6	72.2	
Electricity Production (in-state)	32.3	44.5	58.4	75.8	Total emissions for in-state power plants
Coal	30.9	39.2	42.4	57.5	See electric sector assumptions
Natural Gas	1.3	5.1	15.9	18.3	in appendix
Oil	0.1	0.2	0.0	0.0	
Net Electricity Exports	-7.4	-10.0	-11.8	-3.6	
Res/Comm/Ind (RCI)	7.7	9.3	11.6	13.8	
Coal	1.2	1.5	1.8	1.9	Based on US DOE regional projections
Natural Gas	4.2	4.7	5.7	7.2	Based on US DOE regional projections
Oil	2.2	3.0	4.1	4.6	Based on US DOE regional projections
Wood (CH ₄ and N ₂ O)	0.1	0.1	0.1	0.1	Assumes no change after 2003
Transportation	25.3	35.0	45.4	58.6	
On-road Gasoline	16.8	22.8	28.9	36.3	VMT from MoveAZ, constant energy/VMT
On-road Diesel	3.5	6.5	9.5	13.6	VMT from MoveAZ, constant energy/VMT
Jet Fuel and Aviation Gasoline	3.5	4.3	5.7	7.4	Based on USDOE regional projections
Natural Gas (pipeline use)	1.4	1.1	1.2	1.2	Constant at 2002 levels
Other	0.2	0.2	0.1	0.1	Based on USDOE regional projections
Industrial Processes	1.9	4.1	6.3	9.1	
ODS Substitutes	0.0	1.4	4.0	6.9	Based on national projections (US EPA)
PFCs in Semi-conductor Ind.	0.4	1.0	0.5	0.3	Based on national projections (US EPA)
SF ₆ from Electric Utilities	0.5	0.3	0.2	0.1	Based on national projections (US EPA)
Cement & Other Industry	0.6	1.0	0.9	1.0	Increases with state population
Methane from Oil & Gas Systems	0.4	0.4	0.6	0.8	Increases with natural gas use
Methane from Coal Mining	0.1	0.1	0.1	0.1	Assumes no change after 2003
Agriculture, Land Use, Forestry	-2.6	-2.5	-2.1	-2.1	
Agriculture (CH ₄ & N ₂ O)	4.1	4.2	4.7	4.7	Assumes (for now) no change after 2002
Soils and Forest Sinks	-6.7	-6.7	-6.7	-6.7	Subject to considerable uncertainty
Waste Management	2.1	1.9	2.0	1.9	
Solid Waste Management	1.7	1.3	1.4	1.1	Based on national projections (US EPA)
Wastewater Management	0.4	0.5	0.7	0.8	Increases with state population
Total Emissions - Consumption-Basis (Excluding Emissions from Net Electricity Exports)					
Gross (excluding sinks)	66.0	89.0	116.6	160.3	
<i>increase relative to 1990</i>		35%	77%	143%	
<i>increase relative to 2000</i>			31%	80%	
Net (including sinks)	59.3	82.3	109.9	153.5	
<i>increase relative to 1990</i>		39%	85%	159%	
<i>increase relative to 2000</i>			34%	87%	
Total Emissions - Production-Basis (Including All In-State Electricity Generation)					
Gross (excluding sinks)	73.5	99.0	128.4	163.9	
<i>increase relative to 1990</i>		35%	75%	123%	
<i>increase relative to 2000</i>			30%	66%	
Net (including sinks)	66.7	92.3	121.6	157.2	
<i>increase relative to 1990</i>		38%	82%	135%	
<i>increase relative to 2000</i>			32%	70%	

^a These emissions estimates do not include black carbon and organic carbon contributions. These emissions are difficult to convert into CO₂ equivalents, given the lack of commonly accepted GWPs. Nonetheless, available research provides the basis for some initial GWP estimates, as discussed in Supplement I. Application of these indicative GWPs suggests that Arizona black and organic carbon emissions may have accounted for 3 to 6 million metric tons CO₂ equivalent emissions in 2002.

ODS – Ozone Depleting Substances; PFCs – Perfluorocarbons; SF₆ – Sulfur Hexafluoride

Key Uncertainties and Next Steps

The authors undertook efforts to resolve key data gaps and uncertainties in the inventory and projections. Key tasks included: the incorporation of anticipated actions and policies (efficiency programs, voluntary actions, new cement plants and refineries, etc.), gaining a better understanding of the electricity generation sources currently used to meet Arizona loads (in collaboration with State utilities), and review and revision of key drivers such as the electricity and gasoline use growth rates that will be major determinants of Arizona's future GHG emissions (See Table 2).

These growth rates are driven by economic, demographic, and land use trends (including growth patterns and transportation system impacts), all of which are subject to uncertainty and deserve closer examination. Population estimates are based on official projections from the Arizona Department of Economic Security (DES). These projections, however, are widely recognized as outdated (based on assumptions circa 1997). Population growth has been more rapid than these projections would indicate. The DES projections are currently under revision, and it is likely that revised projections will be available during the stakeholder process. Emissions projections can then be revised accordingly.¹⁴

As described in Supplement I, the need to develop black and organic carbon emissions projections was based on feedback from the Arizona CCAG. CCS had recommended incorporating projections from the Western Regional Air Partnership (WRAP) when they are made available. Specifically, the 2008 and 2018 WRAP projections are best aligned with the GHG forecasts provided in this report. CCS submitted a request to the WRAP for these projections, however as of August 2006, the data were not yet available.

¹⁴ If the projected growth rates are higher than currently projected (2.0%), then some emissions projections could rise. However, it is important to note that several of the key drivers for this analysis, such as electricity demand growth and passenger VMT, are already higher than projected population, and may implicitly reflect population projections higher than the official forecast.

Table 2. Key Annual Growth Rates, Historical and Projected (%)

Parameter	Historical		Projected	Sources/Uses
	1980–1990	1990–2000	2000–2020	
Population*	3.1	3.4	2.0	U.S. Census Bureau for historic, AZ Department of Economic Security for projection
GSP	4.1	6.3	4.9	(not used for projections)
Employment*	3.9	2.9	2.5	AZ- DOT’s MoveAZ report for historic, AZ Department of Economic Security for projection
Electricity sales	4.5	4.0	3.6	EIA SEDS for historic; RCI TWG for projections
Personal Vehicle Miles Traveled*	n/a	n/a	2.4	Bureau of Transport Statistics for historic, AZDOT’s MoveAZ for projections
Freight Vehicle Miles Traveled*	n/a	n/a	3.7	Bureau of Transport Statistics for historic, AZDOT’s MoveAZ for projections

*Population, employment and vehicle-miles traveled (VMT) projections for Arizona were used together with US DOE’s Annual Energy Outlook 2005 projections of changes in fuel use on a per capita, per employee, and per VMT, as relevant for each sector. For instance, growth in Arizona residential natural gas use is calculated as the Arizona population growth times the change in per capita Arizona natural gas use for the Mountain region. Arizona population growth is also used as the driver of growth in cement production, soda ash consumption, solid waste generation, and wastewater generation. MOVEAZ – Arizona DOT’s Long Range Transportation Plan; EIA SEDS – Energy Information Agency (EIA) State Energy Consumption, Price, and Expenditure Estimates (SEDS); RCI TWG –Residential, Commercial and Industrial Technical Working Group

Furthermore, the current reference case does not include an analysis of future agriculture emissions, which might change significantly if water scarcity, commodity programs, and trade agreements, among other factors, induce major shifts among crops and livestock grown in the State.

In addition, the following two areas are subject to considerable uncertainty, not simply because the future is hard to predict, but because of data availability and scientific understanding:

- **Terrestrial carbon emissions and sinks:** The net forest and land use sequestration estimates noted above are based on recent improvements to U.S. Forest Service carbon stock inventory data known as FORCARB2. But they do not fully address all issues that ultimately will be needed to develop final estimates. As a result, initial estimates may change as additional data is developed. For instance, U.S. Forest Service assessments only cover the parts of the State that the U.S. Forest Service defines as forest, representing 16% of the total State land area in 2002 (4.85 of 30.3 million hectares). During the Forest Inventory and Analysis (FIA) survey periods used for FORCARB2 estimates, the definition of forestland changed from a minimum forest cover requirement of 10%, to a minimum of 5%. As a result, rangelands may or may not be included in these estimates, depending on their level of tree stocking. To the extent that

they may sequester or emit carbon, while small on a per acre basis, rangelands may be quite significant at the State level.¹⁵

Second, what the USFS defines as forest area in Arizona has increased by 14% since 1985, when it totaled 4.25 million hectares. This addition appears to account for much of the net gain in carbon stock in the USFS estimates (offsetting a decrease in carbon stock per hectare from 1996 to 2002) and may or may not be attributable to the change in the definition of forestland and the addition of lands at between 5% and 10% forest cover. As a consequence of the change in forest definition, the USFS methods may overestimate carbon gains associated with the lands not formally defined as forest under the previous definition. Any carbon added from this definition change was not covered in the previous cycles and potentially distorts the effects of carbon change in total.

- **Black carbon and other aerosol emissions.** Emissions of aerosols, particularly black carbon from fossil fuel and biomass combustion, could have potentially significant impacts in terms radiative forcing (i.e., climate impacts). Methodologies for conversion of black carbon mass estimates and projections to global warming potential involve significant uncertainty at present. Our methods for estimating black carbon emissions and their CO₂e are provided in Supplement I. Results are also summarized in this appendix and but are not incorporated into the sector-level results below.

¹⁵ However, the carbon cycle for rangelands is not well understood, and has not been included in current surveys.

2. Approach

The principal goal of the inventory and reference case projections was to provide the State, stakeholders and technical work groups (TWGs) with a general understanding of Arizona's historical, current and projected (expected) greenhouse gas emissions. The authors of this report worked with stakeholders and working groups to augment, refine and disaggregate these estimates.

General Principles and Guidelines

A key part of this effort involved the establishment and use of a set of generally accepted accounting principles for evaluation of historical and projected GHG emissions, as follows:

- **Transparency:** We report data sources, methods, and key assumptions to provide open review and opportunities for additional revisions later based on stakeholder and technical work group input.
- **Consistency:** To the extent possible, the inventory and projections are designed to be externally consistent with current or likely future systems for State and national GHG emission reporting. We have used US EPA tools for state inventories and projections as a starting point. These initial estimates were then augmented to conform to local data and conditions, as informed by Arizona-specific sources and experts.
- **Comprehensive Coverage of Gases, Sectors, State Activities, and Time Periods:** This analysis aims to comprehensively cover GHG emissions associated with activities in Arizona. It covers all six greenhouse gases covered by U.S. and other national inventories: carbon dioxide, (CO₂), methane (CH₄), nitrous oxide (N₂O), sulfur hexafluoride (SF₆), hydrofluorocarbons (HFCs), and perfluorocarbons (PFCs). Black carbon and organic carbon emissions have been quantified for a 2002 base year (see Supplement I).
- **Priority of Significant Emissions Sources:** In general, activities with relatively small emissions levels may not be reported in the same level of detail as other activities.
- **Priority of Existing State and Local Data Sources:** In gathering data and in cases where data sources might conflict, highest priority was placed on local and state data and analyses, followed by regional sources, with national data used as defaults where necessary.
- **Use of Consumption-Based Emissions Estimates:** To the extent possible, this report estimates emissions that are caused by activities that occur in Arizona. For example, we report emissions associated with the electricity consumed in Arizona. The rationale for this method of reporting is that it can more accurately reflect the impact of state-based policy strategies such as energy efficiency on overall GHG emissions, and it resolves double-counting and exclusion problems with multi-emissions issues. This approach can differ from how inventories are compiled, i.e., on an in-state production basis, in particular for electricity. For electricity, we estimate, in addition to the emissions due to fuels combusted at electricity plants in the State, the emissions related to electricity *consumed* in Arizona. This entails accounting for the electricity sources used by Arizona utilities to meet consumer demands. As we refined this analysis, we also attempted to estimate other sectoral emissions on a consumption basis, such as fuel used for transportation purchased out-of-state. In some cases this requires venturing into the relatively complex terrain of life cycle analysis. In general, we recommend considering a consumption-based approach where it will significantly improve the estimation of the

emissions impact of potential mitigation strategies. (For example, re-use, recycling, and source reduction can lead to emission reductions resulting from lower energy requirements for material production [such as paper, cardboard, and aluminum], even though these activities and their emissions may not occur within the State.)

General Methodology

We prepared this analysis in close consultation with Arizona agencies, in particular, the Department of Environmental Quality (ADEQ) staff. The overall goal of this effort is to provide simple and straightforward estimates, with an emphasis on robustness and transparency. As a result, we rely on straightforward spreadsheet analysis rather than detailed modeling.

In most cases, we follow the same approach to emissions accounting used by the US EPA in its national GHG emissions inventory¹⁶ and its guidelines for states.¹⁷ These inventory guidelines were developed based on the guidelines from the Intergovernmental Panel on Climate Change, the international organization responsible for developing coordinated methods for national greenhouse gas inventories.¹⁸ The inventory methods provide flexibility to account for local conditions.

The electricity sector is one area in which we expand the US EPA inventory approach, by looking at consumption-based, in addition to production-based emissions, as described above. We encouraged Arizona stakeholders to closely consider the question of whether and how to count GHG emissions from exported electricity in setting and tracking emissions. Stakeholders considered strategies that work together with neighboring states to reduce overall GHG emissions. A number of other accounting questions also needed to be resolved, such as the treatment of transportation fuels used out of state and for international travel.

¹⁶ US EPA, Feb 2005. *Draft Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2003*. <http://yosemite.epa.gov/oar/globalwarming.nsf/content/ResourceCenterPublicationsGHGEmissionsUSEmissionsInventory2005.html>.

¹⁷ <http://yosemite.epa.gov/oar/globalwarming.nsf/content/EmissionsStateInventoryGuidance.html>

¹⁸ <http://www.ipcc-nggip.iges.or.jp/public/gl/invs1.htm>

Table 3. Key Sources for Data, Inventory Methods, and Projection Growth Rates

Source	Information Provided	Use of Information in this Analysis
US EPA State Greenhouse Gas Inventory Tool (SGIT)	EPA SGIT is a collection of linked spreadsheets designed to help users develop state GHG inventories. EPA SGIT contains default data for each state for most of the information required for an inventory.	Where not indicated otherwise, SGIT is used to calculate emissions from industrial processes, agriculture and forestry, and waste. We use SGIT emission factors (CO ₂ , CH ₄ and N ₂ O per BTU consumed) to calculate energy use emissions. ¹⁹
US DOE Energy Information Administration (EIA) State Energy Data System (SEDS)	EIA SEDS source provides energy use data in each state, annually to 2002.	EIA SEDS is the source for all energy use data except on-road gasoline and diesel consumption. Emission factors from EPA SGIT are used to calculate energy-related emissions.
US DOE Energy Information Administration Annual Energy Outlook 2005 (AEO2005)	EIA AEO2005 projects energy supply and demand for the U.S. from 2005 to 2025. Energy consumption is estimated on a regional basis. Arizona is included in the Mountain Census region (AZ, CO, ID, MT, NM, NV, UT, and WY)	EIA AEO2005 is used to project changes in per capita (residential), per employee (commercial/industrial), and per VMT (transportation) fossil fuel use. (See Table 2)
Arizona Department of Transportation (AZDOT)	AZDOT reports on-road gasoline and diesel consumption based on calculations from tax revenue. ²⁰	AZDOT provides data for gasoline and diesel consumption.
Arizona DOT's Long Range Transportation Plan (MOVEAZ)	The MOVEAZ analysis projects population, employment, and transportation demand. ²¹	The MOVEAZ report provides the source vehicle mileage growth rates in the transportation sector.

A series of Supplements to this appendix follow which further explain the data and estimates used in this report. Supplements A – F provide information on the estimates used for each sector. Supplement G provides a list of the many experts contacted, and Supplement H describes global warming potential (GWP) using US EPA's Inventory of U.S. Greenhouse Emissions and Sinks.

¹⁹ We did not use the EPA SGIT tool directly to calculate emissions from energy use because the data in the tool has not been updated to the most recent energy consumption data. By calculating GHG emissions directly from energy use multiplied by the emissions factors from SGIT, we are able to use locally sourced energy data, such as AZDOT gasoline and diesel sales data.

²⁰ www.azdot.gov/Inside_ADOT/fms

²¹ www.moveaz.org

Supplement A. Electricity Use and Supply¹

For reasons described above—largely to better assess the impacts of potential GHG mitigation options—we estimate electricity emissions on both a consumption basis, i.e. accounting for the GHG emissions associated with electricity used in the State. We also calculate electricity emissions on a production basis, based on the fuel used by in-state generators, since this is a simpler calculation, and one more commonly used for historical inventories.

Estimating the sources of electricity associated with electricity consumed in the State, and their emissions, poses some challenges. Precisely tracking the sources of electricity used to meet Arizona loads is impossible; doing so would require a system to trace each kWh as it flowed from the generator throughout the regional transmission and distribution system to the ultimate user. A more technically feasible approach would be to follow the “contract path” of electricity purchases and sales by generators and load-serving entities (e.g., utilities); however, such a system does not currently exist. As a result, we must turn to simpler approximations, such as the fuel mix reporting methods used by several Western states.² In essence, this method relies on utilities to report the sources of electricity they use to meet their loads, based on their plants, contracts, and net market purchases.³ In collaboration with state utilities, we reviewed the feasibility of this methodology.

Meanwhile, we have adopted a simple and transparent approach to estimate consumption-based emissions. We begin by examining the fuel consumed, and emissions generated, by power plants in the State. We then assume, for now, that this in-state generation fuel mix is representative of the fuel mix used to meet in-state loads. As a result, if the State is a net electricity exporter, we deduct the emissions associated with exports to other states, using the same average fuel mix.

Projecting generation sources, sales, and emissions for the electric sector out to 2020 requires a number of key assumptions, such as including economic and demographic activity, changes in electricity-using technologies, regional markets for electricity (and competitiveness of various technologies and locations), access to transmission and distribution, the retirement of existing generation plants, the response to changing fuel prices, and the fuel/technology mix of new generation plants. Key simplifying assumptions used here are summarized in Table 4.

¹ The Energy Supply Technical Working Group reviewed the draft GHG inventory and forecast, and the corresponding assumptions, for this sector. They recommended that the inventory and forecast be accepted with a change to reflect growth in peak demand as distinct from growth in total demand; figures cited in this report reflect growth in peak demand.

² See, for example, the California and Washington fuel mix and emissions reports at http://www.cted.wa.gov/CTED/documents/ID_1338_Publications.pdf and http://www.energy.ca.gov/consumer/power_content_label.html

³ The fuel mix of net market purchases—i.e., short-term and other purchases that are not associated with a specific electricity source—can be estimated in consistent manner using the regional average electricity mix (as Washington and Oregon do) or using other techniques.

Table 4. Key Assumptions and Methods for Electricity Projections

Electricity Sales	3.75% annual growth rate to 2010, and 3.50% growth after 2010, based on input from the RCI Technical Working Group
Electricity Generation	3% annual growth from 2004-2010, based on regional growth in Western Electricity Coordinating Council report, ^a 2% annual growth from 2011-2020, based on regional growth in EIA AEO2005 (region includes AZ, NM and southern NV)
Transmission and Distribution Losses	10%, based on average statewide losses, 1994-2000, (data from EPA Emission & Generation Resource Integrated Database ^b)
New Renewable Generation Sources	For Arizona Public Service and Tucson Electric Power, we assume no renewables beyond compliance with the current Environmental Portfolio Standard (1.1% of generation from 2012 onward, 60% solar). For all other utilities, we assume no additional new renewables.
New Non-Renewable Generation Sources (2004-2010)	From 2006-2010, we assume 17% coal, 78% natural gas, 5% nuclear (based on mix of planned additions from the Western Electricity Coordinating Council, ^a including nuclear uprates of Palo Verde).
New Non-Renewable Generation Sources (2011-2020)	For 2011 to 2020, we assume 80% coal and 20% natural gas, based on a review of studies including EIA AEO2005, ICF/WRAP 2002, and others. ^c To meet peak demands with an increasing shift to coal baseload plants, new natural gas plants are assumed to be predominantly combustion turbines during this period.
Heat Rates	The assumed heat rates for new gas and coal generation are 7000 Btu/kWh and 9000 Btu/kWh, respectively.
Operation of Existing Facilities	We assume that the current sources of coal-based electricity generation will increase output according to analysis completed for the WRAP. ^d (However, future changes in fuel prices may have an important impact.)

^aWestern Electric Coordinating Council, 2004. 10-Year Coordinated Plan Summary, www.wecc.biz/documents/library/publications/10year/tenyr04.pdf

^bwww.epa.gov/cleanenergy/egrid/index.htm.

^cWestern Resource Advocates, 2004. A Balanced Energy Plan for the Interior West.

<http://www.westernresourceadvocates.org/energy/bep.html> and ICF 2002. Economic Assessment of Implementing the 10/20 Goals and Energy Efficiency Recommendations (prepared for Western Regional Air Partnership).

^dSee emissions reconciliation documentation for 2000/2001 at

http://www.wrapair.org/forums/mtf/documents/group_reports/TechSupp/SO2Tech.htm. The results of this analysis are referenced in subsequent WRAP analyses, including An Assessment of Critical Mass for the Regional SO₂ Trading Program (ICF 2002)

Figure 7 shows historical sources of electricity generation in the State by fuel source, along with projections to the year 2020 based on the assumptions described above. Natural gas generation has grown considerably during the past decade, while coal, nuclear, and hydro generation have stayed relatively constant. Based on the above assumptions for new generation, natural gas continues to dominate new generation through 2010, at which point coal assumes an increasing market share, reflecting assumptions that natural gas prices will continue to rise.

Figure 7. Electricity Generated By Arizona Power Plants, 1990-2020

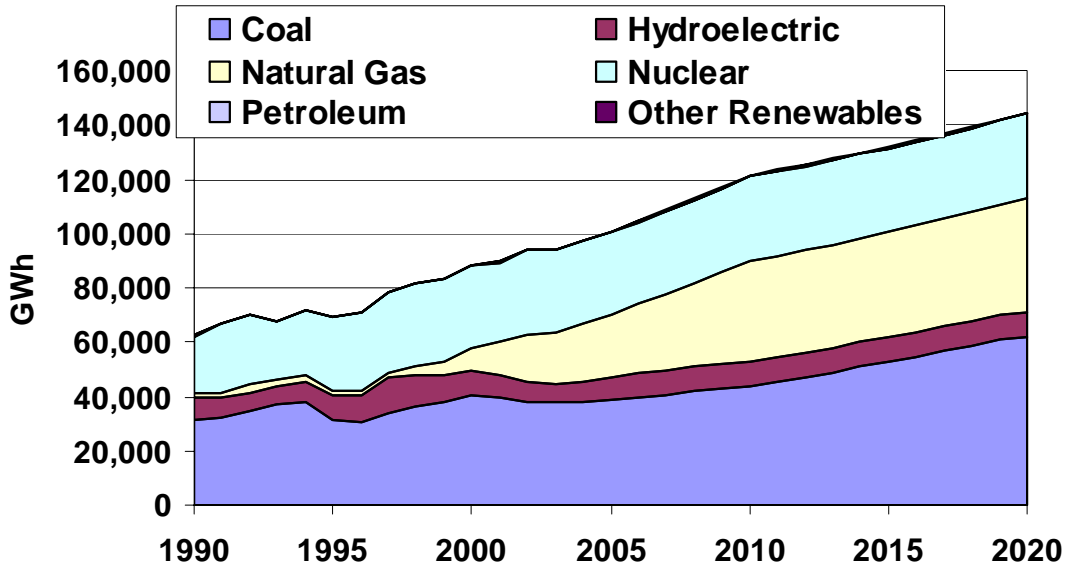
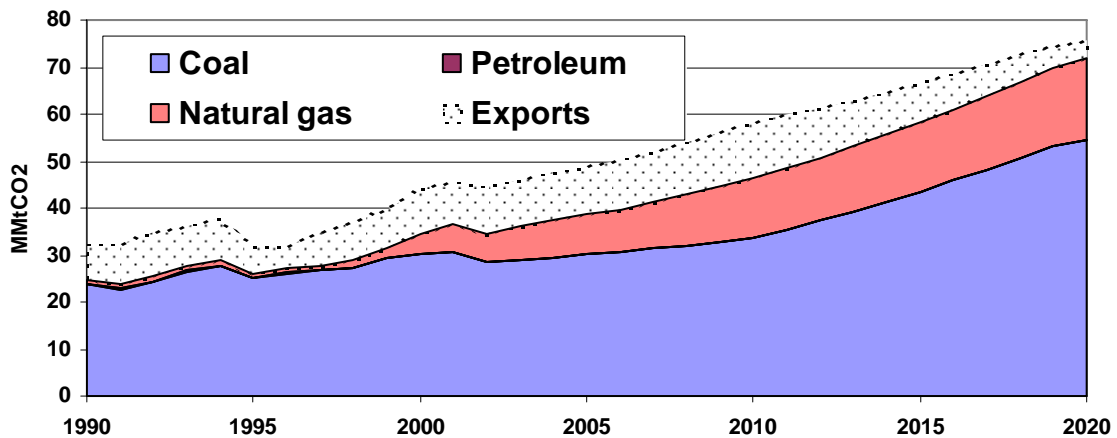


Figure 8 shows the GHG emissions associated with electricity use, based on the assumptions described above. From 1990 to 2000, electricity sales in the State grew by about 4% per year annually, with CO₂ emissions growing at roughly 3% year in this period. Emissions grew more slowly than electricity sales, as the share of natural gas generation increased while the coal share decreased. The decreasing share of coal led to a slight decreasing CO₂ emissions per MWh generated (1,142 lb CO₂/MWh in 1990 to 1,107 lb CO₂/MWh in 2000). From 2000 to 2020, emissions associated with electricity use are projected to grow at 3.8% per year, as the fraction of coal generation increases, especially after 2010.

Supplement I suggests that current GHG emissions associated black and organic carbon emissions from electricity generating units in Arizona could be between 0.2 and 0.4 MMtCO₂e. Nearly all of these emissions are from coal-fired power plants.

Figure 8. CO₂ Emissions Associated with Electricity Use (Consumption-Basis) and Exports



Key Uncertainties

Each of the key assumptions reported in Table 4 represents a key uncertainty in this analysis. We have relied on public information to inform these assumptions as well as discussing the key assumptions with staff from Arizona utilities to further refine our assumptions and the resulting emissions projections.

Supplement B. Residential, Commercial, and Industrial Energy Use¹

Residential, commercial, and industrial² (RCI) sectors produce carbon dioxide, methane, and nitrous oxide emissions as fuels are combusted for space heating, process heating, and other applications. Carbon dioxide accounts for over 99% of these emissions on a tCO_{2e} basis. In addition, since these sectors consume electricity, one can also attribute electricity use emissions to these sectors.³ This is particularly important to consider as stakeholders begin to explore options to improve energy efficiency; as can be seen below, the emissions associated with electricity use exceed those from direct fuel use in each sector, especially in residential and commercial buildings.

Direct use of coal, oil, natural gas, and wood⁴ in RCI accounted for about 11% of gross GHG emissions in 2000. However, if emissions associated with RCI electricity use are included, RCI energy use then accounts for nearly half of gross GHG emissions.

Reference case emissions GHG estimates depend upon estimates of future energy use by sector and source. For electricity use, the assumption is 3.75% per year growth to 2010 and 3.50% per year thereafter, as described above. Assumed electricity sales growth in individual sectors is shown in Table 5, and is based on historical differences (1990-2002) in growth among sectors. For the direct use of fuels, we rely on regional projections from the EIA Annual Energy Outlook 2005, which we adjust for Arizona's growth rates of population and employment (see TABLE 2), resulting in the growth rates shown in TABLE 5.

Table 5. Electricity Sales Projections, 2002-2020

Sector	Growth Rate	
	2002-2010	2010-2020
Residential	5.0%	4.6%
Commercial	4.1%	3.8%
Industrial	0.8%	0.8%
Total	3.75%	3.50%

¹ The Residential, Commercial, and Industrial Technical Working Group reviewed the draft GHG inventory and forecast, and the corresponding assumptions, for this sector. They recommended that the inventory and forecast be accepted with a change in projected growth rate for electricity sales, as shown in Table 5.

² The industrial sector includes agricultural energy use.

³ One could similarly allocate GHG emissions due to natural gas transmission and distribution and other sources, but we have not done so here due to the relatively small level of emissions.

⁴ Emissions from wood combustion include only N₂O and CH₄. Carbon dioxide emissions from biomass are assumed to be "net zero" consistent with US EPA and IPCC methodologies, and any net loss of carbon stocks due to biomass fuel use should be picked up in the land use and forestry analysis.

Table 6. Projected Annual Growth in Energy Use, by Sector and Fuel, 2002-2020

	2002-2010	2010-2015	2015-2020
Residential			
Natural gas	4.2%	2.8%	2.4%
Petroleum	2.5%	2.2%	1.6%
Coal	-0.7%	-0.7%	-0.7%
Wood	0.4%	0.4%	0.4%
Commercial			
Natural gas	3.8%	3.0%	2.9%
Petroleum	3.0%	1.6%	1.0%
Coal	0.9%	0.8%	0.5%
Wood	0.8%	0.8%	0.6%
Industrial			
Natural gas	2.9%	0.9%	0.8%
Petroleum	3.5%	1.1%	0.8%
Petroleum feedstocks	0.0%	0.0%	0.0%
Coal	0.9%	-0.8%	-1.0%
Wood	0.0%	0.0%	0.0%

Figure 9, Figure 10, and Figure 11 illustrate historical and projected emissions for the residential, commercial, and industrial sectors from 1990 to 2020. Electricity consumption accounts for the largest component of each sector's emissions. The residential sector shows the highest emissions growth, due to assumed strong growth in both electricity and natural gas consumption, for which per capita use actually increases. Commercial sector emissions also show strong growth with electricity use growing at about the same rate as commercial sector employment, with natural gas consumption growing slightly faster. The assumed growth rate for industrial sector electricity consumption is lower than the employment growth, and the growth rate of natural gas consumption at a similar level. For both the commercial and industrial sectors energy consumption and resulting GHG

emissions grow at a slower pace than gross state product, indicating an overall decrease in GHG intensity.⁵

Supplement I suggests current GHG emissions associated black and organic carbon emissions from RCI activities in Arizona could be between 0.5 and 1.1 MMtCO₂e, largely from non-road diesel engines used in construction, industry, agriculture, and other areas.

Figure 9. Residential Sector GHG Emissions from Energy Use

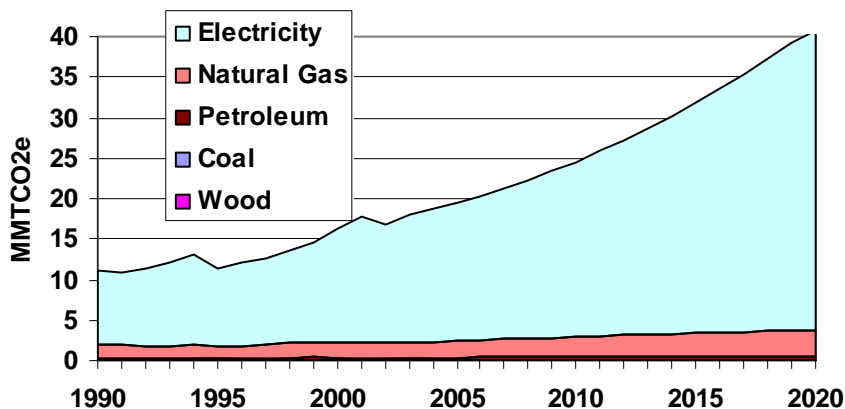
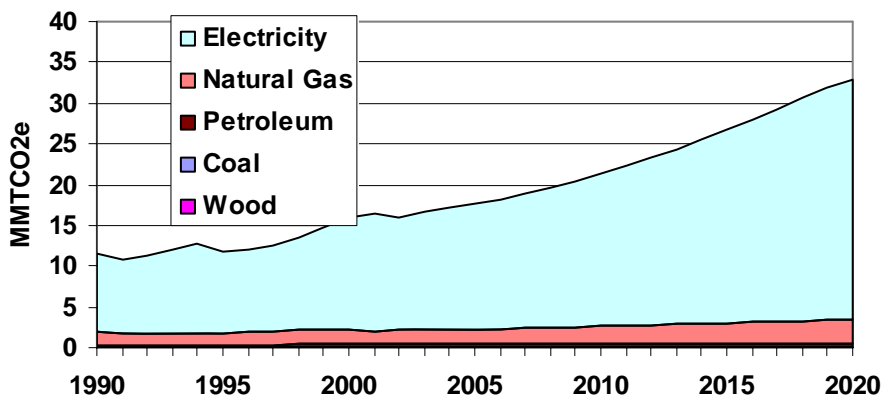
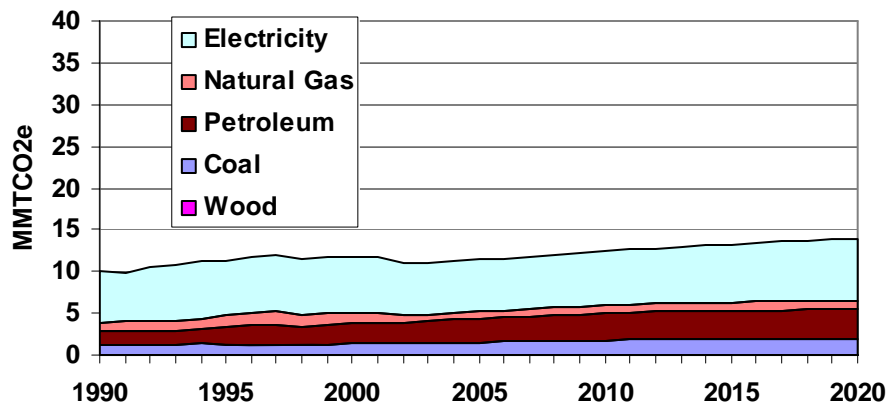


Figure 10. Commercial Sector GHG Emissions from Energy Use



⁵ These estimates of growth relative to population and employment reflect expected responses – as modeled by the EIA NEMS model – to changing fuel and electricity prices and technologies, as well as structural changes within each sector (subsectoral shares, energy use patterns, etc.).

Figure 11. Industrial Sector GHG Emissions from Energy Use



Key Uncertainties

Key sources of uncertainty underlying the projections are as follows:

Natural gas consumption is the major source of on-site GHG emissions in the RCI sectors. We based assumptions of projected natural gas consumption on the regional results of the US DOE Energy Information Administration's Annual Energy Outlook 2005 (EIA AEO2005), adjusting for Arizona's expected population and employment.

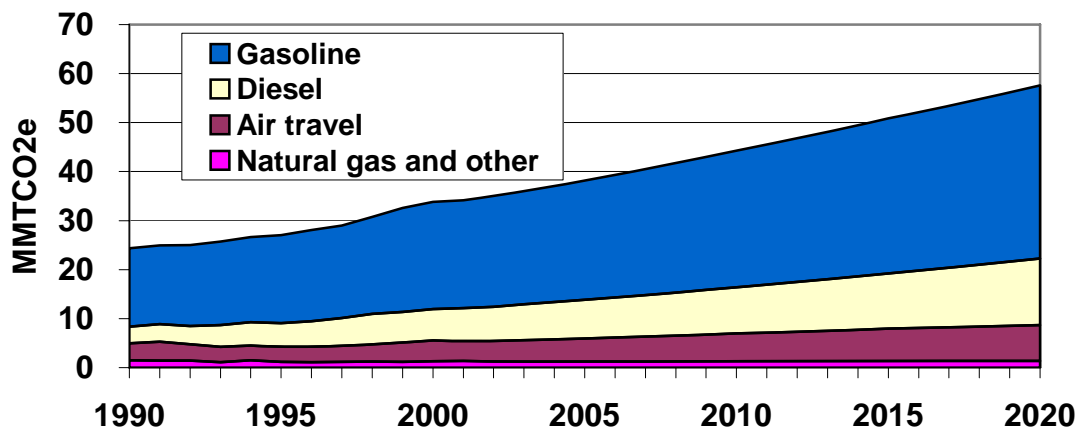
- We also based industrial sector growth on regional results of the EIA AEO2005. We have not directly accounted for proposed new facilities in Arizona, including the clean fuels refinery and new or expanded cement plants. We will work with technical working groups to develop consensus on whether and how such facilities should be included in the reference case.
- The uncertainties related to overall electricity emissions are described in the electricity appendix. With respect to the RCI analysis, further analysis and disaggregation of electricity use (historical and projected) by sector and end-use would be helpful.

Supplement C. Transportation Energy Use¹

The transportation sector is a major source of GHG emissions in Arizona—currently accounting for about 40% of Arizona’s gross GHG emissions. Carbon dioxide accounts for about 97% of transportation GHG emissions from fuel use; much of the remaining 3% is due to nitrous oxide emissions from gasoline engines.

As shown in Figure 12, on-road gasoline consumption accounts for the majority of transportation GHG emissions in 1990 and in 2000 – increasing by over a third during this period.² In 1990, on-road diesel³ and air travel energy consumption⁴ had similar GHG emissions, but diesel consumption nearly doubled from 1990 to 2000 while jet fuel and aviation gasoline increased by only 24%. Consumption of natural gas (largely for pipeline use) and propane plus emissions from petroleum lubricants accounted for about 7% of transportation emissions in 1990 and the total emissions from these sources declined slightly from 1990 to 2000.

Figure 12. Transportation GHG Emissions, 1990-2020



Both Phoenix and Tucson have oxygenate requirements for their winter gasoline that are currently met by mixing ethanol with gasoline. In the 1990s, these requirements were met with a mix of methyl tertiary butyl ether (MTBE) and ethanol.⁵ State agencies only collect data on total fuel sales (based on tax receipts), and thus data reported by AZDOT on total gasoline consumption includes a fraction that is actually ethanol (and historically MTBE as well).

¹ The Transportation and Land Use Technical Working Group reviewed the GHG inventory and forecast, and the corresponding assumptions, for the transportation sector. In particular, this group discussed and reviewed the assumptions regarding constant energy consumption per VMT through 2020. After this review, the group recommended that the inventory and forecast be accepted with no changes.

² Data sources are from AZDOT for 1990 to 2003, http://www.azdot.gov/Inside_ADOT/fms/gasgals.asp

³ Data are from AZDOT for 1990 to 2003, http://www.azdot.gov/Inside_ADOT/fms/diesgals.asp

⁴ Data sources are EIA SEDS for 1990 to 2002.

⁵ Personal communication with Cathy Arthur, Maricopa Association of Governments, and Lee Comrie, Pima Association of Governments, March 30, 2005.

We estimated ethanol consumption based on information from the Maricopa and Pima Associations of Government and deducted this ethanol consumption from gasoline sales in order to calculate GHG emissions.⁶ (Since ethanol is a biomass-derived fuel, its CO₂ emissions are not typically counted in inventory assessments.⁷) We also estimated MTBE consumption and emissions, and these are included in the historical emissions estimates.

Supplement I suggests that current GHG emissions associated black and organic carbon emissions from RCI activities in Arizona could be between 2.1 to 4.4 MMtCO₂e. Over 70% of these emissions are contributed by on-road diesel vehicles. This sector takes on added significance given the projected growth in on-road diesel use mentioned below.

GHG emissions from transportation are expected to grow considerably over the next 15 years due to population growth and increased demand on transportation services. Arizona studies suggest on-road vehicle miles traveled (VMT) will continue to grow faster than population.⁸ As a simplifying assumption, we projected that energy consumption per VMT will remain constant from 2002 to 2020. The MoveAZ report suggests that energy consumption per VMT will grow, while EIA AEO2005 shows this rate declining. Other assumptions are listed in Table 7.

These assumptions combine to produce more than a doubling of GHG emissions from on-road gasoline from 1990 to 2020. On-road diesel consumption is expected to increase even more rapidly, while jet fuel consumption increases at slightly less than population growth. The high overall growth in transportation sector emissions – more than doubling from 1990 to 2020 – suggests many opportunities and challenges for reducing Arizona’s GHG emissions.

⁶ Based on information regarding the months ethanol is blended (5-6), and oxygenate requirements (1.8-3.5%), we estimate ethanol consumption of 12 million gallons in 1990 and 73 million gallons in 2003.

⁷ Nonetheless, ethanol, like gasoline, can require significant upstream GHG emissions in production and refining.

⁸ We used MoveAZ (www.moveaz.org) as the primary data source for VMT growth (appendix E), but also compared VMT growth projections from Maricopa Association of Governments *Conformity Analysis* (<http://www.mag.maricopa.gov/detail.cms?item=3092>), which showed similar VMT growth assumptions.

Table 7. Key Assumptions and Methods for Transportation Projections

Passenger VMT Growth	The average annual growth rate for VMT is assumed to be 2.4% per year from 2002 to 2020, based on MOVEAZ report.
On-road Gasoline consumption	Gasoline use is assumed to grow with passenger VMT; no change in gasoline use per VMT is assumed.
Ethanol Consumption	Average annual ethanol consumption is assumed to remain at 2.8% of total gasoline consumption (representing Phoenix and Tucson winter fuel requirements).
Freight VMT Growth	The average annual growth rate for VMT is assumed to be 3.7% per year from 2002 to 2020, based on MOVEAZ report.
On-Road Diesel Consumption	Diesel use is assumed to grow with freight VMT; no change in diesel use per VMT is assumed.
Aviation Fuel, Jet Fuel, Natural Gas and Propane	The average annual growth rates for these fuels are based on EIA AEO2005 growth rates for region (2.5% for aviation gasoline and jet fuel, 0% for natural gas and 5% for propane). Ethanol consumption is projected to grow by 7.8% per year (EIA AEO2005).

VMT Vehicle-Miles Traveled; AEO2005 – US DOE Energy Information Administration’s Annual Energy Outlook 2005

Key Uncertainties

A major uncertainty in this analysis is the projected increase in on-road gasoline consumption from 2003 to 2020. We found two sources for these projections, the MOVEAZ report from Arizona Department of Transportation (AZDOT 2004) and EIA AEO2005. As mentioned earlier, the EIA AEO2005 projections are regional (including the entire Mountain census region), while the MOVEAZ report is a recent state-specific source. For this reason, we chose to base the projection on MOVEAZ. However, the growth in gasoline use in MOVEAZ far exceeds VMT growth, with gasoline use per VMT growing 4.5% per year (owing presumably to increased congestion). EIA AEO2005, in contrast, projects gasoline use per VMT to a decline slightly as the result of expected improvements in fuel economy. For this analysis, we assumed no change in gasoline use per VMT, an assumption that should be more closely examined.

Supplement D. Industrial Process and Related Emissions

Emissions in this category span a wide range of activities, and reflect GHG emissions from CO₂ produced through industrial manufacturing (cement, lime, and soda ash) to the release of high GWP gases from cooling and refrigeration equipment (HFCs), semiconductor manufacture (PFCs), and electricity transformers (SF₆).^{1,2}

Though small overall today, emissions from this category are expected to continue to grow rapidly, as shown in Figure 13, almost entirely due to the increasing use of HFCs in refrigeration and air conditioning equipment. HFCs are being used to substitute for ozone-depleting substances (ODS)³, most notably chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs) in compliance with the *Montreal Protocol*.⁴ Even low amounts of HFC emissions, from leaks and other releases under normal use of the products, can lead to high GHG emissions. Emissions from the ODS substitutes in Arizona have increased from 0.005 MMtCO_{2e} in 1990 to 1.4 MMtCO_{2e} in 2000, with further increases of 8.4% per year expected from 2000 to 2020.⁵

¹ For example, cement production results in CO₂ emissions as calcium carbonate, CaCO₃ is converted to lime CaO.

² As noted in Supplement I, this sector is an insignificant contributor to black and organic carbon emissions.

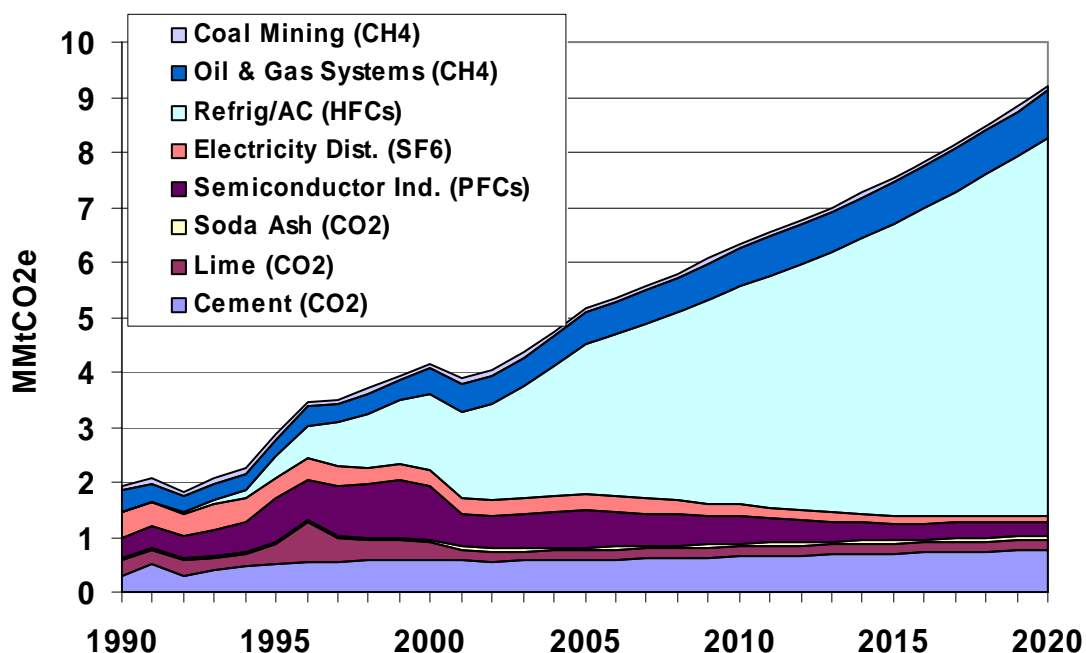
³ ODS substitutes are primarily associated with refrigeration and air conditioning, but also many other uses such as fire extinguishers, solvent cleaning, aerosols, foam production and sterilization.

⁴ Although CFCs and HCFCs include potent global warming gases, they are not included in national and international GHG estimates because of concerns related to implementation of the *Montreal Protocol*. Their net radiative forcing effect on the atmosphere is reduced because they cause stratospheric ozone depletion, which is itself an important greenhouse gas in addition to shielding the Earth from harmful levels of ultraviolet radiation.

⁵ Growth rates are based on growth in projected national emissions from recent EPA report, US EPA 2004, *Analysis of Costs to Abate International ODS Substitute Emissions*, EPA 430-R-04-006.

[http://yosemite.epa.gov/oar/globalwarming.nsf/UniqueKeyLookup/RAMR62AS98/\\$File/IMAC%20Appendices%206-24.pdf](http://yosemite.epa.gov/oar/globalwarming.nsf/UniqueKeyLookup/RAMR62AS98/$File/IMAC%20Appendices%206-24.pdf)

Figure 13. GHG Emissions from Industrial Processes



Emissions of PFCs in the semi-conductor industry and of SF₆ from electrical equipment have experienced declines since the mid-nineties (see Figure 13 above) mostly due to voluntary action by industry. Future emissions could increase due to expected increases in semi-conductor manufacturing and electricity supply, or decrease due to process changes and continued industry efforts. Projections from the US Climate Action Report⁶ shows expected decreases in these emissions at the national level due to a variety of industry actions to reduce emissions, and we have assumed the same rate of decline for emissions in Arizona.

Emissions from cement production, lime manufacture, limestone and dolomite use and soda ash consumption accounted for almost one-third of industrial process emissions in 1990 but have not grown significantly since. By 2000, these emissions were less than 25% of total industrial process emissions. Emissions declined by a further 0.2 MMtCO₂e from 2000 to 2002, due to decreased lime manufacture.

For 2003 to 2020, we applied the following assumptions for projected changes:

- Emissions from cement production and soda ash consumption increase at the same rate as population growth (1.8% per year).
- Emissions from lime manufacture, limestone, and dolomite show no change from 2002 levels.

The emissions from cement production required review and analysis. Clinker and masonry cement production information for Arizona was obtained from the United States Geological Survey (USGS) *Cement Annual*. This report lists production by state where possible, but the

⁶ U.S. Department of State, *U.S. Climate Action Report 2002*, Washington, D.C., May 2002.
[http://yosemite.epa.gov/oar/globalwarming.nsf/UniqueKeyLookup/SHSU5BNQ76/\\$File/ch5.pdf](http://yosemite.epa.gov/oar/globalwarming.nsf/UniqueKeyLookup/SHSU5BNQ76/$File/ch5.pdf)

data for Arizona and New Mexico are combined together, for confidentiality reasons. As a first approximation, we relied on the approach used by the EPA SGIT tool and divided the production data evenly between the two states. We also worked with ADEQ to use information on permits for the Arizona plants to determine better estimates for clinker production. ADEQ also helped estimate production from newly approved plants in the state.

We estimated methane emissions from oil and gas systems based on the length and type of pipeline in the State and number of services, combined with emission factors provided by EPA. From 1990 to 2000, emissions remained constant as length of pipeline increased but leakier pipelines were replaced with better quality ones. For emissions projections, we assumed that emissions increase with natural gas demand. Several key uncertainties exist with these estimates:

- We collected information from the U.S. Office of Pipeline Safety for the length of pipeline in Arizona; this dataset appears to have some missing or inconsistent data. Therefore, we asked ADEQ to review these input values and provide improvements to them.
- Increasing emissions with natural gas demand accounts mostly for increases in the distribution network, but may not accurately estimate emissions from increased transmission network (especially for pipelines that do not serve the Arizona demand).

Methane emissions from coal mining accounts are the final emission source in this category. These emissions are less than 0.1 MMtCO₂e and have remained relatively constant from 1990 to 2002, varying with coal production in the State. Most coal production in the State is from one mine, Kayenta. In the past, this mine has provided coal to the Mohave coal plant in Nevada, which may close down in 2006. It is unknown whether the mine would also shut down or whether the coal will be supplied to other power plants in the region. We have assumed that coal production and resulting methane emissions remain at 2002 levels through 2020.

Supplement E. Agriculture, Forestry, and Other Land Use¹

The emissions discussed in this supplement refer to non-energy emissions from agriculture, forestry, and other land uses. These emissions include emissions from livestock, agriculture soil management and field burning, CO₂ emitted and removed (sinks) due to forestry activities, and emissions linked to rangeland and forest fires.²

Agriculture emissions include CH₄ and N₂O emissions from enteric fermentation, manure management, and agriculture soils and agriculture residue burning. Data on crops and animals in the state from 1990 to 2004 were provided by the USDA National Agriculture Statistical Service.³ As shown in Figure 14, emissions from these sources remained stable from 1990 to 2000, then increased in 2001 and 2004. GHG emissions in 2004 are about 11% above 1990 levels. Emissions from agriculture soils account for the largest portion (about 50%) of agricultural emissions; this category includes N₂O emissions resulting from activities that increase nitrogen in the soil, including fertilizer (synthetic, organic, and livestock) application and production of nitrogen fixing crops. These activities have generally increased slightly from 1990 to 2004 and subsequently emissions have increased by about 0.1% per year. Enteric fermentation and manure management accounted for about 32% and 17% of agriculture emissions in 1990, respectively. Enteric fermentation emissions remained relatively constant to 2002 but manure management emissions rose by 3.6% per year (similar to increase in number of dairy cattle). Emissions from agriculture residue burning are very small and also remained relatively constant from 1990 to 2004.

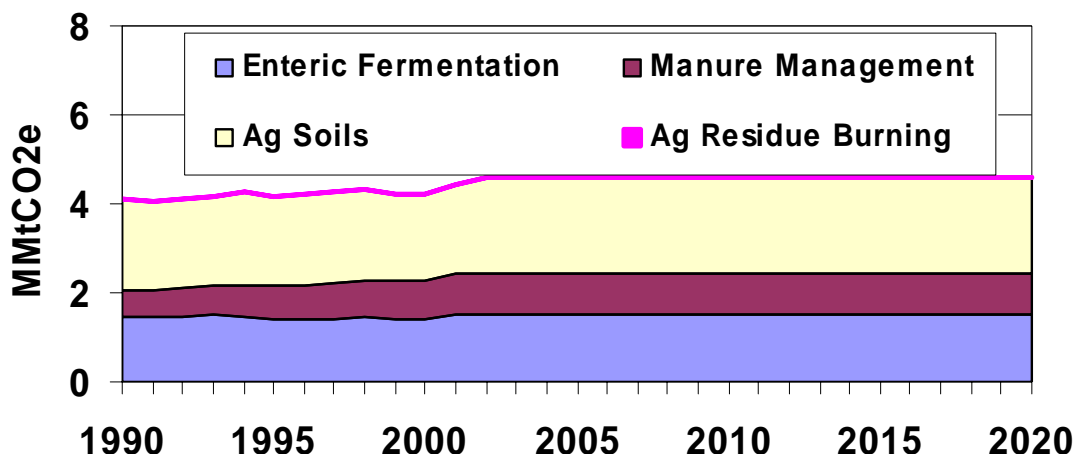
For projecting emissions from this source, we assumed no change from 2004 levels. Emissions from enteric fermentation and manure management depend on the number of livestock and management of these stocks and land. Agricultural soils emissions depend on land-use conversions out of croplands, management of soils and types of crops. After searching existing reports and analyses, we applied the assumption of no growth to these emissions from 2002 to 2020.

¹ The Agriculture and Forestry Technical Work Group reviewed the reference case and forecasts for agriculture and forestry. No changes to the agriculture reference case or forecasts were recommended. For forestry, the work group recommended that the forecasted forestry sinks should remain static from the reference case. Therefore, the total GHG estimates for forestry in 2010 and 2020 remain at -6.7 MMt.

² This sector was not found to contribute any CO₂e impact associated with BC+OM emissions (see Supplement I). Black carbon emissions associated with diesel combustion in agricultural or forestry equipment are included as part of the fossil fuel combustion emissions in the RCI sector.

³ Personal communication, Steve Manheimer, AZ National Agriculture Statistical Service, March 2005.

Figure 14. GHG Emissions from Agriculture



Forestlands

Forestland emissions refer to the net CO₂ flux⁴ from forested lands in Arizona, which account for about 16% of the state’s land area. Recent U.S. Forest Service estimates suggest that Arizona forests and the use of forest products sequestered on average 6.7 MMtCO₂e per year from 1987 to 2002, as shown in Table 8. As noted above, during the FIA survey periods used for FORCARB2 estimates, the definition of forestland changed from a minimum forest cover requirement of 10%, to a minimum of 5%. As a result rangelands may or may not be included in these estimates, depending on their level of tree stocking, although the largest class of forested rangeland, pinyon-juniper, is included in the U.S. Forest Service forest stock assessments. As a result, much of the carbon on rangeland is likely to be covered in the US Forest Service FORCARB assessment.

The net forest and land use sequestration estimates noted above are based on recent improvements to U.S. Forest Service carbon stock inventory data. It is important to note that US Forest Service assessments only cover the parts of the state that the US Forest Service defines as forest, representing 16% of the total state land area (4.85 of 30.3 million hectares in 2002). As noted, during the FIA survey periods used for FORCARB2 estimates, the definition of forestland changed from a minimum forest cover requirement of 10%, to a minimum of 5%. The U.S. Forest Service is not able to make corrections associated with these changes in forest definition, but review of the data conducted by CCS and the U.S. Forest Service suggests that effects are likely to be small.

As with the agricultural sector, emissions of black carbon (BC) and organic material (OM) from forestry equipment fired on fossil fuels are included as part of the RCI sector.

⁴ “Flux” refers to both emissions of CO₂ to the atmosphere and removal (sinks) of CO₂ from the atmosphere.

Table 8. Average Annual Changes in Carbon Stocks from Forest Lands and Related Activities, 1985-2002 (MMtCO₂)

Live and dead-standing trees and understory	2.5
Forest floor and coarse woody debris	-3.8
Soils	-5.5
Wood products and landfills ^a	0.0
Total	-6.7

^aWood products and landfills, according to USFS data, showed no net change in the two most recent estimates (1992 and 1997). <http://www.fs.fed.us/ne/global/pubs/books/epa/states/AZ.htm>

Other Lands and Land Uses

The carbon cycle for rangelands is not well understood; existing studies have focused on forest lands. Rangelands and pasture account for almost 56% of the State’s land area, and therefore the extent to which they sequester or emit carbon, even a net source or net sink, while small on a per acre basis, may be significant at the state level. Time and resource constraints did not allow for the development of a rangeland carbon inventory at this time. However, detailed review of data and conferrals with the U.S. Forest Service indicate that the carbon stock change effects of rangeland are likely to be small. One key reason is that the pinyon-juniper forest system is included in U.S. Forest Service estimates under the definition of forest, while this is often referred to as rangeland in other surveys, such as those conducted by USDA. CCS recommends that additional work be performed in the future to characterize the GHG source or sink potential of rangelands.

Key Uncertainties and Further Analysis

As noted above, there may be significant changes in total statewide biomass-related carbon stocks as estimates are refined, and further analysis in this area should be a high priority, particularly for rangelands.

One of the uncertainties for the historic (1990-2004) emissions is the contribution of cotton crops to emissions. The EPA SGIT does not include emissions from cotton crops in its estimate of N₂O emissions, but these are thought to be minimal from the perspective of crop-residue management and the fertilizer use on cotton is captured in the total amount of N-fertilizer used in the State each year.

SUPPLEMENT F. WASTE MANAGEMENT

GHG emissions from waste management accounted for are summarized in Table 9. Emissions in this category include:-

- Solid waste management – methane emissions from landfills, accounting for any methane that is flared or captured for energy production.
- Wastewater management – methane and nitrous oxide from municipal wastewater treatment facilities.

Any emissions associated with energy consumed for transport of solid waste and wastewater is included in the RCI accounting above.

Table 9. Emissions from Waste Management

Reference Case GHG Emissions for Arizona					
(Million Metric Tons CO ₂ e)	1990	2000	2010	2020	Explanatory Notes for Projections
Waste Management	2.1	1.9	2.0	1.9	
Solid Waste Management	1.7	1.3	1.4	1.1	Based on national projections (USEPA)
Wastewater Management	0.4	0.5	0.7	0.8	Increases with state population

We used the EPA SGIT tool to estimate emissions.¹ However, since emissions from these types of facilities are site-specific, we worked with ADEQ to find better estimates. Of particular concern were emissions from solid waste management where the EPA SGIT tool estimates negative emissions – this tool uses different sources for: 1) methane emission generation from landfills,² 2) methane emissions avoided by flaring at landfills,³ and 3) methane emissions avoided by waste-to-energy plants.⁴ We also worked with the US EPA to check the emissions avoided by flaring and with ADEQ to determine if better data were available for methane generation from landfills. For this report, we have included the EPA SGIT results with simple projections—methane emissions from generation increase with population—on the assumption that municipal solid waste increases with population, while emissions avoided by flaring and waste to energy plants remain at 2002 levels. These avoided emissions depend on adding equipment to landfills and are not directly tied to other drivers in this analysis.

Emissions from wastewater were also estimated using the EPA SGIT tool. These emissions increased by 4.4% per year from 1990 to 2000⁵. Projected emissions are assumed to increase with population growth, 2.1% per year from 2003 to 2020.

¹ As noted in Supplement I, this sector is an insignificant contributor to black and organic carbon emissions.

² Estimates are based on 30-year data on municipal solid waste generation from *Biocycle* magazine, combined with national emission factors.

³ Based on information supplied directly to contractors for EPA from flare vendors.

⁴ EPA (2002) Landfill Gas-to-Energy Project Database 2001, Landfill Methane and Outreach Program.

⁵ Emissions are calculated in EPA SGIT based on state population, assumed biochemical oxygen demand and protein consumption per capita, and emission factors for N₂O and CH₄.

Supplement G. List of Contacts Made

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Supplement H. Greenhouse Gases and Global Warming Potential Values: Excerpts from the *Inventory of U.S. Greenhouse Emissions and Sinks: 1990-2000*

Original Reference: All material taken from the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990 - 2000*, U.S. Environmental Protection Agency, Office of Atmospheric Programs, EPA 430-R-02-003, April 2002. www.epa.gov/globalwarming/publications/emissions The preparation of this document was directed by Michael Gillenwater.

Introduction

The *Inventory of U.S. Greenhouse Gas Emissions and Sinks* presents estimates by the United States government of U.S. anthropogenic greenhouse gas emissions and removals for the years 1990 through 2000. The estimates are presented on both a full molecular mass basis and on a Global Warming Potential (GWP) weighted basis in order to show the relative contribution of each gas to global average radiative forcing.

The Intergovernmental Panel on Climate Change (IPCC) has recently updated the specific global warming potentials for most greenhouse gases in their Third Assessment Report (TAR, IPCC 2001). Although the GWPs have been updated, estimates of emissions presented in the U.S. *Inventory* continue to use the GWPs from the Second Assessment Report (SAR). The guidelines under which the *Inventory* is developed, the *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories* (IPCC/UNEP/OECD/IEA 1997) and the United Nations Framework Convention on Climate Change (UNFCCC) reporting guidelines for national inventories¹ were developed prior to the publication of the TAR. Therefore, to comply with international reporting standards under the UNFCCC, official emission estimates are reported by the United States using SAR GWP values. This excerpt of the U.S. *Inventory* addresses in detail the differences between emission estimates using these two sets of GWPs. Overall, these revisions to GWP values do not have a significant effect on U.S. emission trends.

Additional discussion on emission trends for the United States can be found in the complete *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2000*.

What is Climate Change?

Climate change refers to long-term fluctuations in temperature, precipitation, wind, and other elements of the Earth's climate system. Natural processes such as solar-irradiance variations, variations in the Earth's orbital parameters, and volcanic activity can produce variations in climate. The climate system can also be influenced by changes in the concentration of various gases in the atmosphere, which affect the Earth's absorption of radiation.

The Earth naturally absorbs and reflects incoming solar radiation and emits longer wavelength terrestrial (thermal) radiation back into space. On average, the absorbed solar radiation is balanced by the outgoing terrestrial radiation emitted to space. A portion of this terrestrial radiation, though, is itself absorbed by gases in the atmosphere. The energy from this absorbed terrestrial radiation warms the Earth's surface and atmosphere, creating what is known as the "natural greenhouse effect." Without the natural heat-trapping properties of these atmospheric gases, the average surface temperature of the Earth would be about 33°C lower (IPCC 2001).

Under the UNFCCC, the definition of climate change is "a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods." Given that definition, in its Second Assessment Report of the science of climate change, the IPCC concluded that:

Human activities are changing the atmospheric concentrations and distributions of greenhouse gases and aerosols. These changes can produce a

¹ See FCCC/CP/1999/7 at <www.unfccc.de>.

radiative forcing by changing either the reflection or absorption of solar radiation, or the emission and absorption of terrestrial radiation (IPCC 1996).

Building on that conclusion, the more recent IPCC Third Assessment Report asserts that “[c]oncentrations of atmospheric greenhouse gases and their radiative forcing have continued to increase as a result of human activities” (IPCC 2001).

The IPCC went on to report that the global average surface temperature of the Earth has increased by between 0.6 ± 0.2 °C over the 20th century (IPCC 2001). This value is about 0.15 °C larger than that estimated by the Second Assessment Report, which reported for the period up to 1994, “owing to the relatively high temperatures of the additional years (1995 to 2000) and improved methods of processing the data” (IPCC 2001).

While the Second Assessment Report concluded, “the balance of evidence suggests that there is a discernible human influence on global climate,” the Third Assessment Report states the influence of human activities on climate in even starker terms. It concludes that, “[I]n light of new evidence and taking into account the remaining uncertainties, most of the observed warming over the last 50 years is likely to have been due to the increase in greenhouse gas concentrations” (IPCC 2001).

Greenhouse Gases

Although the Earth’s atmosphere consists mainly of oxygen and nitrogen, neither plays a significant role in enhancing the greenhouse effect because both are essentially transparent to terrestrial radiation. The greenhouse effect is primarily a function of the concentration of water vapor, carbon dioxide, and other trace gases in the atmosphere that absorb the terrestrial radiation leaving the surface of the Earth (IPCC 1996). Changes in the atmospheric concentrations of these greenhouse gases can alter the balance of energy transfers between the atmosphere, space, land, and the oceans. A gauge of these changes is called radiative forcing, which is a simple measure of changes in the energy available to the Earth-atmosphere system (IPCC 1996). Holding everything else constant, increases in greenhouse gas concentrations in the atmosphere will produce positive radiative

forcing (i.e., a net increase in the absorption of energy by the Earth).

Climate change can be driven by changes in the atmospheric concentrations of a number of radiatively active gases and aerosols. We have clear evidence that human activities have affected concentrations, distributions and life cycles of these gases (IPCC 1996).

Naturally occurring greenhouse gases include water vapor, carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O), and ozone (O₃). Several classes of halogenated substances that contain fluorine, chlorine, or bromine are also greenhouse gases, but they are, for the most part, solely a product of industrial activities. Chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs) are halocarbons that contain chlorine, while halocarbons that contain bromine are referred to as bromofluorocarbons (i.e., halons). Because CFCs, HCFCs, and halons are stratospheric ozone depleting substances, they are covered under the Montreal Protocol on Substances that Deplete the Ozone Layer. The UNFCCC defers to this earlier international treaty; consequently these gases are not included in national greenhouse gas inventories. Some other fluorine containing halogenated substances—hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF₆)—do not deplete stratospheric ozone but are potent greenhouse gases. These latter substances are addressed by the UNFCCC and accounted for in national greenhouse gas inventories.

There are also several gases that, although they do not have a commonly agreed upon direct radiative forcing effect, do influence the global radiation budget. These tropospheric gases—referred to as ambient air pollutants—include carbon monoxide (CO), nitrogen dioxide (NO₂), sulfur dioxide (SO₂), and tropospheric (ground level) ozone (O₃). Tropospheric ozone is formed by two precursor pollutants, volatile organic compounds (VOCs) and nitrogen oxides (NO_x) in the presence of ultraviolet light (sunlight). Aerosols—extremely small particles or liquid droplets—often composed of sulfur compounds, carbonaceous combustion products, crustal materials and other human induced pollutants—can affect the absorptive characteristics of the atmosphere. However,

the level of scientific understanding of aerosols is still very low (IPCC 2001).

Carbon dioxide, methane, and nitrous oxide are continuously emitted to and removed from the atmosphere by natural processes on Earth. Anthropogenic activities, however, can cause additional quantities of these and other greenhouse gases to be emitted or sequestered, thereby changing their global average atmospheric concentrations. Natural activities such as respiration by plants or animals and seasonal cycles of plant growth and decay are examples of processes that only

cycle carbon or nitrogen between the atmosphere and organic biomass. Such processes—except when directly or indirectly perturbed out of equilibrium by anthropogenic activities—generally do not alter average atmospheric greenhouse gas concentrations over decadal timeframes. Climatic changes resulting from anthropogenic activities, however, could have positive or negative feedback effects on these natural systems. Atmospheric concentrations of these gases, along with their rates of growth and atmospheric lifetimes, are presented below.

Table 10. Global Atmospheric Concentration (ppm unless otherwise specified), Rate of Concentration Change (ppb/year) and Atmospheric Lifetime (years) of Selected Greenhouse Gases

Atmospheric Variable	CO ₂	CH ₄	N ₂ O	SF ₆ ^a	CF ₄ ^a
Pre-industrial atmospheric concentration	278	0.700	0.270	0	40
Atmospheric concentration (1998)	365	1.745	0.314	4.2	80
Rate of concentration change ^b	1.5 ^c	0.007 ^c	0.0008	0.24	1.0
Atmospheric lifetime	50-200 ^d	12 ^e	114 ^e	3,200	>50,000

^a Concentrations in parts per trillion (ppt) and rate of concentration change in ppt/year.

^b Rate is calculated over the period 1990 to 1999.

^c Rate has fluctuated between 0.9 and 2.8 ppm per year for CO₂ and between 0 and 0.013 ppm per year for CH₄ over the period 1990 to 1999.

^d No single lifetime can be defined for CO₂ because of the different rates of uptake by different removal processes.

^e This lifetime has been defined as an “adjustment time” that takes into account the indirect effect of the gas on its own residence time.

Source: IPCC (2001)

A brief description of each greenhouse gas, its sources, and its role in the atmosphere is given below. The following section then explains the concept of Global Warming Potentials (GWPs), which are assigned to individual gases as a measure of their relative average global radiative forcing effect.

Water Vapor (H₂O). Overall, the most abundant and dominant greenhouse gas in the atmosphere is water vapor. Water vapor is neither long-lived nor well mixed in the atmosphere, varying spatially from 0 to 2 percent (IPCC 1996). In addition, atmospheric water can exist in several physical states including gaseous, liquid, and solid. Human activities are not believed to directly affect the average global concentration of water vapor;

however, the radiative forcing produced by the increased concentrations of other greenhouse gases may indirectly affect the hydrologic cycle. A warmer atmosphere has an increased water holding capacity; yet, increased concentrations of water vapor affects the formation of clouds, which can both absorb and reflect solar and terrestrial radiation. Aircraft contrails, which consist of water vapor and other aircraft emittants, are similar to clouds in their radiative forcing effects (IPCC 1999).

Carbon Dioxide (CO₂). In nature, carbon is cycled between various atmospheric, oceanic, land biotic, marine biotic, and mineral reservoirs. The largest fluxes occur between the atmosphere and terrestrial biota, and

between the atmosphere and surface water of the oceans. In the atmosphere, carbon predominantly exists in its oxidized form as CO₂. Atmospheric carbon dioxide is part of this global carbon cycle, and therefore its fate is a complex function of geochemical and biological processes. Carbon dioxide concentrations in the atmosphere increased from approximately 280 parts per million by volume (ppmv) in pre-industrial times to 367 ppmv in 1999, a 31 percent increase (IPCC 2001). The IPCC notes that “[t]his concentration has not been exceeded during the past 420,000 years, and likely not during the past 20 million years. The rate of increase over the past century is unprecedented, at least during the past 20,000 years.” The IPCC definitively states that “the present atmospheric CO₂ increase is caused by anthropogenic emissions of CO₂” (IPCC 2001). Forest clearing, other biomass burning, and some non-energy production processes (e.g., cement production) also emit notable quantities of carbon dioxide.

In its second assessment, the IPCC also stated that “[t]he increased amount of carbon dioxide [in the atmosphere] is leading to climate change and will produce, on average, a global warming of the Earth’s surface because of its enhanced greenhouse effect—although the magnitude and significance of the effects are not fully resolved” (IPCC 1996).

Methane (CH₄). Methane is primarily produced through anaerobic decomposition of organic matter in biological systems. Agricultural processes such as wetland rice cultivation, enteric fermentation in animals, and the decomposition of animal wastes emit CH₄, as does the decomposition of municipal solid wastes. Methane is also emitted during the production and distribution of natural gas and petroleum, and is released as a by-product of coal mining and incomplete fossil fuel combustion. Atmospheric concentrations of methane have increased by about 150 percent since pre-industrial times, although the rate of increase has been declining. The IPCC has estimated that slightly more than half of the current CH₄ flux to the atmosphere is anthropogenic, from human activities such as agriculture, fossil fuel use and waste disposal (IPCC 2001).

Methane is removed from the atmosphere by reacting with the hydroxyl radical (OH) and is ultimately converted to CO₂. Minor removal processes also include reaction with Cl in the marine boundary layer, a soil sink, and stratospheric reactions. Increasing emissions of methane reduce the concentration of OH, a feedback which may increase methane’s atmospheric lifetime (IPCC 2001).

Nitrous Oxide (N₂O). Anthropogenic sources of N₂O emissions include agricultural soils, especially the use of synthetic and manure fertilizers; fossil fuel combustion, especially from mobile combustion; adipic (nylon) and nitric acid production; wastewater treatment and waste combustion; and biomass burning. The atmospheric concentration of nitrous oxide (N₂O) has increased by 16 percent since 1750, from a pre industrial value of about 270 ppb to 314 ppb in 1998, a concentration that has not been exceeded during the last thousand years. Nitrous oxide is primarily removed from the atmosphere by the photolytic action of sunlight in the stratosphere.

Ozone (O₃). Ozone is present in both the upper stratosphere, where it shields the Earth from harmful levels of ultraviolet radiation, and at lower concentrations in the troposphere, where it is the main component of anthropogenic photochemical “smog.” During the last two decades, emissions of anthropogenic chlorine and bromine-containing halocarbons, such as chlorofluorocarbons (CFCs), have depleted stratospheric ozone concentrations. This loss of ozone in the stratosphere has resulted in negative radiative forcing, representing an indirect effect of anthropogenic emissions of chlorine and bromine compounds (IPCC 1996). The depletion of stratospheric ozone and its radiative forcing was expected to reach a maximum in about 2000 before starting to recover, with detection of such recovery not expected to occur much before 2010 (IPCC 2001).

The past increase in tropospheric ozone, which is also a greenhouse gas, is estimated to provide the third largest increase in direct radiative forcing since the pre-industrial era, behind CO₂ and CH₄. Tropospheric ozone is produced from complex chemical reactions of volatile organic compounds mixing with

nitrogen oxides (NO_x) in the presence of sunlight. Ozone, carbon monoxide (CO), sulfur dioxide (SO₂), nitrogen dioxide (NO₂) and particulate matter are included in the category referred to as “criteria pollutants” in the United States under the Clean Air Act and its subsequent amendments. The tropospheric concentrations of ozone and these other pollutants are short-lived and, therefore, spatially variable.

Halocarbons, Perfluorocarbons, and Sulfur Hexafluoride (SF₆). Halocarbons are, for the most part, man-made chemicals that have both direct and indirect radiative forcing effects. Halocarbons that contain chlorine—chlorofluorocarbons (CFCs), hydrochlorofluorocarbons (HCFCs), methyl chloroform, and carbon tetrachloride—and bromine—halons, methyl bromide, and hydrobromofluorocarbons (HBFCs)—result in stratospheric ozone depletion and are therefore controlled under the Montreal Protocol on Substances that Deplete the Ozone Layer. Although CFCs and HCFCs include potent global warming gases, their net radiative forcing effect on the atmosphere is reduced because they cause stratospheric ozone depletion, which is itself an important greenhouse gas in addition to shielding the Earth from harmful levels of ultraviolet radiation. Under the Montreal Protocol, the United States phased out the production and importation of halons by 1994 and of CFCs by 1996. Under the Copenhagen Amendments to the Protocol, a cap was placed on the production and importation of HCFCs by non-Article 5 countries beginning in 1996, and then followed by a complete phase-out by the year 2030. The ozone depleting gases covered under the Montreal Protocol and its Amendments are not covered by the UNFCCC.

Hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF₆) are not ozone depleting substances, and therefore are not covered under the Montreal Protocol. They are, however, powerful greenhouse gases. HFCs—primarily used as replacements for ozone depleting substances but also emitted as a by-product of the HCFC-22 manufacturing process—currently have a small aggregate radiative forcing impact; however, it is anticipated that their contribution to overall radiative forcing will

increase (IPCC 2001). PFCs and SF₆ are predominantly emitted from various industrial processes including aluminum smelting, semiconductor manufacturing, electric power transmission and distribution, and magnesium casting. Currently, the radiative forcing impact of PFCs and SF₆ is also small; however, they have a significant growth rate, extremely long atmospheric lifetimes, and are strong absorbers of infrared radiation, and therefore have the potential to influence climate far into the future (IPCC 2001).

Carbon Monoxide (CO). Carbon monoxide has an indirect radiative forcing effect by elevating concentrations of CH₄ and tropospheric ozone through chemical reactions with other atmospheric constituents (e.g., the hydroxyl radical, OH) that would otherwise assist in destroying CH₄ and tropospheric ozone. Carbon monoxide is created when carbon-containing fuels are burned incompletely. Through natural processes in the atmosphere, it is eventually oxidized to CO₂. Carbon monoxide concentrations are both short-lived in the atmosphere and spatially variable.

Nitrogen Oxides (NO_x). The primary climate change effects of nitrogen oxides (i.e., NO and NO₂) are indirect and result from their role in promoting the formation of ozone in the troposphere and, to a lesser degree, lower stratosphere, where it has positive radiative forcing effects. Additionally, NO_x emissions from aircraft are also likely to decrease methane concentrations, thus having a negative radiative forcing effect (IPCC 1999). Nitrogen oxides are created from lightning, soil microbial activity, biomass burning – both natural and anthropogenic fires – fuel combustion, and, in the stratosphere, from the photo-degradation of nitrous oxide (N₂O). Concentrations of NO_x are both relatively short-lived in the atmosphere and spatially variable.

Nonmethane Volatile Organic Compounds (NMVOCs). Nonmethane volatile organic compounds include compounds such as propane, butane, and ethane. These compounds participate, along with NO_x, in the formation of tropospheric ozone and other photochemical oxidants. NMVOCs are emitted primarily from transportation and industrial processes, as well as biomass burning and non-industrial consumption of organic

solvents. Concentrations of NMVOCs tend to be both short-lived in the atmosphere and spatially variable.

Aerosols. Aerosols are extremely small particles or liquid droplets found in the atmosphere. They can be produced by natural events such as dust storms and volcanic activity, or by anthropogenic processes such as fuel combustion and biomass burning. They affect radiative forcing in both direct and indirect ways: directly by scattering and absorbing solar and thermal infrared radiation; and indirectly by increasing droplet counts that modify the formation, precipitation efficiency, and radiative properties of clouds. Aerosols are removed from the atmosphere relatively rapidly by precipitation. Because aerosols generally have short atmospheric lifetimes, and have concentrations and compositions that vary regionally, spatially, and temporally, their contributions to radiative forcing are difficult to quantify (IPCC 2001).

The indirect radiative forcing from aerosols are typically divided into two effects. The first effect involves decreased droplet size and increased droplet concentration resulting from an increase in airborne aerosols. The second effect involves an increase in the water content and lifetime of clouds due to the effect of reduced droplet size on precipitation efficiency (IPCC 2001). Recent research has placed a greater focus on the second indirect radiative forcing effect of aerosols.

Various categories of aerosols exist, including naturally produced aerosols such as soil dust, sea salt, biogenic aerosols, sulphates, and volcanic aerosols, and anthropogenically manufactured aerosols such as industrial dust and carbonaceous aerosols (e.g., black carbon, organic carbon) from transportation, coal combustion, cement manufacturing, waste incineration, and biomass burning.

The net effect of aerosols is believed to produce a negative radiative forcing effect (i.e., net cooling effect on the climate), although because they are short-lived in the atmosphere—lasting days to weeks—their concentrations respond rapidly to changes in emissions. Locally, the negative radiative forcing effects of aerosols can offset the positive forcing of greenhouse gases (IPCC 1996). “However, the aerosol effects do not

cancel the global-scale effects of the much longer-lived greenhouse gases, and significant climate changes can still result” (IPCC 1996).

The IPCC’s Third Assessment Report notes that “the indirect radiative effect of aerosols is now understood to also encompass effects on ice and mixed-phase clouds, but the magnitude of any such indirect effect is not known, although it is likely to be positive” (IPCC 2001). Additionally, current research suggests that another constituent of aerosols, elemental carbon, may have a positive radiative forcing (Jacobson 2001). The primary anthropogenic emission sources of elemental carbon include diesel exhaust, coal combustion, and biomass burning.

Global Warming Potentials

Global Warming Potentials (GWPs) are intended as a quantified measure of the globally averaged relative radiative forcing impacts of a particular greenhouse gas. It is defined as the cumulative radiative forcing—both direct and indirect effects—integrated over a period of time from the emission of a unit mass of gas relative to some reference gas (IPCC 1996). Carbon dioxide (CO₂) was chosen as this reference gas. Direct effects occur when the gas itself is a greenhouse gas. Indirect radiative forcing occurs when chemical transformations involving the original gas produce a gas or gases that are greenhouse gases, or when a gas influences other radiatively important processes such as the atmospheric lifetimes of other gases. The relationship between gigagrams (Gg) of a gas and Tg CO₂ Eq. can be expressed as follows:

$$Tg\ CO_2\ Eq = (Gg\ of\ gas) \times (GWP) \times \left(\frac{Tg}{1,000\ Gg} \right)$$

where,

Tg CO₂ Eq. = Teragrams of Carbon Dioxide Equivalents

Gg = Gigagrams (equivalent to a thousand metric tons)

GWP = Global Warming Potential

Tg = Teragrams

GWP values allow policy makers to compare the impacts of emissions and reductions of different gases. According to the IPCC, GWPs typically have an uncertainty of roughly ±35 percent, though some GWPs have larger uncertainty than others, especially those in

which lifetimes have not yet been ascertained. In the following decision, the parties to the UNFCCC have agreed to use consistent GWPs from the IPCC Second Assessment Report (SAR), based upon a 100 year time horizon, although other time horizon values are available (see Table 11).

In addition to communicating emissions in units of mass, Parties may choose also to use global warming potentials (GWPs) to reflect their inventories and projections in carbon dioxide-equivalent terms, using information provided by the Intergovernmental Panel on Climate Change (IPCC) in its Second Assessment Report. Any use of GWPs should be based on the effects of the greenhouse gases over a 100-year time horizon. In addition,

Parties may also use other time horizons. (FCCC/CP/1996/15/Add.1)

Greenhouse gases with relatively long atmospheric lifetimes (e.g., CO₂, CH₄, N₂O, HFCs, PFCs, and SF₆) tend to be evenly distributed throughout the atmosphere, and consequently global average concentrations can be determined. The short-lived gases such as water vapor, carbon monoxide, tropospheric ozone, other ambient air pollutants (e.g., NO_x, and NMVOCs), and tropospheric aerosols (e.g., SO₂ products and black carbon), however, vary spatially, and consequently it is difficult to quantify their global radiative forcing impacts. GWP values are generally not attributed to these gases that are short-lived and spatially inhomogeneous in the atmosphere.

Table 11. Global Warming Potentials (GWP) and Atmospheric Lifetimes (Years) Used in the Inventory

Gas	Atmospheric Lifetime	100-year GWP ^a	20-year GWP	500-year GWP
Carbon dioxide (CO ₂)	50-200	1	1	1
Methane (CH ₄) ^b	12±3	21	56	6.5
Nitrous oxide (N ₂ O)	120	310	280	170
HFC-23	264	11,700	9,100	9,800
HFC-125	32.6	2,800	4,600	920
HFC-134a	14.6	1,300	3,400	420
HFC-143a	48.3	3,800	5,000	1,400
HFC-152a	1.5	140	460	42
HFC-227ea	36.5	2,900	4,300	950
HFC-236fa	209	6,300	5,100	4,700
HFC-4310mee	17.1	1,300	3,000	400
CF ₄	50,000	6,500	4,400	10,000
C ₂ F ₆	10,000	9,200	6,200	14,000
C ₄ F ₁₀	2,600	7,000	4,800	10,100
C ₆ F ₁₄	3,200	7,400	5,000	10,700
SF ₆	3,200	23,900	16,300	34,900

^a GWPs used here are calculated over 100 year time horizon

^b The methane GWP includes the direct effects and those indirect effects due to the production of tropospheric ozone and stratospheric water vapor. The indirect effect due to the production of CO₂ is not included.

Source: IPCC (1996)

Table 12 presents direct and net (i.e., direct and indirect) GWPs for ozone-depleting substances (ODSs). Ozone-depleting substances directly absorb infrared radiation and contribute to positive radiative forcing; however, their effect as ozone-depleters also

leads to a negative radiative forcing because ozone itself is a potent greenhouse gas. There is considerable uncertainty regarding this indirect effect; therefore, a range of net GWPs is provided for ozone depleting substances.

Table 12. Net 100-year Global Warming Potentials for Select Ozone Depleting Substances*

Gas	Direct	Net _{min}	Net _{max}
CFC-11	4,600	(600)	3,600
CFC-12	10,600	7,300	9,900
CFC-113	6,000	2,200	5,200
HCFC-22	1,700	1,400	1,700
HCFC-123	120	20	100
HCFC-124	620	480	590
HCFC-141b	700	(5)	570
HCFC-142b	2,400	1,900	2,300
CHCl ₃	140	(560)	0
CCl ₄	1,800	(3,900)	660
CH ₃ Br	5	(2,600)	(500)
Halon-1211	1,300	(24,000)	(3,600)
Halon-1301	6,900	(76,000)	(9,300)

* Because these compounds have been shown to deplete stratospheric ozone, they are typically referred to as ozone depleting substances (ODSs). However, they are also potent greenhouse gases. Recognizing the harmful effects of these compounds on the ozone layer, in 1987 many governments signed the *Montreal Protocol on Substances that Deplete the Ozone Layer* to limit the production and importation of a number of CFCs and other halogenated compounds. The United States furthered its commitment to phase-out ODSs by signing and ratifying the Copenhagen Amendments to the *Montreal Protocol* in 1992. Under these amendments, the United States committed to ending the production and importation of halons by 1994, and CFCs by 1996. The IPCC Guidelines and the UNFCCC do not include reporting instructions for estimating emissions of ODSs because their use is being phased-out under the *Montreal Protocol*. The effects of these compounds on radiative forcing are not addressed here.

Source: IPCC (2001)

The IPCC recently published its Third Assessment Report (TAR), providing the most current and comprehensive scientific assessment of climate change (IPCC 2001). Within that report, the GWPs of several gases were revised relative to the IPCC's Second Assessment Report (SAR) (IPCC 1996), and new GWPs have been calculated for an expanded set of gases. Since the SAR, the IPCC has applied an improved calculation of CO₂ radiative forcing and an improved CO₂ response function (presented in WMO 1999). The GWPs are drawn from WMO (1999) and the SAR, with updates for those cases where

new laboratory or radiative transfer results have been published. Additionally, the atmospheric lifetimes of some gases have been recalculated. Because the revised radiative forcing of CO₂ is about 12 percent lower than that in the SAR, the GWPs of the other gases relative to CO₂ tend to be larger, taking into account revisions in lifetimes. However, there were some instances in which other variables, such as the radiative efficiency or the chemical lifetime, were altered that resulted in further increases or decreases in particular GWP values. In addition, the values for radiative forcing and

lifetimes have been calculated for a variety of halocarbons, which were not presented in the SAR. The changes are described in the TAR as follows:

New categories of gases include fluorinated organic molecules, many of which are ethers that are proposed as halocarbon substitutes. Some of the GWPs have larger uncertainties than that of others, particularly for those gases where detailed laboratory data on lifetimes are not yet available. The direct GWPs have been calculated relative to CO₂ using an improved calculation of the CO₂ radiative forcing, the SAR response function for a CO₂ pulse, and new values for the radiative forcing and lifetimes for a number of halocarbons.

Table 11 compares the lifetimes and GWPs for the SAR and TAR. As can be seen in Table 12, GWPs changed anywhere from a decrease of 15 percent to an increase of 49 percent.

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Supplement I. White Paper: 2002 Arizona Reference Case Emissions Inventory for Black Carbon and Organic Material

The Center for Climate Strategies
Stephen Roe, E.H. Pechan & Associates (Lead Author),
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Revised: December 2005

This White Paper summarizes the methods, data sources, and results of an estimate of 2002 emissions for black carbon (BC) and organic material (OM) in Arizona. To develop this inventory, we relied on several different data sources. Where possible and within the time-frame available, we used emissions data from the Western Regional Air Partnership (WRAP) to achieve consistency with the regional haze inventory developed for the western States. Data were taken from the following sources:

- Particulate matter (PM) speciation data from EPA's SPECIATE database: these data include aerosol fractions of elemental carbon (aka black carbon) and primary organic aerosols (POA; aka organic material or OM). Our starting point was the speciation data currently being used for regional haze modeling by the Carolina Environmental Program (Vukovich, 2004). Most of these data come from EPA's current SPECIATE3.2 database. We augmented these data with new profiles developed under our on-going EPA project to update SPECIATE. Note that these new profiles have not yet been released by EPA.
- Western Regional Air Partnership's (WRAP's) Emissions Data Management System (EDMS): We obtained emissions data for Arizona directly from EDMS for all sources, except wildfires and prescribed burns. We used the particulate matter (PM) emission estimates for Arizona from EDMS as one of the primary starting points in this analysis. According to ADEQ, these data represent the best available emissions data compiled for the State. Note that although EDMS was designed to house BC and organic carbon¹ (OC) emission estimates and that WRAP has developed BC and OC estimates for some source sectors, no BC/OC estimates are currently available for Arizona in EDMS.

For the mobile source sector, WRAP developed BC and OC estimates (Environ et al., 2004); however, EDMS indicates that the Arizona mobile source data are from EPA's 2002 National Emissions Inventory (NEI). This means that non-road and on-road Maricopa County data are included, as well as on-road Pima County data (for criteria pollutants). For the rest of the State, EPA populated the data using the National Mobile Inventory Model (NMIM). NMIM uses top-down methods and data sources and the EPA models MOBILE6 and NONROAD 2004 to estimate emissions.

We reviewed the documentation on how the WRAP mobile source inventory was speciated to derive BC and OC. In most cases, the speciation profiles we used are comparable to those used in the WRAP work as shown below. There are fairly significant differences shown for brake and tire wear. The WRAP fractions for tire wear are based on the original SPECIATE PM profile (circa 1988). Our profile is based on recent data from CARB that will be contained in the latest SPECIATE version. This profile is

¹ Note that OC is a measurement of carbon mass only for the organic material. Other functional groups associated with OM contain atoms of oxygen, nitrogen, hydrogen, and other compounds. Jacobson (2002) used a factor of 1.3 to convert between OC and OM. This compares to a factor of 1.2 used by EPA for its POA estimates (PES, 2003). For this analysis, we assumed POA is equivalent to OM as defined by Jacobson.

supported by a study of car tires showing that carbon black makes up 25-35% of tire rubber (Wik and Dave, 2005). The brake wear profile is also based on new CARB profile data. Instead of using the same BC/OC data for non-road gasoline exhaust and on-road gasoline exhaust (as was done in the WRAP work), we used an existing SPECIATE profile, which is similar to pre-1991 on-road vehicles. We believe that this profile better represents non-road gasoline engine emissions (e.g., primarily non-catalyzed and less combustion efficient than newer on-road engines). Secondly, although we do not have speciation data for 2-stroke engines, we expect the OC fractions to be much higher than in on-road gasoline vehicles (thus, the selected profile is a better fit).

Table 13. Mass Emission Results

Sector	Subsector	WRAP		This Study	
		Weight Fraction ^a			
		BC	OC	BC	OC
On-road Gasoline	Exhaust	0.239	0.518	0.169	0.597
	Tire Wear	0.609	0.2175	0.22	0.472
	Brake Wear	0.028	0.972	0.0261	0.107
On-road Diesel	Light Duty Exhaust	0.613	0.303	0.613	0.303
	Heavy Duty Exhaust	0.75	0.189	0.75	0.189
	Tire Wear	0.609	0.2175	0.22	0.472
	Brake Wear	0.028	0.972	0.0261	0.107
Non-road Gasoline		0.239	0.518	0.0801	0.655
Non-road Diesel		0.75	0.189	0.7411	0.187

^a Note that the weight fractions do not add to one, since other aerosol species (not shown) also make up the PM profile – e.g. sulfates, nitrates, metals, etc.

WRAP – Western Regional Air Partnership

Except for wildfires/prescribed burns, we are not aware of any BC/OC emission estimates from the WRAP (or elsewhere) covering the rest of the stationary source sector (e.g., Pechan developed much of the WRAP’s point source inventory data; however we did not provide BC/OC estimates as part of that work).

- For wildfires and prescribed burns: we used State-level particulate matter less than 2.5 microns (PM_{2.5}) emissions from the WRAP’s draft 2002 inventory (Air Sciences, 2004). We then speciated the BC and POA from the PM_{2.5}, using new speciation data from our ongoing SPECIATE update project for EPA. As shown below, these aerosol fractions are nearly identical to those used to develop the WRAP inventory. Note that we could not develop BC/OC estimates directly from the WRAP documentation, since the prescribed

burn and wildfire emissions were not broken out separately. For the same reason, we could not use the WRAP BC/OC fractions in this study; however as shown below, the values we used are very similar.

Table 14. Black Carbon (BC)/Organic Carbon (OC) for Fires and Wildfires

WRAP Draft 2002 Inventory				This Study	
Prescribed Fire – Piled Fuels		Prescribed/Wildfires – Non-Piled Fuels		Prescribed Fires and Wildfires	
Weight Fraction					
BC	OC	BC	OC	BC	OC
0.072	0.54	0.062	0.48	0.075	0.532

Development of BC and OM Mass Emission Estimates

In order to convert the BC/POA estimates into CO₂ equivalents, we first assumed that the POA estimate is a reasonable estimate for OM. The BC and POA (OM) mass emission estimates were derived by multiplying the PM₁₀ emission estimates by the appropriate aerosol fraction. After some additional consideration of this approach, we decided that, for certain sources, particulate matter less than 2.5 microns (PM_{2.5}) emission estimates would be a better starting point for BC and OM emissions. The source categories where PM_{2.5} estimates were favored over PM₁₀ estimates are those associated with fugitive dust emissions. These categories include agricultural tilling, paved and unpaved road dust, and construction activities. These categories tend to have a large amount of coarse mass (particles with mass between PM₁₀ and PM_{2.5}). Much of this coarse mass is not transported far from the source.

After estimating both BC and OM emissions for each source category, we summed these two aerosol species into a BC+OM estimate. We then collapsed the inventory to the sector level to be consistent with the gaseous portion of Arizona’s greenhouse gas (GHG) inventory. The mass emission results are shown in Table 13.

Development of CO_{2e} for BC+OM Emissions

We used similar methods to those applied in the northeast for converting BC mass emissions to CO₂ equivalents (ENE, 2004). These methods are based on the modeling of Jacobson (2002) and his updates to this work (Jacobson, 2005a). Jacobson (2005) estimated a range of 90:1 to 190:1 for the climate response effects of BC+OM emissions as compared to CO₂ carbon emissions (depending on either a 30-year or 95-year atmospheric lifetime for CO₂). It is important to note that the BC+OM emissions used by Jacobson were based on a 2:1 ratio of OM:BC (his work in these papers focused on fossil fuel BC+OM).

For Maine and Connecticut, ENE (2004) applied climate response factors from the earlier Jacobson work (220 and 500) to the estimated BC mass to estimate the range of CO_{2e} associated with BC emissions. Note that the analysis in the northeast was limited to BC emissions from on-road diesel exhaust. An important oversight from this work is that the

climate response factors developed by Jacobson (2002, 2005a) are on the basis of CO₂ carbon (not CO_{2e}). Therefore, in order to express the BC emissions as CO_{2e}, the climate response factors should have been adjusted upward by a factor of 3.67 to account for the molecular weight of CO₂ to carbon (44/12).

For this inventory, we started with the 90 and 190 climate response factors adjusted to 330 and 697 to obtain a low and high estimate of CO_{2e} for each sector. An example calculation of the CO_{2e} emissions for 10 tons of PM₁₀ from on-road diesel exhaust follows:

- BC mass = (10 tons PM₁₀) x (0.613 ton EC/ton PM₁₀) = 6.13 short tons BC
- Low estimate CO_{2e} = (6.13 tons BC) (330 tons CO_{2e}/ton BC+OM) (3 tons BC+OM/ton BC) (0.907 metric ton/ton) = 5,504 metric tons CO_{2e}
- High estimate CO_{2e} = (6.13 tons BC) (697 tons CO_{2e}/ton BC+OM) (3 tons BC+OM/ton BC) (0.907 metric ton/ton) = 11,626 metric tons CO_{2e}
- The factor 3 tons BC+OM/ton BC comes directly from the modeling assumptions used by Jacobson (2002, 2005a; i.e., 2 tons of OM/ton of BC).

For source categories that had an OM:BC mass emission ratio >4.0, we zeroed out these emission estimates from the CO_{2e} estimates. The reason for this is that the net heating effects of OM are not currently well understood. Therefore, for source categories where the PM is dominated by OM (e.g., biomass burning), the net climate response associated with these emissions is highly uncertain. Further, OM:BC ratios of 4 or more are well beyond the 2:1 ratio used by Jacobson in his work.

Results, Conclusions, and Next Steps

We estimate that BC mass emissions in Arizona total 12,370 tons in 2002 (see Table 15). The CO_{2e} emissions range from about 2.8 to 6.0 million metric tons. These estimates are approximately 3 to 6% of the entire CO_{2e} estimated for the gaseous GHG inventory. Wildfires and prescribed burns contributed nearly 68% of the BC mass emissions; however they were removed from the CO_{2e} estimates due to the high OM to BC ratio (about 7:1). Emissions for residential wood combustion and open burning, two more important biomass combustion sectors, were also left out of the CO_{2e} estimates for the same reason.

By far, the highest contributions to CO_{2e} are from the on-road diesel sector at 59% (this includes exhaust, plus brake and tired wear). Non-road diesel engines contribute 18% of the CO_{2e} emissions. Construction diesel engines contributed nearly 60% of the CO_{2e} for the non-road diesel engines sector. The “non-road other” sector contributes about another 11% of the CO_{2e}. This sector is dominated by railroad engines. On-road gasoline vehicles contribute another 3%, however these emissions are strictly related to tire wear (the OM:BC ratios for exhaust and brake wear are both >4). Coal-fired electricity generating units (EGUs) contribute 6% of the CO_{2e}.

The next step in this analysis could be to develop projections for future years. We suggest focusing on just the primary CO_{2e} contributors (e.g., on-road diesel and the non-road diesel sectors). Forecast inventories from the Western Regional Air Partnership (WRAP) process could be used and are recommended in order to maintain consistency with the regional haze program. To represent 2010 conditions, the WRAP 2008 forecast year would provide the best estimates. For 2020, the WRAP 2018 forecast is the best surrogate.

While the state of science in aerosol climate forcing is still developing, there is a good body of evidence supporting the net warming impacts of black carbon. Aerosols have a *direct*

radiative forcing because they scatter and absorb solar and infrared radiation in the atmosphere. Aerosols also alter the formation and precipitation efficiency of liquid water, ice, and mixed-phase clouds, thereby causing an *indirect* radiative forcing associated with these changes in cloud properties (IPCC, 2001). There are also a number of other indirect radiative effects that have been modeled (e.g., Jacobson, 2002).

The quantification of aerosol radiative forcing is more complex than the quantification of radiative forcing by greenhouse gases because the direct and indirect radiative forcing, and the fact that aerosol mass and particle number concentrations are highly variable in space and time. This variability is largely due to the much shorter atmospheric lifetime of aerosols compared with the important greenhouse gases. Spatially and temporally resolved information on the atmospheric burden and radiative properties of aerosols is needed to estimate radiative forcing.

The quantification of indirect radiative forcing by aerosols is especially difficult. In addition to the variability in aerosol concentrations, some complicated aerosol influences on cloud processes must be accurately modeled. For example, the warm (liquid water) cloud indirect forcing may be divided into two components. The first indirect forcing is associated with the change in droplet concentration caused by increases in aerosol cloud condensation nuclei. The second indirect forcing is associated with the change in precipitation efficiency that results from a change in droplet number concentration. Quantification of the latter forcing necessitates understanding of a change in cloud liquid-water content and cloud amount. In addition to warm clouds, ice clouds may also be affected by aerosols.

To put the radiative forcing potential of BC in context with CO₂, the Intergovernmental Panel on Climate Change estimated the radiative forcing for a doubling of the earth's CO₂ concentration to be 3.7 watts per square meter (W/m²). For BC, various estimates of current radiative forcing have ranged from 0.16 to 0.42 W/m² (IPCC, 2001). These BC estimates are for direct radiative effects only. There is a higher level of uncertainty associated with the direct radiative forcing estimates of BC compared to those of CO₂ and other GHGs. There are even higher uncertainties associated with the assessment of the indirect radiative forcing of aerosols.

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Table 15. Black Carbon (BC) and Organic Material (OM) Emissions Summary

Sector	Subsector	Mass Emissions					CO ₂ e	
		BC	POA	BC	POA	BC + OM	Low	High
		Short Tons		Metric Tons			Metric Tons	
Electric Generating Units (EGUs)	Coal	193	275	175	250	425	173,028	365,456
	Oil	1.1	0.4	1.0	0.33	1.3	994	2,100
	Gas ^a	0	94	0	86	86	0	0
Non-EGU Fuel Combustion (Residential, Commercial, and Industrial)	Coal	5.7	8.2	5.2	7.5	13	5,161	10,900
	Oil	22	11	20	9.5	29	19,691	41,589
	Gas	0.03	241	0.03	218	218	0	0
	Other ^b	237	1,161	215	1,054	1,269	1,985	4,193
On-road Gasoline (Exhaust, Brake Wear, & Tire Wear)		192	737	174	669	843	82,966 ^c	175,235 ^c
On-road Diesel (Exhaust, Brake Wear, & Tire Wear)		1,864	728	1,692	661	2,353	1,671,922	3,531,302
Aircraft ^d		50	28	45	25	70	44,589	94,177
Other Energy Use	Non-road Gasoline	52	560	47	508	555	0	0
	Non-road Diesel	579	193	526	175	701	520,169	1,098,660
	Non-road Other ^e	338	106	307	96	403	303,511	641,160
	Other Combustion ^f	8.7	72	7.9	65	73	237	500
Industrial Processes ^g		42	606	38	550	588	326	690
Agriculture ^h		27	1,362	25	1,236	1,261	0	0
Waste Management	Landfills	0.12	7.3	0.11	6.6	7	0	0
	Incineration ⁱ	5.3	9.8	4.8	8.9	14	4,741	10,015
	Open Burning ^j	260	3,039	236.28	2,758.88	2,995	0	0

Sector	Subsector	Mass Emissions					CO _{2e}	
		BC	POA	BC	POA	BC + OM	Low	High
		Short Tons		Metric Tons			Metric Tons	
Wildfires/ Prescribed Burns ^k		8,400	71,501	7,626	64,909	72,534	0	0
Miscellaneous ^l		94	1,446	85	1,312	1,398	86	182
Totals		12,370	82,183	11,230	74,606	85,835	2,829,406	5,976,157

NOTE: CO_{2e} is zeroed out for sources with OM:BC ratio >4.0 (see text).

^a The SPECIATE3.2 PM profile showed zero for PEC (BC). A review of other in-house data showed that BC is present in PM emissions from natural gas combustion at a OM:BC ratio of around 1:1. This ratio was used to calculate BC+OM and the associated CO_{2e} emissions.

^b Most of these emissions are from residential wood combustion.

^c The CO_{2e} estimates are associated with tire wear only, since the exhaust and brake wear components have OM:BC ratios >4:1.

^d Note for aircraft, criteria pollutant emissions are only estimated for the boundary (mixing) layer (i.e., mainly landing and take-off cycle emissions). Therefore, these estimates do not include emissions occurring above the mixing layer but within AZ airspace.

^e Nearly all emissions are from the railroad source categories.

^f About 60% of emissions are from vehicle fires. Other contributors include structure fires and aircraft/rocket engine firing and testing.

^g In this summary, construction is included in the Industrial Processes sector. Construction source categories (industrial/commercial/institutional, residential, road, and other) are the major contributors (96%) of the Industrial Processes emissions.

^h The Agriculture sector includes food industries. 80% of the BC emissions come from agricultural tilling. Agricultural tilling and commercial cooking each contribute about 43% of the POA emissions.

ⁱ About 97% of BC and POA emissions come from commercial/institutional incineration.

^j Open burning of land clearing debris contributes about 68% of BC/POA emissions. Other contributors include open burning of yard waste and household waste.

^k Wildfire/Prescribed burn emissions were excluded from the CO_{2e} estimates due to the much higher OM to BC ratio (about 7:1).

^l Paved and unpaved road dust are significant contributors to the EC and OC emissions.



**APPENDIX E:
CENTER FOR CLIMATE STRATEGIES MEMO:
METHODS FOR QUANTIFICATION AND ANALYSIS**



WWW.AZCLIMATECHANGE.US

Draft Memo

To: Arizona Technical Work Group (TWG) members
From: The Center for Climate Strategies (CCS)
CC: Arizona DEQ
Re: Standard CCS methods for quantification of draft greenhouse gas (GHG) mitigation policy options
Date: April 21, 2006

This memo describes in brief the methodology CCS uses in quantifying the GHG impacts and costs of policy options, and provides some examples of the distinction between “direct” and “indirect” costs. CCS uses the following methods, widely accepted among climate change analysts:

- Focus of analysis: Net GHG reduction potential in physical units of million metric tons carbon dioxide equivalent (MMTCO_{2e}) and net cost per metric ton reduced in units of dollars/MTCO_{2e}.
- Geographic inclusion: Measure GHG impacts of activities that occur within the state, regardless of the actual location of emissions reductions.
- Direct vs. Indirect Effects: Define “direct effects” as those borne by the entities implementing the option. For example, direct costs are net of any benefits or savings to the entity. Define “indirect effects” as those borne by the entities other than those implementing the option. Quantify these indirect effects on a case-by-case basis depending on magnitude, importance, need and availability of data. (See additional discussion and list of examples below.)
- Non-GHG impacts and costs: Include in qualitative terms where deemed important. Quantify on a case by case as needed depending on need and where data is readily available.
- Discounted and “Levelized” Costs: Discount costs using the discount rate applied by the State in other policy arenas (or apply a real discount rate of 5% if a state-approved rate is not available). Discount a multiyear stream of net costs (total costs net of any savings) to

arrive at the “present value cost” of an option. Create a “levelized” cost per ton by dividing the “present value cost” by the cumulative reduction in tons of GHG. This is a widely used method to estimate the “dollars per ton” cost of reducing GHG emission (all in CO₂ equivalence). A “levelized” cost is a “present value average” used in a variety of financial cost applications.¹

- Time period of analysis: Count the impacts of actions that occur during the project time period and, using levelized emissions reduction and cost analysis, report emissions reductions and costs for specific target years such as 2010 and 2020. Where additional GHG reductions or costs occur beyond the project period as a direct result of actions taken during the project period, show these for comparison and potential inclusion.
- Aggregation of impacts: Avoid simple double counting of GHG reduction potential and cost when adding options. Note and or estimate interactive effects between policy options using analytical methods where overlap is likely.
- Policy design specifications: Include timing, goal levels, implementing parties, and the type of implementation mechanism.
- Transparency: Include data sources, methods, key assumptions, and key uncertainties.

The approaches here do not necessarily take a “standard” benefit-cost perspective as used in regulatory policy impact analysis. For instance, there is no direct/indirect distinction under standard procedures: one takes the “societal perspective” and tallies everything, and quantifies where possible. Regarding GHG mitigation costs, often the best available data is focused at the level of implementation as opposed to the societal level. Regarding GHG benefits, market prices (monetized benefits) are normally taken as good proxies of societal costs and benefits in standard analysis unless there are market imperfections or subsidies that create distortionary effects. Because we do not have good information on the dollar value of GHG reduction benefits, we use physical benefits instead, measured as MMTCO_{2e}.

The “direct cost” approach described here is useful in estimating the costs (and benefits) to the implementing entity: person, company, governmental body, etc. “Indirect costs” (and benefits) are those experienced by other entities in society. In examining utility Demand Side Management (DSM) programs for gas and electric utilities, analysts sometimes look at three perspectives: “participant”, “non-participant”, and “societal” (the latter being equivalent to “standard” benefit-cost perspective). Depending on program design, “direct cost” to a DSM participant can be high or low (if the latter, it may be attributable to a shifting of some costs non-participants).

¹ For additional details and formulas, see www.tellus.org/energy/publications/policies&measures.pdf, p. 33, See especially the discussion of how some analysts advocate some form of discounting the multi-year stream of GHG reductions, while others do not.

Note also that the “direct cost” approach does not necessarily account for market imperfections or subsidies. Typically a state perspective on “direct costs” takes any federal government subsidies as a given. For example, substantial federal government subsidies exist for some alternative fuels. If the existing market price (with subsidy) of the alternative fuel is used in cost analysis, the option appears as relatively low cost. If the subsidy were included in the cost analysis (i.e., looking at societal costs in the standard benefit-cost perspective), then the alternative fuel would appear more costly.

Finally, some direct costs may look very large despite the attractiveness of the policy option for a variety of reasons, including co-benefits. For instance, in one state a bundle of Transit/Smart Growth/VMT Reductions was estimated to have a direct cost of \$280/MTCO_{2e} – a comparatively high figure -- but stakeholders still endorsed the policy option for the multiple benefits it would generate. In this case stakeholders also believed that a large state investment cost would have been incurred anyway for conventional transportation investment, and that redirection of part of this existing stream of funds to smart growth alternatives made sense. In this case the cost of the existing stream of transportation funds could have been treated as a sunk cost, and the true cost measured instead as the incremental costs of smart growth redirected funding that was over and above the BAU funding stream.

CCS will provide transparency on related data sources, methods and assumptions in its analysis of draft mitigation policy options to ensure that these issues are known, and rely on feedback from the TWGs and CCAG to identify any suggested modifications that may be needed. One key constraint we often face is the availability of data. It is not unusual for data to be imperfect and require pragmatism and transparency during analysis.

For additional reference we recommend the economic analysis guidelines developed by the Science Advisory Board of the US EPA available at:

<http://yosemite.epa.gov/ee/epa/eed.nsf/webpages/Guidelines.html>.

Examples of Direct/Indirect Net Costs and Benefits, RCI

Direct Costs and/or Benefits

- Net capital costs (or incremental costs relative to standard practice) of improved buildings, appliances, equipment (cost of higher-efficiency refrigerator versus refrigerator of similar features that meets standards)
- Net O&M costs (relative to standard practice) of improved buildings, appliances, equipment, including avoided/extra labor costs for maintenance (less changing of CFL or LED lamp relative to incandescent)
- Net fuel (gas, electricity, biomass, etc.) costs (typically as avoided costs from a TRC or societal perspective)
- Cost/value of net water use/savings
- Cost/value of net materials use/savings (for example, raw materials savings via recycling, or lower/higher cost of low-GWP refrigerants)
- Direct improved productivity for as a result of industrial measures (measured as change in cost per unit output, for example, for an energy/GHG-saving improvement that also speeds up a production line or results in higher product yield)

Indirect Costs and/or Benefits

- Re-spending effect on economy
- Net value of employment impacts
- Net value of health benefits/impacts
- Value of net environmental benefits/impacts (value of damage by air pollutants on structures, crops, etc.)
- Net embodied energy of materials used in buildings, appliances, equipment, relative to standard practice
- Improved productivity as a result of an improved working environment, such as improved office productivity through improved delighting (though the inclusion of this as indirect might be argued in some cases)

Examples of Direct/Indirect Net Costs and Benefits, ES

Direct Costs and/or Benefits

- Net capital costs (or incremental costs relative to reference case technologies) of renewables or other advanced technologies resulting from policies
- Net O&M costs (relative to reference case technologies) renewables or other advanced technologies resulting from policies
- Avoided or net fuel savings (gas, coal, biomass, etc.)of renewables or other advanced technologies relative to reference case technologies resulting from policies
- Total system costs (net capital + net O&M + avoided/net fuel savings + net imports/exports + net T&D costs) relative to reference case total system costs

Indirect Costs and/or Benefits

- Re-spending effect on economy
- Higher cost of electricity reverberating through economy
- Energy security
- Net value of employment impacts
- Net value of health benefits/impacts
- Value of net environmental benefits/impacts (value of damage by air pollutants on structures, crops, etc.)

Examples of Direct/Indirect Net Costs and Benefits, AF

Direct Costs and/or Benefits

- Net capital costs (or incremental costs relative to standard practice) of facilities or equipment (e.g. manure digesters and associated infrastructure, generator; ethanol production facility)
- Net O&M costs (relative to standard practice) of equipment or facilities
- Net fuel (gas, electricity, biomass, etc.) costs or avoided costs
- Cost/value of net water use/savings

Indirect Costs and/or Benefits

- Net value of employment impacts
- Net value of health benefits/impacts
- Value of net environmental benefits/impacts (value of damage by air pollutants on structures, crops, etc.)
- Net embodied energy of water use in equipment or facilities relative to standard practice
- Reduced VMT and fuel consumption associated with land use conversions (e.g. as a result of forest/rangeland/cropland protection policies).

Examples of Direct/Indirect Net Costs and Benefits, TLU

Direct Costs and/or Benefits

- Incremental cost of more efficient vehicles net of fuel savings.
- Incremental cost of implementing Smart Growth programs, net of saved infrastructure costs.
- Incremental cost of mass transit investment and operating expenses, net of any saved infrastructure costs (e.g., roads)
- Incremental cost of alternative fuel, net of any change in maintenance costs

Indirect Costs and/or Benefits

- Health benefits of reduced air and water pollution.
- Ecosystem benefits of reduced air and water pollution.
- Value of quality-of-life improvements.
- Value of improved road safety.
- Energy security
- Net value of employment impacts



**APPENDIX F:
CROSS-CUTTING ISSUES-DETAILED POLICY
DESCRIPTION/ANALYSIS**

Overview

Some issues considered by the CCAG apply to multiple sectors and are therefore better addressed as “cross-cutting” issues across all sectors rather than assigned to any individual sector. This set includes GHG reduction goals, GHG emissions reporting, GHG emission reduction registries, public education and outreach, and adaptation. The Cross-Cutting Issues TWG developed includes policy options for each of these issues.

The CCAG was not initially charged with establishing GHG reduction goals, or including adaptive responses to climate change (as opposed to GHG mitigation policies), but came to believe that both should be included in this effort. After carefully considering Arizona’s elevated growth rate, feasibility of GHG emissions reductions, and goals in other jurisdictions, the CCAG identified a GHG emission reduction goal that it believes is aggressive, yet achievable. In terms of adaptation, any delay in adapting to the climate impacts already affecting Arizona will increase the difficulty of doing so in the future, so the CCAG suggests a comprehensive effort be undertaken to develop policy options to address adaptation.

Three cross-cutting policies create awareness and infrastructure needed to encourage and accomplish broad mitigation actions: 1) a GHG emissions reporting program to better understand mitigation opportunities and measure future progress; 2) a GHG registry to help recognize and share accomplishments and provide “baseline protection” for entities; and 3) public education and outreach to build public awareness of climate change risks and opportunities.

Cross-Cutting Issues Work Group

Summary of Results

#	Policy Name	Estimated 2010 GHG Reductions (MMtCO ₂ e)	Estimated 2020 GHG Reductions (MMtCO ₂ e)	Estimated Costs or Cost Savings Per Ton (\$/tCO ₂ e)	Cumulative 2007-2020 GHG Reductions (MMtCO ₂ e)	Level of CCAG Support
		<i>Quantification of GHG Reductions and Costs or Savings are not applicable to these options.</i>				
CC-1	State Greenhouse Gas Reduction Goal	<i>The CCAG recommended a goal of reducing Arizona's GHG emissions to 2000 levels by 2020, with an additional 50% below those levels by 2040.</i>				Unanimous
CC-2	GHG Reporting	<i>The CCAG recommended the implementation of a GHG reporting program in Arizona.</i>				Unanimous
CC-3	GHG Registry	<i>The CCAG recommended the implementation of a GHG registry in Arizona, preferably in concert with other states.</i>				Unanimous
CC-4	Public Education and Outreach	<i>The CCAG recommended that the State undertake concerted climate change education and outreach activities directed toward, but not limited to, several key audiences.</i>				Unanimous
CC-5	Adaptation	<i>The CCAG recommended that the Governor consider appointing a task force or advisory group to develop recommendations for a State adaptation strategy.</i>				Unanimous
Total All Options		Not Applicable				

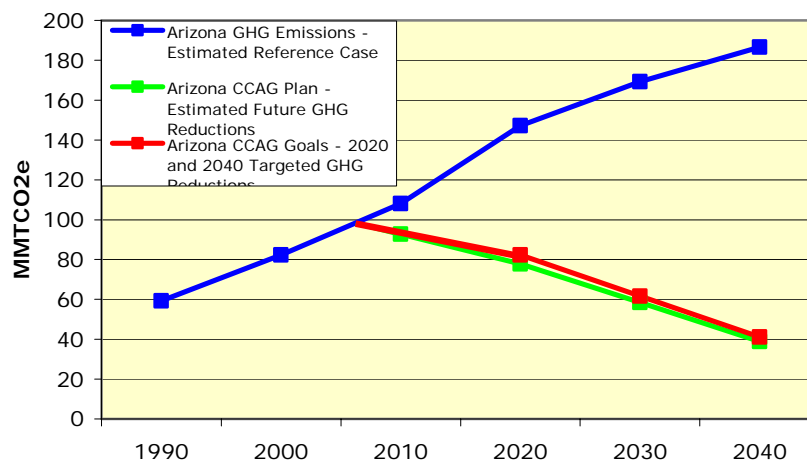
CC-1 State Greenhouse Gas Reduction Goal

Policy Description:

The CCAG recommends that Arizona establish a statewide, economy-wide GHG reduction target to reduce GHG emissions to 2000 levels by 2020, and to an additional 50% reduction below those levels by 2040. In lieu of establishing a specific target for 2010, the CCAG also strongly recommends the early and aggressive implementation of the recommendations in this report, along with a corresponding set of incentives to promote early adoption.

As the reference case forecast in Figure 1 illustrates, Arizona's extraordinary growth in population and economic activity is expected to generate very high percentage growth in carbon emissions compared to other states. Early and aggressive action in Arizona is thus crucial to slowing – and ultimately reversing – the rate of GHG emissions.

Figure 1. 1990-2040 GHG Emissions: Reference Case Forecast, CCAG Goal, and Estimated Cumulative Reductions with CCAG Options



Policy Design:

Not applicable.

Implementation Method(s):

Implementation methods are not applicable to a reduction goal itself, but do apply to the numerous CCAG policy recommendations concerning how the goal is to be achieved, and are detailed under each of those options.

Related Policies/Programs in Place:

No comprehensive, statewide GHG reduction goal is in place in Arizona.

Type(s) of GHG Benefit(s):

Not applicable.

Estimated GHG Savings and Costs per tCO₂e:

Not applicable.

Data Sources, Methods, and Assumptions:

Not applicable.

Key Uncertainties:

Not applicable.

Ancillary Benefits and Costs:

Not applicable.

Feasibility Issues:

None cited.

Status of Group Approval:

Completed.

Level of Group Support:

Unanimous.

Barriers to Consensus:

None cited.

CC-2 Greenhouse Gas Reporting

Policy Description:

Measurement and public reporting of GHG emissions at a statewide, sector, or sub-sector level are important to support tracking and management of emissions. GHG reporting can help sources identify emission reduction opportunities and reduce potential risks associated with possible future GHG mandates by “starting up the learning curve.” Tracking and reporting of GHG emissions will also help in the construction of periodic state GHG inventories.

GHG reporting is a key precursor for sources to participate in voluntary GHG reduction programs, opportunities for recognition, a GHG emission reduction registry, and to secure “baseline protection.” Further, GHG reporting is an opportunity for the State to influence reporting practices throughout the region and nation, and to build consistency with other reporting programs. Subject to consistently rigorous quantification, GHG reporting should not be constrained to particular sectors, sources, or approaches so as to encourage GHG mitigation activities from all quarters.

Policy Design:

The CCAG recommends implementing a reporting mechanism that includes the following key elements:

- Phasing in mandatory GHG reporting by sectors as rigorous, standardized quantification protocols, base data, and tools become available and responsible parties become clear; allowing for voluntary reporting before mandatory reporting applies; allowing the state itself to be a participant, reporting emissions associated with its own activities and the programs it implements.
- Applying to all source types (e.g., combustion, processes, vehicles, etc.) but using common sense regarding de minimis emissions.
- Having a goal of reporting “organization-wide emissions within Arizona” but doing so with greatest possible “granularity” to facilitate baseline protection (e.g., the “rolling up” of facility and field emissions reports in a reporting database would provide organization totals in Arizona).
- Reporting annually on a calendar year basis for all six traditional GHGs and, to the extent possible, black carbon.

- Requiring reporting of direct emissions, phasing in reporting of indirect emissions associated with purchased power and heat, and allowing voluntary reporting of other indirect emissions.
- Maximizing consistency with other state and federal reporting programs.
- Verifying emissions reports through self-certification and ADEQ spot-checks, and adding third-party verification for registry purposes.
- Allowing for appropriate public transparency of reported emissions, and allowing voluntary project-based emissions reporting when properly quantified.

Other specific design elements of an effective GHG reporting program are noted in the ***GHG Reporting Design Options Matrix*** included below.

Implementation Method(s):

- Reporting

Related Policies/Programs in Place:

No comprehensive, statewide GHG emissions reporting program is in place in Arizona.

Type(s) of GHG Benefit(s):

Not applicable.

Estimated GHG Savings and Costs per tCO₂e:

Not applicable.

Data Sources, Methods, and Assumptions:

Not applicable.

Key Uncertainties:

Not applicable.

Ancillary Benefits and Costs:

Not applicable.

Feasibility Issues:

None cited.

Status of Group Approval:

Completed.

Level of Group Support:

Unanimous.

Barriers to Consensus:

None cited.



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Cross Cutting Issues Technical Working Group GHG Reporting Design Options Matrix July 14, 2006

For Reference:

WRI/WBCSD *GHG Protocol's*

Principles for GHG accounting and reporting:

1. Relevance
2. Completeness
3. Consistency
4. Transparency
5. Accuracy
6. Enable other goals

Potential Goals of GHG Reporting:

1. Identifying reduction opportunities
2. Reducing risks (e.g., start learning curve)
3. Tracking GHG emissions, assisting the state in constructing annual inventories
4. Participating in voluntary programs
5. Participating in – or preparing for – mandatory programs
6. Precursor for registry participation
7. Opportunities for recognition
8. Public reporting
9. Consistency with other programs

	Design Element	Options	Design Considerations	TWG Recommendation
1.	Type of Program	<ul style="list-style-type: none"> • Voluntary • Mandatory 	<ul style="list-style-type: none"> • May need or want to constrain sectors and/or sources (e.g., applicability). • Mandatory GHG reporting for major sources is in place in some states (ME, CT, NJ); anticipated soon for several others in Northeast and Far West. 	<ul style="list-style-type: none"> • <u>Mandatory</u> when (a) standard quantification protocols & tools are available for a sector (to avoid differing protocols over multiple jurisdictions); and (b) responsible parties are clear (e.g., Residential/commercial, Transportation). • “Phase in” mandatory reporting by sector, but <u>allow voluntary</u> reporting by other sectors & sources until they are required to report. • The State may also register GHG reductions from programs.
2.	Sectors	<ul style="list-style-type: none"> • All sectors eligible • Limited to certain sectors 	<ul style="list-style-type: none"> • Participation may be limited by availability of quantification methods; may need to “stage” sector participation. • WRI calculation protocols: Stationary combustion, mobile, Electric power, cement, iron & steel, aluminum, pulp & paper, wood products, lime, ammonia, purchased heat or power, others. 	<ul style="list-style-type: none"> • Include <u>all sectors</u>, but only as quantification protocols and data availability enables equally rigorous treatment across sectors (to provide consistency when ultimately linked to a registry). • <u>Phase In</u> sectors as quantification protocols and data become available.

	Design Element	Options	Design Considerations	TWG Recommendation
3.	Sources	<ul style="list-style-type: none"> • All • Stationary combustion emissions • Mobile combustion emissions • Process emissions • Fugitive emissions 	<ul style="list-style-type: none"> • Could limit sources even within sectors, (e.g., via types, size thresholds, etc.). • Broader array promotes inventory building, public information, identification of GHG strategies, etc. 	<ul style="list-style-type: none"> • Reporting should be open to <u>all sources</u>. • As with sectors, “<u>Phase In</u>” mandatory reporting based on availability of: (a) standard quantification protocols; and (b) adequate base data (e.g., for different fuels, etc.) for specific source types. • For mandatory sources, use <u>common sense</u> regarding diminishing returns (e.g., de minimis emissions, cutpoints, etc.).
4.	Organizational Boundary	<ul style="list-style-type: none"> • Entity-wide (e.g., corporation-wide) • Facility • Emissions unit or source point • Other 	<ul style="list-style-type: none"> • Clear definitions needed to avoid double counting where shared ownership exists. • Should strive to have design be consistent with possible future directions (e.g., mandatory reporting would not be enforceable above the facility level). • Combinations are possible (e.g., finer resolution aggregated to a greater whole). 	<ul style="list-style-type: none"> • Reporting goal: “<u>Organization-wide emissions within AZ</u>” with greatest possible “granularity” to facilitate baseline protection. • This generally equates to emissions from in-state facilities, but not all sources may be “facilities.” • “Rolled up” total of “facility” and “field” emissions reports in a reporting database would provide total “organization-wide emissions in AZ.”

	Design Element	Options	Design Considerations	TWG Recommendation
5.	Reporting Period	<ul style="list-style-type: none"> • Annual <ul style="list-style-type: none"> - Calendar - Fiscal • Other 	<ul style="list-style-type: none"> • Should strive for consistency with other reporting programs. 	<ul style="list-style-type: none"> • <u>Annual</u> emissions on a <u>calendar</u> year basis.
6.	Greenhouse Gases Included	<ul style="list-style-type: none"> • Six "Kyoto gases" (CO₂, HFCs, CH₄, N₂O, PFCs, SF₆) • Black Carbon (BC) 	<ul style="list-style-type: none"> • Should strive for consistency with other reporting programs. • Broader array promotes inventory building, public information, identification of GHG strategies, etc. • No single, clear global warming potential (GWP) exists for BC. 	<ul style="list-style-type: none"> • Include <u>all six "Kyoto Gases"</u> (emitted above de minimis levels). • Include, or provide a placeholder for, reporting Black Carbon emissions as well.

	Design Element	Options	Design Considerations	TWG Recommendation
7.	Scope of Emissions Covered	<ul style="list-style-type: none"> • Direct - “Scope 1” • Indirect - “Scope 2” - Indirect from purchased Heat & Electricity - “Scope 3” - other indirect (e.g., outsourced activities, employee travel, etc.) • Both 	<ul style="list-style-type: none"> • May need or want to “stage” coverage (e.g., start small & expand). • Direct emissions are most like current reporting requirements, but may omit GHG reduction opportunities or encourage direct-indirect trade-offs. • For many entities, most GHG emissions are from indirect emissions sources. 	<ul style="list-style-type: none"> • Goal: Greatest detail and greatest consistency, applied with common sense (e.g., to emissions above de minimis levels). • Require reporting of <u>direct “Scope 1” emissions</u> ASAP. • “<u>Phase In</u>” required reporting of <u>indirect “Scope 2”</u> emissions, but report them separately for greater transparency. • <u>Allow voluntary</u> reporting of “<u>Scope 3</u>”; phase it in if/when similarly rigorous protocols exist.
8.	Emissions Quantification & Monitoring	<ul style="list-style-type: none"> • Calculation methods & tools • Direct measurement (e.g., CEMs, Stack Testing) 	<ul style="list-style-type: none"> • Should strive to use current best practice methods, such as <i>GHG Protocol</i> calculation tools, and to have consistency with other reporting programs. • Some “other” or “home grown” approaches may be necessary when the <i>GHG Protocol</i> is silent (e.g., Flashing emissions; IPIECA, API’s SANGEA). 	<ul style="list-style-type: none"> • Develop a “<u>Hierarchy of Consistency</u>,” whereby quantification protocols are applied in a priority order (e.g., EPA, IPCC, WRI/WBCSD, IPIECA/API, etc.). • Maximize <u>consistency with existing</u> reporting requirements (e.g., CO₂ reporting for Acid Rain sources should echo current CO₂ reporting to EPA).

	Design Element	Options	Design Considerations	TWG Recommendation
9.	Verification	<ul style="list-style-type: none"> state verification Third-party verification Self-certification 	<ul style="list-style-type: none"> If mandatory, the State may be able to use current verification procedures for criteria pollutants. CCAR requires third-party verification. 	<ul style="list-style-type: none"> For reporting, allow "<u>Self-Certification</u>," and have ADEQ do <u>spot inspections</u>. For ultimate Registry purposes, have <u>third-party verification</u>.
10.	Public Access & Reports	<ul style="list-style-type: none"> Internet access and/or Online reports Paper reports Both 	<ul style="list-style-type: none"> "Confidential Business Information" (CBI) concerns 	<ul style="list-style-type: none"> Allow sources to <u>report</u> GHG emissions <u>electronically</u>. Provide electronic public access to GHG emissions reporting data that is "rolled up" to a level such that CBI is reasonably protected.
11.	Project Level Reporting or "Offsets"	<ul style="list-style-type: none"> Yes/No Constrain 	<ul style="list-style-type: none"> WRI: Raises quantification, baseline, "additionality," secondary effects, reversibility, and double-counting issues. Location of co-benefits achieved. May be most useful when there is an externally-imposed constraint (e.g., a "Cap"). 	<ul style="list-style-type: none"> Primarily useful as a registry function. Requires accepted project-based quantification tools & protocols (now starting to arrive; e.g., WRI/WBCSD). Allow for voluntary reporting of properly quantified mitigation projects.

CC-3 Greenhouse Gas Registry

Policy Description:

A GHG registry refers to the measurement and recording of GHG emissions reductions at a macro- or micro-scale level in a central repository with a “transaction ledger” capacity. A GHG registry can support tracking, management, and “ownership” of emission reductions as well as encourage GHG reductions, enable potential recognition, provide baseline protection, and/or crediting of actions by implementing programs and parties in relation to possible emissions reduction goals. Further, it can provide a mechanism for regional, multi-state, and cross-border cooperation. Subject to consistently rigorous quantification, registration of GHG reductions should not be constrained to particular sectors, sources, or approaches in order to encourage GHG mitigation activities from all quarters.

Policy Design:

The CCAG recommends that the State implement a registry mechanism with the following key elements:

- Geographic applicability at least at the statewide level and as broadly (i.e., regionally or nationally) as possible.
- Allowing sources to start as far back chronologically as good data exists, as affirmed by third-party verification, and allowing registration of project-based reductions or “offsets” that are equally rigorously quantified.
- Incorporating adequate safeguards to ensure that reductions aren’t double-counted by multiple registry participants; providing appropriate transparency; and allowing the State itself to be a participant, registering GHG reductions associated with its programs, direct activities, or efforts.
- Striving for maximum consistency with other State, regional, and/or national efforts; greatest flexibility as GHG mitigation approaches evolve; and providing guidance to assist participants.

Other specific design elements of an effective GHG registry program are noted in the *GHG Registry Design Options Matrix* included below.

Implementation Method(s):

- Registry

Related Policies/Programs in Place:

No comprehensive, State or regional GHG registry is currently in place for Arizona.

Type(s) of GHG Benefit(s):

Not applicable.

Estimated GHG Savings and Costs per tCO₂e:

Not applicable.

Data Sources, Methods, and Assumptions:

Not applicable.

Key Uncertainties:

Not applicable.

Ancillary Benefits and Costs:

Not applicable.

Feasibility Issues:

None cited.

Status of Group Approval:

Completed.

Level of Group Support:

Unanimous.

Barriers to Consensus:

None cited.



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Cross-Cutting Issues Technical Working Group GHG Registry Design Options Matrix

July 14, 2006

Notes:

- Builds upon GHG Reporting Design Options Matrix
- Some Reporting preferences could be outweighed by Registry preferences (e.g., if a regional registry has different specifications).

Potential Goals of GHG Registry:

1. Recording of GHG reductions (vs. emissions)
2. A central, independent repository for credible info about emissions activities
3. A "transaction ledger" – providing data management & accounting critical for trading (with or without a cap)
4. "Baseline protection" – enabling early action current or future credit for trading
5. An incentive to track & manage emissions, seek productivity and energy efficiency gains, accelerate learning curve regarding competitiveness & carbon markets
6. Enhance public recognition and demonstrate corporate citizenship
7. Possible vehicle for regional, multi-state, & cross-border cooperation

	Design Element	Options	Design Considerations	TWG Recommendation
1.	Key Design Criteria (beyond <i>GHG Reporting Design Options Matrix</i>)			
	Define geographical boundaries	<ul style="list-style-type: none"> • Arizona • Regional (or broader) 	<ul style="list-style-type: none"> • Span of control • Cost, economies of scale, & broader = better? 	<ul style="list-style-type: none"> • Statewide at least, but as broad as possible, consistent with best practices • WRAP region may be possible
	Verification	<ul style="list-style-type: none"> • State verification • Third-party verification 	<ul style="list-style-type: none"> • See <i>GHG Reporting Design Options Matrix</i> 	<ul style="list-style-type: none"> • Third-party verification
	Base Year	<ul style="list-style-type: none"> • Single specified year • Single entity-chosen year • Average of multiple years • Adjustment rules? 	<ul style="list-style-type: none"> • Flexibility vs. Simplicity • Must have good data for Base Year 	<ul style="list-style-type: none"> • Unless otherwise required for a specific purpose, allow entity to choose base year. (This allows entities to go back as far as good data exists.)
	Project-level submittals	<ul style="list-style-type: none"> • Yes / No / Constrain 	<ul style="list-style-type: none"> • Against what baseline? • Additionality issues (what would have happened anyway?) 	<ul style="list-style-type: none"> • Yes, keep as open and flexible as possible, but require third-party verification against solid quantification protocols.
	"Offsets"	<ul style="list-style-type: none"> • Yes / Some / No 	<ul style="list-style-type: none"> • Co-benefits location? • Nature / character? 	<ul style="list-style-type: none"> • Note: Offsets assume a GHG reduction obligation, and then work in concert with it. • Yes; door should be open to spur others to act and possible regional action.
	Start Date	<ul style="list-style-type: none"> • 	<ul style="list-style-type: none"> • Establish a "to be in operation" date? 	<ul style="list-style-type: none"> • Mandatory reporting starting in 2008; registry to follow ASAP for sectors/sources as soon as solid quantification protocols exist.
	Ownership	<ul style="list-style-type: none"> • 	<ul style="list-style-type: none"> • Risk of double-counting 	<ul style="list-style-type: none"> • Must have adequate safeguards and protocols to ensure no double counting. • State is a valid "owner" for GHG reductions achieved as a result of state mandates.

	Design Element	Options	Design Considerations	TWG Recommendation
	Transparency	•	•	• Must have adequate transparency to ensure quality.
	Others?	•	•	• Strive for consistency and compatibility with other similar efforts (as done with Renewable Energy Certificates (RECs)).
2.	Technical Issues			
	Treatment of minority ownership	<ul style="list-style-type: none"> • Equity share • Financial control 	<ul style="list-style-type: none"> • WRI-WBCSD <i>GHG Protocol</i>¹ covers both 	<ul style="list-style-type: none"> • Comport with <i>GHG Protocol</i>.
	Merger & acquisition issues	<ul style="list-style-type: none"> • Recalculate base year emissions in event of acquisition or divestment 	<ul style="list-style-type: none"> • <i>GHG Protocol</i> covers 	<ul style="list-style-type: none"> • Comport with <i>GHG Protocol</i>.
	Quality Assurance; Uncertainty Analysis	<ul style="list-style-type: none"> • Disclose areas of potential uncertainty 	<ul style="list-style-type: none"> • <i>GHG Protocol</i> covers 	<ul style="list-style-type: none"> • Comport with <i>GHG Protocol</i>.
	Regulatory guidance (Protocols, guidance documents, etc.)	<ul style="list-style-type: none"> • Prepare & provide to interested parties 	•	<ul style="list-style-type: none"> • Arizona should prepare & offer reasonable guidance and tools to encourage participation.
	Data flow; filing methods, etc.	<ul style="list-style-type: none"> • State agency, third-party, etc. 	<ul style="list-style-type: none"> • Confidential business information (CBI), legal authority, etc. 	<ul style="list-style-type: none"> • Retain state authority, ensure adequate data protection, and use web filing to the greatest extent possible.

¹ <http://www.ghgprotocol.org/plugins/GHGDOC/details.asp?type=DocDet&ObjectId=MTM3NTc>

	Design Element	Options	Design Considerations	TWG Recommendation
3.	Ancillary, Administrative, & Operational Issues			
	Location (Agency)	<ul style="list-style-type: none"> • ADEQ • Other? 	<ul style="list-style-type: none"> • Regional potential 	<ul style="list-style-type: none"> • Within Arizona, ADEQ is probably the best place to house the registry (but adequate resources will be necessary). • If regional, then TDB.
	Software; Web Interface, etc.	<ul style="list-style-type: none"> • Arizona-specific • CCAR, RGGR, CCX, ERT, EATS? • Other? 	<ul style="list-style-type: none"> • Multiple needs (emissions inventory, allowances, mandatory, voluntary, etc.) • Rapidly changing “state-of-the-art” 	<ul style="list-style-type: none"> • Strive for: (a) consistency with other registry efforts; (b) flexibility to serve both mandatory and voluntary participants & sectors; (c) ability to change as registries evolve; and (d) maximum implementation via web capabilities.
	Cost	<ul style="list-style-type: none"> • Transaction fee • Publicly supported? • Other? 	<ul style="list-style-type: none"> • Development costs • Ongoing operating costs 	<ul style="list-style-type: none"> • Costs should be borne principally by participants.
	Oversight & Management	<ul style="list-style-type: none"> • ADEQ • Publicly appointed board • Other? 	<ul style="list-style-type: none"> • 	<ul style="list-style-type: none"> • Either ADEQ or a public board OK; but must maintain current positive momentum. • If regional, then TDB.
	Reporting of Results; Recognition	<ul style="list-style-type: none"> • 	<ul style="list-style-type: none"> • 	<ul style="list-style-type: none"> • Registry should do outreach with results; provide recognition for participants.

CC-4 State Climate Action Public Education and Outreach

Policy Description:

Public education and outreach is vitally important to foster a broad awareness of climate change issues and effects (including co-benefits, such as clean air and public health) among the State's citizens and to engage them in actions to reduce GHG emissions. Such efforts should seek to integrate with and build upon existing outreach efforts involving climate change and related issues in the State. Ultimately, public education and outreach will be the foundation for the long-term success of all the mitigation actions proposed by the CCAG as well as those which may evolve in the future.

Policy Design:

The CCAG recommends that the State undertake concerted climate change education and outreach activities directed toward, but not limited to, the following audiences:

- Policymakers (e.g., legislators, regulators, executive branch, agencies) – because implementation of climate actions hinges on policymakers' approval.
- Younger Generations – by integrating climate change into educational curricula, post-secondary degree programs, and professional licensing programs.
- Community Leaders and Community-Based Organizations (e.g., businesses, institutions, municipalities, service clubs, social & affinity groups, non-governmental organizations, etc.) – in order to recognize leadership; share success stories and role models; and expand climate involvement and participation within civic society.
- The General Public – to increase awareness and engage citizens in climate actions in their personal and professional lives.

Suggestions for specific activities by audience are noted in the *Education Options Matrix* included below.

Implementation Method(s):

- Information and education

Related Policies/Programs in Place:

Several public and private efforts have occurred to raise public consciousness of climate change causes and impacts in Arizona, but no comprehensive overall State climate action public education and outreach program is in place in Arizona.

Type(s) of GHG Benefit(s):

Not applicable.

Estimated GHG Savings and Costs per tCO₂e:

Not applicable.

Data Sources, Methods, and Assumptions:

Not applicable.

Key Uncertainties:

Not applicable.

Ancillary Benefits and Costs:

Not applicable.

Feasibility Issues:

None cited.

Status of Group Approval:

Completed.

Level of Group Support:

Unanimous.

Barriers to Consensus:

None cited.



www.azclimatechange.us

Cross-Cutting Issues Technical Working Group Education Options Matrix July 14, 2006

Goals of Public Education & Outreach:

1. Overarching goal: Promote awareness about the impacts of climate change, solutions, and co-benefits of action.
2. Education provides a foundation essential for all climate action.
3. Others?

General Approach:

1. "Walk the Talk" in terms of the State's own education and outreach activities, and reach out to the four key audiences below:
 - a. Policymakers (legislators, executive, agencies, regulators, etc.)
 - b. Community Leaders and Organizations
 - c. Younger Generations
 - d. The General Public

	Measures & Strategies	Tasks & Examples	Notes & Elaborations
	State Government Actions The State should lead by example (i.e., “walk the talk”) regarding education and outreach.		
	Engage higher education instructors in conducting on-going research and communication with students.	<ul style="list-style-type: none"> • First task: Identify already existing resources & programs. • Identify additional needs and potential funding sources. 	<ul style="list-style-type: none"> • A “two-way street”: education officials bring research & info to the body, act as outreach arm for reaching students and others.
	Educate State employees on an on-going basis about climate change and practices to reduce GHG emissions.	<ul style="list-style-type: none"> • 	<ul style="list-style-type: none"> •
	Target Audience: Policymakers (legislators, regulators, executive branch, agencies) implementation of climate actions hinges on policymakers’ approval.		
	Educate policy makers on climate change & CCAG recommendations to promote acceptance and implementation.	<ul style="list-style-type: none"> • Conduct regular legislative briefings. • Identify & offer agency-specific info on climate issues & opportunities. 	<ul style="list-style-type: none"> • Use input derived from policymaker interactions to develop new mitigation measures going forward.
	Provide continuing outreach & assistance to Governor’s office, legislature, and implementing agencies on a regular basis.	<ul style="list-style-type: none"> • Educate press liaisons from agencies, etc. • Provide regular press releases or updates on reductions, events, etc. 	<ul style="list-style-type: none"> •

	Measures & Strategies	Tasks & Examples	Notes & Elaborations
	Target Audience: Younger Generations Integrate climate change into educational curricula, post-secondary degree programs, and professional Licensing.		
	Integrate “best practices” into public school design & construction to educate students (and parents) first-hand in their communities & colleges (i.e., walk the talk).	<ul style="list-style-type: none"> Investigate whether AZ could provide bonding for school districts to fund energy efficient construction. Include in-building signage & displays to explicitly point out efficiency aspects built in to public buildings. 	•
	Promote research into climate change and solutions at State universities.	•	•
	Integrate climate change into existing and/or new educational competition programs (e.g., Envirothon, science fairs, etc.).	•	•
	Work with science centers, zoos, and museums to include a climate science focus appropriate to their core mission.	<ul style="list-style-type: none"> A key area for an Outreach Coordinator to focus on. 	<ul style="list-style-type: none"> Examples exist in other regions (e.g., Clean Air-Cool Planet science center initiative). Could provide speaking opportunities for teachers; have college professors host forums for high school students on weekends, etc.
	Introduce core competencies on climate change into professional licensing programs (e.g., energy efficiency in building design and construction, use of recycled materials, etc.).	•	•

	Measures & Strategies	Tasks & Examples	Notes & Elaborations
	Target Audience: Community Leaders & Community-Based Organizations (Businesses, institutions, municipalities, service clubs, social & affinity groups, NGOs, etc.) Recognize leadership; share success stories & role models; expand involvement and participation within civic society.		
	Identify individual community leaders who are acting effectively on climate change; showcase and share their successes.	<ul style="list-style-type: none"> • Enlist/encourage them to be a de facto "Speakers' Bureau." • Host discussion forums featuring them. 	<ul style="list-style-type: none"> • Include all walks of work & life (retail, services, manufacturing, health care, auto, facilities, etc.) • Put examples, guidance, links, contacts, etc. on the web clearinghouse.
	Identify individual community leaders who have not yet acted on climate change and make a special effort to educate them.	<ul style="list-style-type: none"> • 	<ul style="list-style-type: none"> •
	Engage associations and participate in their meetings periodically to educate them about climate change and sector-specific mitigation actions.	<ul style="list-style-type: none"> • 	<ul style="list-style-type: none"> •
	Develop statewide recognition program(s) for community leaders and entities.	<ul style="list-style-type: none"> • 	<ul style="list-style-type: none"> •
	Organize & host outreach events that focus on leading by example, sharing how-to, co-benefits, illuminating financial risks and opportunities, etc.	<ul style="list-style-type: none"> • 	<ul style="list-style-type: none"> •

	Measures & Strategies	Tasks & Examples	Notes & Elaborations
	Identify, assist, and leverage community-based organizations with expertise or interest in climate-related issues.	<ul style="list-style-type: none"> • Faith community • Service clubs; sportsmen; recreational/hobbyist groups • Metropolitan planning organizations • environmental, social, & civic advocacy organizations 	•
	Work with community-based organizations to identify & build upon climate issues related to their core mission.	<ul style="list-style-type: none"> • Public health vs. new disease vectors? • Low-income vs additional stressors? 	•
	Support and facilitate outreach and education within community-based organizations regarding climate change issues and actions.	<ul style="list-style-type: none"> • Provide content for websites, newsletters, ListServes? • Coach & assist community Outreach coordinators? 	•
	Encourage municipal leaders to join ICLEI's ² Cities for Climate Protection program and/or the Mayors Climate Protection Agreement ³ .	•	•
Target Audience: General Public Increase awareness and engage citizens in climate actions in their personal and professional lives.			
	Work with state broadcasters and print media associations to develop & run climate change articles and public service announcements.	•	•

² ICLEI is the International Council for Local Environmental Initiatives. See www.iclei.org.

³ See <http://www.ci.seattle.wa.us/mayor/climate/>.

	Measures & Strategies	Tasks & Examples	Notes & Elaborations
	Keep a focus on climate change issues and actions through regular public comments by Governor and other public leaders.	•	•
	Develop and use a state-based “brand” on climate awareness and action.	•	•
	Develop & maintain a State climate change website for the public; maintain a web-based clearinghouse for climate change information and education resources.	• Link to scientific developments--what you can do, how you can help, what the state is doing, etc.	• Post annual progress reports on commitments, plan implementation, etc.
	Work with existing company outreach efforts to customers (e.g., utilities) to enhance awareness of climate change issues & actions.	<ul style="list-style-type: none"> • Retail advertising and/or “bill stuffers” • Environmental disclosure of electricity fuel mix/emissions; recycled content, etc. • Product messages (e.g., yogurt labels) 	•
	Develop and provide concrete information on co-benefits to entities to use in boosting their climate efforts.	•	•
	Undertake a concerted planning effort to identify and address climate adaptation issues & needs in the State.	<ul style="list-style-type: none"> • ADEQ lead? • Multi-stakeholders? 	•

CC-5 State Climate Change Adaptation Strategy

Policy Description:

Because of the build-up in the atmosphere of greenhouse gases that already has occurred, Arizona will experience the effects of climate change for years to come, even if immediate action is taken to reduce future GHG emissions. As such, it is essential that the state develop a strategy to identify and manage the projected impacts of on-going climate change.

Policy Design:

While taking action to reduce GHG emissions in Arizona, the CCAG recommends that a comprehensive state climate change adaptation strategy be developed and implemented. The strategy should include time- and program-based goals, characterization of the potential risks and costs of inaction, and the potential costs, benefits, and co-benefits associated with specific policy and program actions and time periods. Further, the strategy should outline actions to be taken to respond to existing climate change impacts and to coordinate these actions with response plans and efforts that are underway or may be contemplated at other agencies or organizations or through other initiatives. Such impacts include the concerns outlined by the Governor in her February 2005 Executive Order (e.g., prolonged drought, severe forest fires, warmer temperatures, increased snowmelt, and reduced snow pack) as well as other serious issues, including risks to public health.

The Governor may wish to consider appointing a task force or advisory group to develop recommendations for the state climate change adaptation strategy. Moreover, the Governor should direct state agencies and other appropriate institutions to identify and characterize potential current and future risks in Arizona to human, natural and economic systems, including potential risks to water resources, temperature sensitive populations and systems, energy systems, transportation systems, vital infrastructure and public facilities, and natural lands (e.g., forests, rangelands, and farmland).

Adaptation measures that also help mitigate GHG emissions should be given priority in the state climate change adaptation strategy, particularly water use conservation and efficiency, forest and agriculture conservation and management, energy production and use, facility siting and management (including residential), infrastructure development, and efficient transportation and land use systems. These actions should be linked to implementation of other specific recommendations of this Climate Change Advisory Group to the greatest extent possible.

Implementation Method(s):

- Information and education

Related Policies/Programs in Place:

No comprehensive State climate change adaptation strategy or plan is in place or underway in Arizona.

Type(s) of GHG Benefit(s):

Not applicable.

Estimated GHG Savings and Costs per tCO₂e:

Not applicable.

Data Sources, Methods, and Assumptions:

Not applicable.

Key Uncertainties:

Not applicable.

Ancillary Benefits and Costs:

Not applicable.

Feasibility Issues:

None cited.

Status of Group Approval:

Completed.

Level of Group Support:

Unanimous.

Barriers to Consensus:

None cited.

Implementation Method(s):

- Information and education

Related Policies/Programs in Place:

No comprehensive State climate change adaptation strategy or plan is in place or underway in Arizona.

Type(s) of GHG Benefit(s):

Not applicable.

Estimated GHG Savings and Costs per tCO₂e:

Not applicable.

Data Sources, Methods, and Assumptions:

Not applicable.

Key Uncertainties:

Not applicable.

Ancillary Benefits and Costs:

Not applicable.

Feasibility Issues:

None cited.

Status of Group Approval:

Completed.

Level of Group Support:

Unanimous.

Barriers to Consensus:

None cited.



**APPENDIX G: RCI, AND WASTE -
DETAILED POLICY DESCRIPTION/ANALYSIS**

Overview

The Residential, Commercial and Industrial (RCI) sector includes emissions and mitigation opportunities related to electricity use by residential, commercial, and industrial consumers, as well as to the on-site combustion of natural gas, oil, and coal, the release of CO₂ and fluorinated gases (HFCs, PFCs) during industrial processes, and the leakage of HFCs from refrigeration and related equipment. The CCAG recommends a set of 13 policy options for the RCI sector that offer the potential for major GHG emissions reductions from the reference projection. As summarized in the table below, these 13 policy recommendations could lead to net emissions savings from reference case projections of 31.1 MMtCO₂e per year by 2020 and cumulative savings of 222 MMtCO₂e from 2007 through 2020. The weighted average cost of saved carbon from the policy options for which quantitative estimates of both costs and savings were prepared was minus \$30 per metric ton of CO₂ equivalent, meaning that there is a net savings to the Arizona economy in implementing these options.

For each recommended RCI policy, this technical appendix provides details on design, analysis, quantification of impacts, and other related information. (See Appendix E for explanation of the general methods applied across all groups). When these RCI policies were quantified, some policies were considered to have overlapping impact. To avoid double-counting of GHG emission reductions, the following steps were taken to arrive at the estimates of “overlaps” between policies that are reported in the last of the three tables shown below (“Adjustment for Estimated Overlap Between RCI Options”):

- RCI-2, State Lead by Example, has two elements, building (not appliance) energy efficiency improvements, and green power purchasing. If state agencies are eligible for RCI-1 programs, then there may be some overlap between RCI-2 and RCI-1. The Estimated overlap shown below in the table below assumes 50% overlap with RCI-1 from RCI-2 energy efficiency improvements.
- RCI-3 has no overlap with RCI-1, since savings from appliance efficiency in RCI-1 would be over and above standards.
- RCI-4, building standards for Smart Growth, would have no overlap with RCI-1, as RCI-1 would be over and above standards. RCI-4 would also have no significant overlap with RCI-2, as RCI-2 would provide savings beyond codes.
- RCI-5, “Beyond Code” Building Design Incentives and Programs for Smart Growth may have some overlap with RCI-1, and also with RCI-2, although RCI-5 is focused on building energy measures. This overlap is estimated roughly at one-third, or 33% of total RCI-5 savings.
- RCI-6, Distributed Generation/Combined Heat and Power, has no significant overlap with other RCI policies (note that the estimate of RCI-2 impacts does not quantify the contribution of CHP to RCI-2 savings).
- RCI-7, Distributed Generation/Renewable Energy Applications, has no significant overlap with other RCI policies.
- RCI-8, Electricity Pricing Strategies, may have some overlap with RCI-1 to the extent that higher upper-tier tariffs induce consumers to take advantage of DSM programs in greater numbers, but DSM programs are not allowed to expand to meet demand. On the other

hand, however, stronger market forces might allow DSM programs to operate with lower incentives, yielding higher savings per dollar of program cost and allowing more consumers to be served by DSM programs. It is assumed that 50% of estimated savings in RCI-8 is due to conservation (not energy efficiency improvement) as a result of higher-tier tariffs, and that thus only the other 50% of RCI-8 savings is subject to an overlap of 50% maximum with RCI-1, yielding the overlap shown in the table below.

- RCI-10, Demand-Side Fuel Switching, may overlap with RCI-1 to the extent that Solar Water Heat (SWH) is included in RCI-1. Overlap of RCI-10 with RCI-1 is calculated assuming an overlap of 50% of SWH savings would yield the overlap shown above.
- In RCI-12, quantitative estimates of impacts focus mostly on reduction in manufacturing energy and materials requirements due to reductions in materials requirements resulting from mixed paper recycling. As most of Arizona's paper comes from outside Arizona, overlap of RCI-12 with industrial efficiency measures in RCI-1 or with other RCI options will be very small, thus no overlap is assumed.
- In RCI-13 Water Use and Wastewater Management, pump efficiency improvement elements of RCI-13 would likely overlap to a degree with the industrial (and other sector) electric motor and drives savings in RCI-1. As the quantification of RCI-13 focuses on the reduction of water use, rather than pumping efficiency improvements, it is assumed that RCI-13 has no significant overlap with RCI-1.

Additional Detail on the Analyses of Options Benefits and Costs for Policies Described Below

The "Policy Descriptions" provided below (starting on page G-6 of this Appendix) for each of the 13 RCI Mitigation Policy Options recommended by the CCAG include brief summaries, if applicable, of the methods and data used to estimate the emissions reduction potential, costs, and/or other benefits of the Options. Additional details of the estimates of costs and benefits of Policy options, including notes on assumptions and data used, and intermediate results, can be found in the document [Residential Commercial and Industrial Technical Working Group: Detailed Description of Data Sources, Methods, and Assumptions for Analysis of Policy Options](#), which can be accessed through the "Residential, Commercial, and Industrial TWG" section of the <http://www.azclimatechange.us/documents.cfm> web page.

**Residential, Commercial and Industrial Technical Work Group
Summary List of Policy Options**

#	Policy Name	GHG Savings (MMtCO _{2e})	Cost-Effectiveness (\$/tCO _{2e})	Level of CCAG Support
RCI-1	Demand-Side Efficiency Goals, Funds, Incentives, and Programs	2010: 3.1 2020: 15.1	- \$36	Unanimous
RCI-2	State Leadership Programs	2010: 0.04 2020: 0.4	- \$4	Unanimous
RCI-3	Appliance Standards	2010: 0.2 2020: 1.0	- \$66	Unanimous
RCI-4	Building Standards/Codes for Smart Growth	2010: 0.3 2020: 2.2	- \$18	Unanimous
RCI-5	"Beyond Code" Building Design Incentives and Programs for Smart Growth	2010: 0.2 2020: 3.1	- \$17	Unanimous
RCI-6	Distributed Generation/Combined Heat and Power	2010: 0.4 2020: 2.7	- \$25	Unanimous
RCI-7	Distributed Generation/Renewable Energy Applications	2010: 0.1 2020: 2.1	\$31	Unanimous
RCI-8	Electricity Pricing Strategies	2010: 1.1 2020: 1.5	-\$63	Unanimous
RCI-9	Mitigating High Global Warming Potential (GWP) Gas Emissions (HFC, PFC)	Not Quantified		Unanimous
RCI-10	Demand-Side Fuel Switching	2010: 0.1 2020: 1.2	Not estimated	Unanimous
RCI-11	Industrial Sector GHG Emissions Trading or Commitments	See ES-4	See ES-4	Unanimous
RCI-12	Solid Waste Management	2010: 2.2 2020: 3.7	Not estimated	Unanimous
RCI-13	Water Use and Wastewater Management	2010: 0.2 2020: 0.8	Not estimated	Unanimous

Summary Results and Totals for RCI Policy Options

	Policy Name	GHG Reductions (MMtCO _{2e})		Cost-Eff (\$/tCO _{2e})	NPV 2006-2020 (\$million)	Cumulative Emissions Reductions (MMt CO _{2e} , 2006-2020)
		2010	2020			
RCI-1	Efficiency Goals, Funds, Incentives, and Programs	3.1	15.1	-\$36	-\$3,671	103
RCI-2	State Leadership Programs	0.04	0.4	-\$4	-\$12	3
RCI-3	Appliance Standards	0.2	1.0	-\$66	-\$453	7
RCI-4	Building Standards/Codes for Smart Growth	0.3	2.2	-\$18	-\$243	14
RCI-5	"Beyond Code" Building Design for Smart Growth	0.2	3.1	-\$17	-\$59	18
RCI-6	DG/Combined Heat and Power	0.4	2.7	-\$25	-\$395	16
RCI-7	DG/Renewable Energy Applications	0.1	2.1	\$31	\$293	10
RCI-8	Electricity Pricing Strategies	1.1	1.5	-\$63	-\$985	16
RCI-9	Mitigating High (GWP) Gas Emissions	<i>Not Quantified</i>				
RCI-10	Demand-Side Fuel Switching	0.1	1.2	<i>Not Estimated</i>		7
RCI-11	Industrial Sector GHG Emissions Trading	<i>Not Quantified</i>				
RCI-12	Solid Waste Management	2.2	3.7	<i>Not Estimated</i>		36
RCI-13	Water Use and Wastewater Management	0.2	0.8	<i>Not Estimated</i>		6
	Total Gross Savings	7.9	32.9	-\$30	-\$5,525	236

Adjustment for Estimated Overlap Between RCI Options	GHG Reductions (MMtCO _{2e})		NPV 2006-2020 (\$million)	Cumulative Emissions Reductions (MMt CO _{2e} , 2006-2020)
	2010	2020		
RCI-2 Overlap with RCI-1	0.0	0.1	-\$4	1
RCI-3, Overlap with RCI-1	0.0	0.0	\$0	0
RCI-4, Overlap with RCI-1 and RCI-2	0.0	0.0	\$0	0
RCI-5, Overlap with RCI-1 and RCI-2	0.1	1.0	-\$19	6
RCI-6 Overlap with Other Quantified Policies	0.0	0.0	\$0	0
RCI-7 Overlap with Other Quantified Policies	0.0	0.0	\$0	0
RCI-8 Overlap with RCI-1	0.3	0.4	-\$246	4
RCI-10 Overlap with RCI-1	0.0	0.4	\$0	2
RCI-12, -13 Overlap with RCI-1	0.0	0.0	\$0	0
Total Estimated Overlap Among RCI Policies	0.4	1.9	-\$269	13
Total Savings Net of Overlaps	7.5	31.1	-\$5,255	222

The energy savings (measured in GWh of electricity, Billion BTU of natural gas, and Billion BTU of other fuels, and measured in dollars) associated with RCI policy recommendations are presented in the table below.

ENERGY SAVINGS FROM RCI OPTIONS

		NPV 2006-2020, million 2005 dollars)											
	Policy Name	Estimated Fuel Cost (negative values denote net savings)				Incremental Non-fuel Costs of Option	Net Cost of Option	2020			Cumulative Fuel Savings (2006 - 2020)		
		Electricity	Natural Gas	Other Fuels	Total			Electricity (GWh)	Natural Gas (Billion Btu)	Other Fuels (Billion Btu)	Electricity (GWh)	Natural Gas (Billion Btu)	Other Fuels (Billion Btu)
RCI-1	Efficiency Goals, Funds, Incentives, and Programs	(\$5,436)	(\$70)	\$0	(\$5,506)	\$1,835	(\$3,671)	19,339	4,388	-	136,444	14,930	-
RCI-2	State Leadership Programs	(\$80)	(\$8)	\$0	(\$88)	\$80	(\$8)	335	0	-	2,050	1,623	-
RCI-3	Appliance Standards	(\$405)	(\$8)	\$0	(\$413)	(\$41)	(\$453)	1,234	261	-	8,949	1,306	-
RCI-4	Building Standards/Codes for Smart Growth	(\$594)	(\$47)	\$0	(\$641)	\$398	(\$243)	2,696	1,852	-	17,342	9,185	-
RCI-5	"Beyond Code" Building Design for Smart Growth	(\$492)	(\$40)	\$0	(\$532)	\$492	(\$40)	2,560	1,902	-	15,512	7,949	-
RCI-6	DG/Combined Heat and Power	(\$1,164)	\$603	(\$2)	(\$563)	\$169	(\$395)	4,585	-21,445	(4,429)	25,999	(132,169)	(23,502)
RCI-7	DG/Renewable Energy Applications	(\$495)	\$0	\$0	(\$495)	\$788	\$293	2,440	-	(4,664)	11,490	-	(26,739)
RCI-8	Electricity Pricing Strategies	(\$738)	\$0	\$0	(\$738)	\$0	(\$738)	1,313	-	-	14,086	-	-
RCI-9	Mitigating High (GWP) Gas Emissions	<i>Not Quantified</i>											
RCI-10	Demand-Side Fuel Switching	<i>Not Quantified</i>											
RCI-11	Industrial Sector GHG Emissions Trading	<i>Not Quantified</i>											
RCI-12	Solid Waste Management	<i>Not Quantified in Terms of Fuel Savings</i>											
RCI-13	Water Use and Wastewater Management	<i>Not Quantified in Terms of Fuel Savings</i>											
SUM OF QUANTIFIED VALUES		(\$9,405)	\$430	(\$2)	(\$8,977)	\$3,721	(\$5,255)	34,502	(13,043)	(9,093)	231,872	(97,176)	(50,241)

RCI-1 Demand-Side Efficiency Goals, Funds, Incentives, and Programs

Policy Description:

This policy option considers energy savings goals for electricity and natural gas, and the policy, program, and funding mechanisms that might be used to achieve these goals. These are intended to work in tandem with other strategies under consideration by the RCI and ES TWGs.

Policy Design:

This option contains three principal elements – goals, funding and implementation mechanisms, and planning -- along with several supporting activities, as described below.

Goals: Suggested energy savings goals are as follows:

- Electricity (energy savings target): 5% savings by 2010, 15% savings by 2020. These savings targets would be for electricity sales (MWh), and would reflect cumulative (from today), verified savings as a percentage of those years' (projected) loads, starting from the time of policy adoption.
- Natural Gas (utility spending target): ramp up to spending 1.5% of gas utility revenues by 2015.¹ Further decisions by the ACC to decouple gas sales and revenues are viewed as central to achieving this target².

Implementation Mechanisms:

Several policy options are commonly used to overcome market, administrative, and institutional barriers to cost-effective efficiency improvements. These options can include public benefit charges, tariff riders, enabling legislation, and/or regulatory directives. They can also work together with state and national tax incentives for energy efficient equipment. Indeed, an evolving and flexible mix of these policy mechanisms may be needed to achieve the efficiency goals described here.

Incorporation of Efficiency in a Planning Context: Inclusion of energy efficiency resource in an integrated resource planning (IRP) process can enable the overall most efficient and cost-effective delivery of energy services. IRP is currently practiced in Arizona, and is under consideration by the ES TWG.

In addition, supporting activities may be important elements in the success of energy efficiency strategies. These supporting strategies could include consumer education and outreach programs (including, for example, enhanced State Energy Office and University-

¹ These targets would apply to all utilities in the state. Electricity and natural gas goals are deliberately expressed in different metrics -- energy savings and revenue targets, respectively -- due to recognized differences in experience with efficiency programs with each fuel. Experience with electricity efficiency is sufficient to enable targets to be established, as has been done in several states (such as CA and TX). Experience with natural gas efficiency programs is more limited, thus it may be premature to establish energy savings goals.

² CCAG members expressed a desire to ensure that these targets are adequately ambitious, and thus to revisit these targets once initial analysis is complete.

based energy-efficiency extension services), and market transformation programs and organizations. Supporting strategies will be considered as part of overall recommendations, but their impacts will not be quantified. They could also include decoupling utility sales and revenues and creating performance incentives that reward utilities for implementing effective DSM programs.

Related Policies/Programs in Place:

- The ACC recently approved DSM funding by Southwest Gas (SW Gas) at a level of 0.8% of revenues.
- Arizona utilities (including APS, SRP, TEP and SW Gas) operate a number of DSM programs, including audits, new home programs, shade tree programs, appliance rebates, and others. In addition, the Arizona Department of Commerce's Energy Office provides energy efficiency programs for businesses, communities and homeowners in Arizona.
- In 2004, the Arizona Corporation Commission (ACC) issued a recommended order in a recent Arizona Public Service Co. rate case, supporting a funding level of \$16 million per year for APS demand-side management (DSM) programs, an increase from \$1 million per year.
- In 2002, Tucson Electric Power was approved to spend \$1 million of System Benefits Charge funding for low income and energy efficiency programs
- Arizona home sellers can subtract 5% (up to \$5,000) of the sales price of a single family home or condominium that is 50% more efficient than the 1995 Model Energy Code (MEC) from their income for the purpose of calculating their state income tax. The income tax deduction is available through 2010.

Types(s) of GHG Benefit(s):

The principle benefit is the reduction in GHG emissions (largely CO₂) from avoided electricity production and avoided on-site fuel combustion. Less significant benefits are the reduction in CH₄ emissions from avoided fuel combustion and avoided pipeline leakage. Other GHG impacts are also conceivable, but are likely to be small (black carbon, N₂O) and/or very difficult to estimate (materials use, life cycle, market leakage, etc.).

Estimated GHG Savings and Costs per tCO₂e:

RCI-1	2010	2020	Units
GHG Emission Savings	3.1	15.1	MMtCO ₂ e
Net Present Value (2006-2020)		-\$3,671	\$ million
Cumulative Emissions Reductions (2006-2020)		103	MMtCO ₂ e
Cost-Effectiveness		-\$36	\$/tCO ₂ e

Other Key Results (RCI-1)	2010	2020	Units
Fraction of Electric Utility Revenues spent on efficiency	2.6%	2.5%	
Equivalent Public Benefit Charge (electricity)	1.9	1.8	\$/MWh
Electricity Savings (including recent actions)	4,208	18,400	GWh (sales)
Natural Gas Savings (including recent actions)	1,719	10,890	Billion BTU

Recent Actions (current/planned efficiency spending levels) not included in forecast (GHG Emissions Savings not included above)	2010	2020	Units
Electricity	0.3	0.9	MMtCO ₂ e
Natural Gas	<u>0.1</u>	<u>0.3</u>	MMtCO ₂ e
Total	0.4	1.3	MMtCO ₂ e

Discussion: Savings from recent actions reflects the emissions reductions that are likely to accrue from current and planned statewide spending levels on energy efficiency (\$12 million/year for electricity; 0.8% of SW Gas natural gas revenues for natural gas). The impact of additional effort in RCI-1 reflects the added statewide economic savings (nearly \$4 billion, NPV through 2020) and emissions reductions that would accrue from the statewide goals in this policy measure over and above the current and planned statewide spending levels. The negative cost-effectiveness and NPV reflect a *net benefit* statewide.

The fraction of electric utility revenues spent on efficiency averages about 2.5%. This level of spending is similar to that maintained by utilities in the Pacific Northwest in the 1990s. If this level of spending were translated into a public benefit charge, it would require a public benefit charge on the order of about \$2/MWh (0.2 cents or 2 mills per kWh).

Data Sources, Methods, and Assumptions:

See the document referenced on page G-3 of this Appendix for a more detailed listing of methods, data sources, and assumptions used in this analysis. In summary:

- **Data Sources:** Key data sources include US DOE Energy Information Agency (historical and projected prices, SW Gas market share), WGA CDEAC EE Task Force, Northwest Power Council, and California Energy Commission (costs of efficiency programs), SW Energy Efficiency Project (current level of electricity efficiency spending.)
- **Quantification Methods:** The estimation of electricity and natural gas savings (MWh and million Btu) is relatively straightforward. For electricity, savings are simply the goal times that years' projected loads. For natural gas, projected gas revenues are estimated (based on projected prices and sales), then multiplied by the goal (1.5%) and by the assumed savings per program dollar spent (below). GHG savings are estimated based on marginal emissions rates for electricity (0.7 to 0.8 tCO₂e/MWh – See the document referenced on page G-3 of this Appendix for a more detailed listing of methods, data sources, and assumptions used in this analysis) and on standard emission rates for natural gas (see inventory). Cost analysis is based on the differential between avoided costs and the levelized cost of efficiency savings.
- **Key Assumptions:** Key assumptions include avoided electricity and gas costs (levelized prices used as a proxy), levelized total costs of efficiency programs (\$25/MWh, \$2.1/MMBtu), and program spending requirements (6 MWh/yr per \$1000 spent, 75 MMBtu/yr per \$1000 spent). Another key assumption is that the savings goals apply to all electric and gas utilities in the state.

Key Uncertainties:

- Avoided electricity and natural gas costs.
- Costs and availability of efficiency resources.

Ancillary Benefits and Costs:

These include (source: WGA CDEAC, 2005)

- Saving consumers and businesses money on their energy bills;
- Reducing dependence on imported fuel sources;
- Reducing vulnerability to energy price spikes;
- Reducing peak demand and improving the utilization of the electricity system;
- Reducing the risk of power shortages;
- Supporting local businesses and stimulating economic development;
- Enabling avoidance of the most controversial energy supply projects;
- Reducing water consumption by power plants; and
- Reducing non-GHG pollutant emissions by power plants and improving public health.

Feasibility Issues:

None cited.

Status of Group Approval:

Completed.

Level of Group Support:

Unanimous.

Barriers to Consensus:

None cited.

RCI-2 State Leadership Programs

Policy Description:

Government-led, or “Lead by Example”, initiatives help state and local governments achieve substantial energy cost savings while promoting the adoption of clean energy technologies by the public and private sectors.

Policy Design:

The policy actions under consideration include:

- Extension of state building energy savings goals (Statute A.R.S. 34-45) to include a further 15% reduction in energy use per square foot in state buildings from 2011 to 2020, along with purchasing EnergyStar equipment.
- Standards for new state buildings, with possible design parameters including recommendations that new state buildings be more energy-efficient than current building codes require, or to adopt LEED³-related requirements, such as those recommended by the Arizona Working Group on Renewable Energy and Energy Efficiency and by the WGA CDEAC EE⁴ Task Force (See also Option RCI-5), as well as mechanisms to support the state in achieving its goals.
- Green Procurement Strategies, such as installation of renewable energy systems for additional backup in emergency services buildings (e.g., police stations, fire stations, National Guard facilities), and efforts to promote or require the purchase by state buildings of 5% of their building energy needs from renewable sources (over a phased-in period) by 2012, increasing to 10% by 2020⁵.
- The promotion of new combined heat and power (CHP) facilities in State Buildings, such as the facilities in place and under construction at Arizona State University and the University of Arizona (approximately 35 MW total), and the expansion of existing performance contracting law to require life cycle analysis for CHP in State lease-purchase construction.

The TWG suggests that the State Energy Office add staff capability and responsibility for a) ensuring effective compliance with state procurement and savings goals, and b) sharing and communicating the state’s accomplishments and lessons learned (by, for example, assuming a “cooperative extension” role). Furthermore, the state should consider adopting procurement guidance, such as that included in the Energy Policy Act of 2005. A number of

³ Leadership in Energy and Environmental Design, a “...voluntary, consensus-based national standard for developing high-performance, sustainable buildings.”. See <http://www.usgbc.org/>.

⁴ Energy Efficiency Task Force Report to the Clean and Diversified Energy Advisory Committee of the Western Governors’ Association.

⁵ CCAG members suggested that the State revisit the green purchase target to ensure that it is adequately ambitious, and to ensure that the state leadership targets, in general, could not be circumvented through outsourcing (i.e., that the targets be applicable to private entities working as contractors to the State). Additional policy description text provided below includes a number of additional components including the state ombudsman role noted during the CCAG meeting.

additional elements of State Leadership programs should be considered as well, as noted at the end of this option.

Additional Recommendations for State Leadership Programs: The following are based on findings of the WGA CDEAC EE Task Force and AZ EE/RE Working Group⁶.

- With respect to the LEED green building standards, the State should investigate the feasibility of requiring additional commissioning as well as measurement and verification to ensure that they are meeting the energy savings targets noted above.
- The State should construct new buildings that serve as examples of energy-efficiency by surpassing minimum energy code requirements by a wide margin.
- The Governor should use public events, such as installing energy efficiency products in the Governor's residence, or openings of new energy efficient projects, or public awards (energy efficiency or renewable energy awards) to draw attention to the State's renewable energy and energy efficiency ethic.
- The Governor and state agencies should promote the use of State and other public facilities as demonstrations of energy efficiency and renewable energy.
- The State should provide financial and technical assistance for implementation of energy savings projects in existing buildings and facilities.
- The State should use energy service companies (ESCOs) and performance contracting to implement efficiency projects without public sector capital investment.
- The Governor and the Department of Administration should establish a program to install renewable energy systems as additional backup services in emergency services buildings
- The Governor should require state buildings – including schools – to purchase, install and operate cost-effective renewable energy equipment or purchase green power to meet 5% of their building energy needs over a phased-in period by 2012.
- The Governor and State agencies should require State offices to buy a percentage of their electricity from renewable resources, if cost-effective.
- Current state law (ARS 34-355) allows the use of cogeneration (combined heat and power) in performance contracting. This law should be expanded to require life cycle analysis for CHP in State lease-purchase construction.
- HB 2430 expands the use of CHP for State facilities and schools. This bill (if ultimately adopted) should be built upon in the future.⁷

Implementation Method(s):

⁶ As expressed in the Energy Efficiency Task Force Report to the Clean and Diversified Energy Advisory Committee of the Western Governors' Association, *The Potential for More Efficient Electricity Use in the Western United States*, December 19, 2005. This report is referred to elsewhere in this Appendix as the "WGA CDEAC EE report" and can be found at: <http://www.westgov.org/wga/initiatives/cdeac/Energy%20Efficiency.htm>. A companion WGA CDEAC report, the Combined Heat and Power White Paper, dated January, 2006, is also quite germane to the some of the policy options that follow, as is the Solar Task Force Report, also dated January, 2006.

⁷ See http://www.azleg.state.az.us/FormatDocument.asp?inDoc=/legtext/47leg/2r/summary/h.hb2430_02-24-06_asengrossedandpassedhouse.doc.htm.

These could include, among others, funding mechanisms and incentives, legislation/statutes, codes and standards, and reporting.

Related Policies/Programs in Place:

- Statute A.R.S. 34-451 directs state agencies and universities to achieve a 10% reduction in energy use per unit of floor area by 2008, and a 15% reduction by 2011; purchase cost-effective ENERGY STAR or Federal Energy Management Program-designated energy-efficient products; and meet energy conservation standards developed by the Arizona Department of Commerce’s Energy Office.
- HB 2501 “Schools: Energy Efficiency Funds”, if adopted, will promote the establishment of energy efficiency funds by schools, with monies deposited by utilities. The funds will be used to purchase energy-efficiency products and services. Schools use utility bill savings to repay the capital cost of energy efficiency measures (see http://www.azleg.state.az.us/FormatDocument.asp?inDoc=/legtext/47leg/2r/summary/h.hb2501_02-15-06_caucuscow.doc.htm).
- Executive Order 2005-05 implementing renewable energy and energy efficiency in new state buildings (http://www.governor.state.az.us/eo/2005_05.pdf)
- A May 2001 [Executive Order](#) directed state agencies and employees to implement energy conservation measures in state facilities.

Types(s) of GHG Benefit(s):

To the extent state actions are focused on reducing electricity and natural gas purchases or increasing renewable energy production, GHG impacts are likely to be similar to those described for RCI-1 above.

Estimated GHG Savings and Costs per tCO₂e:

RCI-2	2010	2020	Units
GHG Emission Savings	0.04	0.4	MMtCO ₂ e
Net Present Value (2006-2020)		-\$12	\$ million
Cumulative Emissions Reductions (2006-2020)		4	MMtCO ₂ e
Cost-Effectiveness		-\$3	\$/tCO ₂ e

Other Key Results (RCI-2)	2010	2020	Units
Green Power Purchased	45	183	GWh (sales)
GHG Emission Savings from Green Power Purchasing	0.04	0.2	MMtCO ₂ e
GHG Emission Savings from Extending Building Savings Goals	0.00	0.2	MMtCO ₂ e

Recent Actions not included in forecast (GHG Emissions Savings not included above)	2010	2020	Units
Current state building savings goals	0.16	0.28	MMtCO ₂ e
Recent CHP installations	<u>0.12</u>	<u>0.12</u>	MMtCO ₂ e
Total	0.28	0.39	MMtCO ₂ e

Discussion of Results: Savings from recent actions reflect the emissions reductions that are likely to accrue from current state building savings goals and the combined heat and power installations recently installed or coming on line at Arizona universities. Two elements of this policy option are readily quantifiable: extending and deepening the state building energy savings goals from 2011 onward, and green power purchasing. The benefits of promoting CHP at state buildings are incorporated in the overall assessment of commercial CHP potential (see policy RCI-6), and are not reported separately here. Similarly, the benefits of standards for new state buildings are not estimated separately here, but are incorporated in the analysis of new building strategies below (see policies RCI-4 and RCI-5).

The negative cost-effectiveness and NPV reflect an overall net benefit statewide. The cost savings of the extended state buildings goals (\$18 million, NPV) more than offsets the net costs of the green power purchasing efforts (\$5 million, NPV).

Data Sources, Methods, and Assumptions:

See the document referenced on page G-3 of this Appendix for a more detailed listing of methods, data sources, and assumptions used in this analysis. In summary:

- **Data Sources:** The Arizona Department of Commerce (Jim Westberg, Energy Program Administrator) provided estimates of State building energy consumption. The cost of State building efficiency efforts (\$47/MWh) is based on the review of relevant literature summarized in the WGA CDEAC Energy Efficiency Task Force report. The incremental cost of green power (\$9/MWh) is based on current bulk programs (such as Pacificorp's BlueSky program).
- **Quantification Methods:** Emissions savings and costs are calculated in a straightforward manner analogous to RCI-1.
- **Key Assumptions:** State building square footage is assumed to grow at the rate of commercial Gross State Product (GSP) growth assumed used in the emission forecast (4.9%/year).

Key Uncertainties:

- Avoided electricity and natural gas costs.
- Costs and availability of efficiency resources.
- Incremental costs of green power.
- Rate of growth in state building area.
- Ability to track and enforce building efficiency and green purchasing goals.

Ancillary Benefits and Costs:

Additional impacts are similar to those described for RCI-1 above.

Feasibility Issues:

None cited.

Status of Group Approval:

Completed.

Level of Group Support:

Unanimous.

Barriers to Consensus:

None cited.

RCI-3 Appliance Standards

Policy Description:

Implementation of State appliance efficiency standards for appliances not covered by federal standards or where higher-than-federal standard efficiency requirements are appropriate.

Policy Design:

Appliance efficiency standards reduce the market cost of energy efficiency improvements by incorporating technological advances into base appliance models, thereby creating economies of scale. Arizona, along with several other states, recently adopted efficiency standards for appliances not covered by federal standards. These state actions ultimately resulted in the adoption of standards for additional appliances in the Energy Policy Act of 2005. Moreover, California has established standards for a number of appliances not currently included in Arizona or national legislation, such as pool pumps, consumer electronics (stand-by power use), and general-service incandescent lamps.

The specific policy approach suggested by the TWG is to:

- First, advocate for stronger federal appliance efficiency standards where this is technically feasible and economically justified.
- Second, for those appliances not likely to be covered by federal efforts, pursue efficiency standards already adopted by California and/or other states⁸.
- Where possible, consider encouraging local manufacturing of high-efficiency appliances and equipment when adopting state standards.

Implementation Method(s):

Codes and Standards

Related Policies/Programs in Place:

- Arizona Appliance Efficiency Standards [HB2390]
- Existing Federal Appliance Efficiency Standards [2005 Energy Bill]. These federal standards will effectively build upon and replace the Arizona standards for the same appliance types. However, the impact of these standards (AZ and federal) is not included in the emissions projections included in the State inventory report.⁹

Types(s) of GHG Benefit(s):

Similar to RCI-1.

⁸ A CCAG member suggested that the CCAG and TWG also consider including in this option efficiency standards for biomass stoves, solar water heaters, and other renewable energy technologies, as well as for other thermal appliances where efficiency standards do not exist or are inadequate.

⁹ The electricity use forecast used in the AZ GHG emissions projections is based on the US Department of Energy's [2005 Annual Energy Outlook](#), which did not take these standards into account.

Estimated GHG Savings and Costs per tCO₂e:

RCI-3	2010	2020	Units
GHG Emission Savings	0.2	1.0	MMtCO ₂ e
Net Present Value (2006-2020)		-\$453	\$ million
Cumulative Emissions Reductions (2006-2020)		7	MMtCO ₂ e
Cost-Effectiveness		-\$66	\$/tCO ₂ e

Recent Actions (HB2390) not included in forecast (GHG Emissions Savings not included above)	2010	2020	Units
Total	0.2	0.8	MMtCO ₂ e

Data Sources, Methods, and Assumptions:

See the document referenced on page G-3 of this Appendix for a more detailed listing of methods, data sources, and assumptions used in this analysis. In summary:

- **Data Sources:** A recent study by the Appliance Standards Assistance Project and the American Council for an Energy Efficiency Economy provides estimates for new standards.¹⁰ The savings from recent actions (previous Arizona efficiency standards) are based on an earlier analysis by the same sources, adapted to the specifications of AZ HB2390.¹¹
- **Quantification Methods:** The ASAP/ACEEE report uses estimates of appliance sales by states along standard incremental cost and savings analysis to develop state-specific results for 15 specific appliances.¹² The study's NPV results were derived using the same discount rate (5%) as in our analysis, but a longer time span (to 2030). For consistency, the NPV savings were reduced (by about 30%) to reflect the shorter time horizon used for cost analysis in the CCAG process (to 2020).
- **Key Assumptions:** The ASAP/ACEEE study used prices slightly different than used for the CCAG analyses – they use 9.0c/kWh (\$13.52/Mbtu gas) residential and 7.6c/kWh (\$9.65/Mbtu gas) commercial. The resulting NPV savings differ slightly from those that would be obtained using our avoided delivered electricity and gas cost estimates¹³.

¹⁰ ASAP and ACEEE, 2006. "Leading the Way: Continued Opportunities for New State Appliance and Equipment Efficiency Standards", <http://www.standardsasap.org/stateops.htm>.

¹¹ A TWG member provided a copy of this analysis.

¹² See http://www.standardsasap.org/a062_az.pdf for a table listing the 15 appliances considered, and their costs and savings. The carbon emissions savings shown in this document are not used here; instead the marginal electricity emission factors used for other CCAG policies are used.

¹³ The authors of the ASAP/ACEEE study have agreed to re-estimate the cost impacts based on the electricity and gas prices used for the CCAG analysis – updated results to be reported when available.

Key Uncertainties:

- Ability to track and enforce compliance with standards.
- Avoided electricity and natural gas costs.

Ancillary Benefits and Costs:

Similar to RCI-1.

Feasibility Issues:

None cited.

Status of Group Approval:

Completed.

Level of Group Support:

Unanimous.

Barriers to Consensus:

None cited.

RCI-4 Building Standards/Codes for Smart Growth

Policy Description:

Given the State's growth and the long lifetime of buildings, the current and future building codes will have a considerable impact on future energy use in buildings, and on related greenhouse gas emissions. Thus improved and increasingly stringent energy efficiency codes for Arizona are proposed.

Policy Design:

Building energy codes specify minimum energy efficiency requirements for new buildings or for existing buildings undergoing major renovations¹⁴. It is recommended that Arizona take the following actions in order to realize the energy savings and other benefits offered by state-of-the-art building energy codes¹⁵:

- Arizona should either establish a statewide mandatory code or strongly encourage local jurisdictions to adopt and maintain state-of-the-art codes. Adoption is targeted for 2007, with codes in force in early 2008, but with the recognition that some municipalities in Arizona may implement energy efficiency codes later than others.
- Arizona and/or local jurisdictions should adopt the 2004 International Energy Conservation Code (IECC), to the extent that adoption has not already occurred. Also, Arizona and/or local jurisdictions should consider adopting innovative features of California's latest Title 24 building energy codes, such as lighting efficiency requirements in new homes. In considering the adoption of building code elements, Arizona and/or local jurisdictions should take into account the time-dependent value of energy by, for example, noting the extra benefits from code revisions that are particularly effective in saving on-peak electricity or gas.
- Arizona and local jurisdictions should update energy codes regularly. A 3-year cycle could be timed to coincide with release of the national model codes.
- Revised building codes for Arizona as a whole and for local jurisdictions should be prepared with the involvement of local chapters of code organizations to assist in obtaining support for and compliance with the new policies. All buildings should be covered, including manufactured homes, and local building inspectors should enforce compliance with codes. Inspectors need to be properly trained in new elements of the codes.

Implementation Method(s):

- Information and education: Would include training and education programs and certification for building planners, builders/contractors, energy managers and

¹⁴ A CCAG member noted that the threshold for major renovation needs to be further defined. This issue should be addressed as this policy is further detailed and as implementation plans are developed.

¹⁵ Many of these suggestions are consistent with recommendations included in the WGA CDEAC EE report (for example, page 59).

operators, local officials, and others in the building industry, including training on building energy performance analysis tools and software. Would also include programs for consumer and elementary/secondary education.

- Training and technical assistance for code enforcement officials, including training and assistance in the use of building energy performance analysis tools and software, and in the review and analysis of the outputs of building energy performance tools.
- Funding mechanisms and or incentives: Utility programs (designed to encourage building energy performance beyond codes) may help to provide financial assistance for training code officials in the application of building energy codes. Increases in permit fees and/or increase in “impact fees” may also be considered to assist with funding of training for code officials.
- Voluntary and or negotiated agreements: Agreements within Metropolitan Area Government councils to collaborate on building energy codes in order to make compliance easier for building contractors and other building trade professionals.
- Codes and standards—In addition to adoption of state and/or local and/or metropolitan area building energy performance codes, Arizona may consider starting a State Building Energy Codes Collaborative process and/or joining a Regional Building Codes Collaborative, as referenced (for example) on pages 65-66 of the WGA CDEAC EE report.

Related Policies/Programs in Place:

Code changes advanced in some localities, beginning in others. Most urban areas have adopted the IECC 2004 codes, and some (notably Tucson) have adopted more stringent codes.

Types(s) of GHG Benefit(s):

- CO₂ reduction from avoided electricity production and avoided on-site fuel combustion.
- Modest reduction in CH₄ emissions from avoided fuel combustion and avoided natural gas pipeline leakage, relatively small reductions in N₂O, Black Carbon emissions from avoided fuel consumption.

Estimated GHG Savings and Costs per tCO₂e:

RCI-4	2010	2020	Units
GHG Emission Savings	0.3	2.2	MMtCO ₂ e
Net Present Value (2006-2020)		-\$243	\$ million
Cumulative Emissions Reductions (2006-2020)		14	MMtCO ₂ e
Cost-Effectiveness		-\$18	\$/tCO ₂ e

Recent Actions (Current/planned building code changed) not included in forecast (GHG Emissions Savings not included above)	2010	2020	Units
Total	0.2	0.8	MMtCO ₂ e

Discussion of Results: Savings here are relatively modest in part because significant improvements over codes in place in the last few years are expected as a part of the WGA CDEAC EE Reports “Current Activities” case, and the savings reported here are the difference between the “Current Activities” case (used as the basis for the estimate of “Recent Action” impacts shown above) and the more aggressive “Best Practices” case. Savings in emissions related to reduced electricity consumption account for well over 90% of the GHG savings from this policy.

Data Sources, Methods, and Assumptions:

- **Data Sources:** Major data sources include the WGA CDEAC EE report, including background materials for that report developed by the Building Code Assistance Project (BCAP), The Southwest Energy Efficiency Project's (SWEET) Report Increasing Energy Efficiency in New Buildings in the Southwest: Energy Codes and Best Practices, and results from Table 5.8 of the 2002 Energy Consumptions by Manufacturers--Data Tables published by the US Department of Energy's Energy Information Administration.
- **Quantification Methods:** Results from the WGA CDEAC EE analysis at the State level were adjusted to achieve the results above. See the document referenced on page G-3 of this Appendix for a more detailed listing of methods, data sources, and assumptions used in this analysis.
- **Key Assumptions:** Level of code improvements assumed same as in the WGA CDEAC EE analysis, though parameters are included to allow adjustments of those assumptions. The cost of electricity savings through building code improvements, beyond “baseline values”, was assumed to be 4.7 cents/kWh on a levelized basis (same source). Savings in the commercial sector assumes that at least some renovated space is included in code requirements, and that the ratio of renovated space included in energy code requirements to new space included is 0.3. Ratio of gas to electricity savings as in the SWEET Report, above.

Key Uncertainties:

The degree to which improved codes in Arizona may be similar to those assumed in the WGA CDEAC EE analysis. Results have not yet been adjusted for the degree to which statewide code adoption will be different in different parts of the state, due to varying weather regimes.

Ancillary Benefits and Costs¹⁶:

- Saving consumers and businesses money on their energy bills
- Potential to also yield water savings
- Comfort/indoor air quality improvements, with related improvements in health and productivity
- Reducing dependence on imported fuel sources, and reducing vulnerability to energy price spikes
- Electricity system benefits: reduced peak demand, reduced capital and operating costs, improved utilization and performance of the electricity system, reduced pollutant emissions from power plants and related public health improvements

¹⁶ Many of these additional benefits are adapted from those listed on page 2 of the WGA CDEAC EE report.

- Supporting local businesses and stimulating economic development
- Low-income populations living in buildings covered by the policy will benefit through lower annual energy costs.

Feasibility Issues:

None cited.

Status of Group Approval:

Completed.

Level of Group Support:

Unanimous.

Barriers to Consensus:

None cited.

RCI-5 “Beyond Code” Building Design Incentives and Programs for Smart Growth

Policy Description:

Building energy performance standards are implemented in State-funded and other (such as local) government buildings, and similar standards are promoted in other buildings, such that new buildings achieve high standards of energy efficiency, and existing buildings are renovated or retrofitted to yield significant energy efficiency improvements.

Policy Design:

Implementation of LEED (Leadership in Energy and Environmental Design, a program of the U.S. Green Building Council) standards/certifications and/or other “green building” certifications and/or measured or modeled building energy performance criteria may be used to specify building energy performance standards.¹⁷ Incorporating white roofs, rooftop gardens (“green roofs,” and shade trees would also be included by this policy. In addition to directly influencing energy use in state-funded and government buildings, this policy will help to raise awareness of energy-efficiency improvement methods in building construction and operation, and will help to “drive” such improvements in other market segments. This policy includes:

- A performance standard for State-owned or State-leased buildings to demonstrate the feasibility of achieving the minimum code requirements as well as exceeding them. This will demonstrate and encourage the use of advanced energy efficiency products and designs, and will also reward the State with the inherent benefits of more efficient buildings. New State-owned or State-leased buildings will be required to use at least 10% less energy per square foot of floor space relative to what the same building would have used if designed to just meet existing energy codes. The requirement of 10% lower energy use will be reviewed periodically, but is expected to remain in force as long as the level of improvement remains cost-effective.
- A requirement that state-owned or leased facilities use life-cycle costing, including full consideration of future energy costs, in the selection and implementation of building designs and components for both new and renovated space, or for the selection of replacement components. Further, following life cycle cost analysis, require that the most cost-effective design/equipment/component options be chosen.
- Provide financial or tax incentive for non-public and non-state public buildings (such as municipal buildings) to improve their energy performance beyond that required by existing codes.¹⁸ Incentives should be provided for building projects (new, renovated,

¹⁷ Note that it is not the intent of this policy that achieving LEED or other certifications be required in order to receive incentives, so long as a project achieves an adequate level of energy savings.

¹⁸ There are, as of the writing of this Policy Description, a number of ongoing discussions regarding the LEED certification program, other certification programs, and potential performance guidelines for new and renovated buildings, and as a result, it is not yet clear which certifications or performance guidelines might be adopted or suggested for use in this program. Whichever set of certifications/performance guidelines are adopted should provide designers, builders and

or remodeled space) where energy consumption per unit floor area is at least 10% less that would be the case if the project met existing codes, noting that energy codes will change over time.¹⁹ Incentives should be structured so that projects that produce higher savings per unit floor area relative to meeting code requirements receive greater incentives.

- Provide similar financial or tax incentives to encourage retrofits of existing buildings to levels of energy efficiency exceeding those required by existing energy codes.
- Performance standards, life cycle costing requirements, and incentive programs to begin at some point to be determined in the future.

Implementation Method(s):

- Information and education: Would include training and education programs and certification for state officials, building planners, builders/contractors, energy managers and operators, and local officials on certification that buildings and building subsystems have met program requirements. Would also include programs for consumer and elementary/secondary education.
- Technical assistance: Assistance to building planners, engineers, and others in energy-efficient design and in building energy efficiency analysis, possibly including reference materials, performance/design guidelines, and assistance with energy performance analysis software.
- Funding mechanisms and or incentives: Tax credits and/or incentives related to the rate of amortization of expenses related to buildings or renovation. State grants to help cover additional costs of energy performance enhancements for municipal government buildings.
- Voluntary and or negotiated agreements: Agreements by municipal governments, builders to meet higher energy performance standards in exchange for special certification and/or financial incentives.
- Codes and standards: For state-owned or state-leased space, requirements to exceed codes in force as noted above.
- Pilots and demos: Applications of building energy performance improvements (possibly including demonstration of construction of buildings to LEED or other relevant standards) and urban landscaping for government buildings.

Related Policies/Programs in Place:

[Note that many of the state programs listed below are either very recently enacted or currently under consideration, and thus may effectively constitute "new" State GHG policies rather than "Business as Usual" (BAU) policies]:

- Related notes in early version of RCI TWG Policy Matrix: "Executive Order 2005-05 implementing renewable energy and energy efficiency in new state buildings; Solar

contractors with a means to advertise that their work meets a high energy-efficiency standard (through a specific labeling or certification), while also assuring that the actual energy performance of the building significantly exceeds the level required by codes.

¹⁹ A CCAG member noted that even in the absence of a building energy code improvement policy, energy codes will improve over time, and this "baseline" improvement will need to be taken into account in quantifying the benefits and costs of policies to improve building energy efficiency.

Design Standards for State Buildings; Tucson-Pima Sustainable Energy Program; City of Scottsdale Green Building program”

- Notes in early version of RCI TWG Policy Matrix related to professional education/certification: APS and state Energy Office offer building science training; APS subsidizes contractor training; Energy office provides training [in building codes];
 - Technical assistance from Rebuild Arizona and Arizona Energy Office [for energy management/building operator training]
- Newly-adopted Federal Energy Credit for houses “that reduce energy use for heating and cooling only (not hot water) by 50% compared to the national model code – the 2004 IECC Supplement”, as well as for commercial buildings that “achieve a 50% reduction in annual energy cost to the user, compared to a base building defined by the industry standard ASHRAE/IESNA 90.1-2001”
- Legislation proposed as HB 2858 including a LEED standard for schools, and including methods by which the degree to which schools meet the standard will be monitored.
- Legislation proposed as HB 2430 emphasizing life cycle costing.
- Legislation proposed as HB 2429 for solar tax credits.
- Legislation proposed as HB 2843 for tax credits for high-efficiency residential central air conditioners and ceiling fans (as well as clothes washers).
- Legislation proposed as HB 2324 and recently enacted as ARS 34-451 setting energy efficiency standards for new and existing public buildings.

Types(s) of GHG Benefit(s):

- CO₂ reduction from avoided electricity production and avoided on-site fuel combustion.
- Modest reduction in CH₄ emissions from avoided fuel combustion and avoided natural gas pipeline leakage, relatively small reductions in N₂O, Black Carbon emissions from avoided fuel consumption.

Estimated GHG Savings and Costs per tCO₂e:

RCI-5	2010	2020	Units
GHG Emission Savings	0.2	3.1	MMtCO ₂ e
Net Present Value (2006-2020)		-\$59	\$ million
Cumulative Emissions Reductions (2006-2020)		18	MMtCO ₂ e
Cost-Effectiveness		-\$17	\$/tCO ₂ e

Discussion of Results: Commercial sector measures account for over half of total reduction in electricity use (and thus GHG emissions reductions). GHG emissions savings from avoided electricity generation account for over 90 % of total reductions.

Data Sources, Methods, and Assumptions:

- **Data Sources:** Major data sources include the WGA CDEAC EE report, including background materials for that report developed by the Building Code Assistance Project

(BCAP), The Southwest Energy Efficiency Project's (SWEET) Report Increasing Energy Efficiency in New Buildings in the Southwest: Energy Codes and Best Practices, and results from Table 5.8 of the 2002 Energy Consumptions by Manufacturers--Data Tables published by the US Department of Energy's Energy Information Administration.

- **Quantification Methods:** Quantification starts with an estimate of average electricity use per household and per unit commercial floor space after taking into account changes due to improved energy codes, then applies participation estimates and fractional savings assumptions to estimate potential savings, first in new construction, and then, through application of factors to reflect the participation of other types of buildings (existing, space, renovated space), estimates an overall level of electricity savings. Gas savings are estimated from electricity savings based on SWEET data (from document above). See the document referenced on page G-3 of this Appendix for a more detailed listing of methods, data sources, and assumptions used in this analysis.
- **Key Assumptions:** Cost of beyond-code improvements assumed to be similar to improvements needed to attain the higher codes included in RCI-4. "Beyond-code" savings assumed to save 15% of household and commercial electricity use (initial assumption).

Key Uncertainties:

Levels of participation and savings achieved by policy in different sectors and markets.

Ancillary Benefits and Costs²⁰:

- Potential to also yield water savings, comfort/indoor air quality improvements with related improvements in health and productivity, plus urban design, market transformation, and other benefits.
- White roofs, rooftop gardens, and landscaping, if widely implemented, may have a favorable impact on local climate, for example, reducing nighttime temperatures, potentially allowing a further reduction in energy use for space cooling ("urban heat island" effects).
- Saving consumers and businesses money on their energy bills
- Reducing dependence on imported fuel sources, and reducing vulnerability to energy price spikes
- Electricity system benefits: reduced peak demand, reduced capital and operating costs, improved utilization and performance of the electricity system, reduced pollutant emissions from power plants and related public health improvements
- Supporting local businesses and stimulating economic development
- Low-income populations living in buildings covered by the policy will benefit through lower annual energy costs.

Feasibility Issues:

None cited.

Status of Group Approval:

Completed

²⁰ Many of these additional benefits are adapted from those listed on page 2 of the WGA CDEAC EE report.

Level of Group Support:

Unanimous

Barriers to Consensus:

None cited.

RCI-6 Distributed Generation/Combined Heat and Power

Policy Description:

Distributed generation with clean combined heat and power systems improves the overall efficiency of fuel use as well as electricity system benefits. Implementation of these systems should be encouraged through a combination of regulatory changes and incentive programs.

Policy Design:

Distributed generation in the form of clean combined heat and power systems give electricity consumers the capability of generating electricity or mechanical power on-site to meet all or part of their own needs, sell power back to the grid, and, through capture of heat typically lost during power generation, meet on-site thermal needs (hot water, steam, space heat, or process heat) or cooling (for example, through application of absorption chillers)²¹. In so doing, distributed generation with combined heat and power (CHP) raises the overall efficiency with which fuel is used. In addition to improvements in the efficiency of fuel use, and related reduction in greenhouse gas emissions, expanded use of distributed CHP offers significant electricity system benefits (including avoided electricity transmission and distribution losses, and avoided requirements for electricity grid expansion). Policies to encourage the adoption of CHP include a combination of regulatory changes and possibly incentives for adoption of CHP systems. CHP systems of 10 MW or smaller (or of equivalent mechanical power) would be covered, and policies in place by the end of 2006, and in force thereafter, with periodic review as needed. The combination of regulatory changes and incentives will be designed to allow a certain percent of Arizona's estimated remaining CHP potential to be realized at some in the future.

Implementation Method(s):

[Note that in the list of incentives below technical assistance, codes and standards, market-based mechanisms, and utility planning (in that order) are considered by TWG members to be of primary importance, while other mechanisms are considered of secondary importance.]

- Information and education: Would include training and education programs and certification for building planners, builders/contractors, energy managers and operators, and state and local officials related to the incorporation of CHP into building plans/designs/operation. Would also include programs for consumer and elementary/secondary education.
- Technical assistance: Assistance in siting and planning CHP systems.
- Funding mechanisms and or incentives: A program similar to that offered in California with up to \$500 per kW or equivalent incentives per horsepower (hp) of capacity is possible. Another possible financial incentive is production incentives as included in

²¹ The CCAG suggested that this policy option could be expanded to include on-site electricity generation from waste heat.

the proposed legislative bill (HB 2427) of \$0.015 per kWh or equivalent incentives per hp-hour.

- Voluntary and or negotiated agreements
- Codes and standards: A national IEEE standard, IEEE #1547, has been adopted to facilitate DG installations. FERC has adopted a national interconnect standard for installation to transmission lines. A number of other states, including Texas, California, New Jersey, and New York, have adopted interconnect standards to facilitate DG installation. A similar standard is needed in Arizona, and has recently been under discussion at the ACC²².
- Market based mechanisms: Net metering, avoided-cost pricing rules, and/or other utility tariff policies that promote CHP. Performance contracting is another possible mechanism, for example, HB 2430 expands the definition of allowed performance contracting for State facilities and schools to include the use of CHP, and extends the allowable payback period to 25 years (see http://www.azleg.state.az.us/FormatDocument.asp?inDoc=/legtext/47leg/2r/summary/h.hb2430_02-24-06_asengrossedandpassedhouse.doc.htm).
- Pilots and demos: CHP systems in government buildings.
- Research and development: Support for research on combined power and cooling systems most germane to Arizona
- Utility Planning: Include CHP as an element of resource planning for utilities.

Related Policies/Programs in Place:

Interconnection rules and similar topics are under discussion at the Arizona Corporation Commission (ACC).

Types(s) of GHG Benefit(s):

- CO₂ reduction from avoided electricity production and avoided on-site fuel combustion less additional on-site CO₂ emissions from fuel used in CHP systems.
- Other gases: modest potential changes in emissions of CH₄: from avoided fuel combustion and avoided natural gas pipeline leakage, net of any additional on-site emissions or additional leakage from increased gas use, likely relatively small reductions in emissions of N₂O: from avoided fuel combustion, net of any increased on-site emissions, and also some possible small net changes in emissions of black carbon, depending on the balance between avoided and additional consumption of oil, coal, and biomass fuels, and of emission control equipment used on CHP and heating systems.

²² Includes in part text provided by the Distributed Energy Association of Arizona.

Estimated GHG Savings and Costs per tCO₂e:

RCI-6	2010	2020	Units
GHG Emission Savings	0.4	2.7	MMtCO ₂ e
Net Present Value (2006-2020)		-\$395	\$ million
Cumulative Emissions Reductions (2006-2020)		16	MMtCO ₂ e
Cost-Effectiveness		-\$25	\$/tCO ₂ e

Discussion of Results:

Net emissions reduction as calculated include consideration of avoided central station electricity generation, avoided on-site fuel use (including electricity use) for heating (or cooling) displaced by co generated heat and additional fuel used by CHP systems. Commercial sector measures account for over half of total reduction in electricity use (and thus GHG emissions reductions). Similarly, GHG emissions savings from avoided electricity generation account for over 90% of total reductions.

Data Sources, Methods, and Assumptions:

- **Data Sources:** The Combined Heat and Power White Paper, dated January, 2006, to the Clean and Diversified Energy Initiative of the Western Governors Association; and the 2003 Commercial Buildings Energy Consumption Survey Detailed Tables, published by the US Department of Energy's Energy Information Administration.
- **Quantification Methods:** Starting with an estimate for Arizona's share of CHP potential in the West, as provided in the "CHP White Paper" referenced above, assumptions regarding the penetration of and fuel shares for new CHP systems, estimates of future capacity of CHP developed under the policy are generated. Estimates of CHP cost and performance for different kinds of systems are then used to estimate the overall net GHG emissions reduction and net cost of the policy.
- **Key Assumptions:** Gas-fired systems are assumed to dominate new CHP in Arizona, but some biomass- and coal-fired capacity is also included. Systems are assumed to operate an average of 5000 hours per year (at full capacity), and 90% of co-generated heat is assumed to be usable (and displaces heat from purchased fuels).

See the document referenced on page G-3 of this Appendix for a more detailed listing of methods, data sources, and assumptions used in this analysis.

Key Uncertainties:

Achievable rate of implementation of CHP systems in Arizona, types and amounts of heating fuels that will be displaced, and average future costs of systems.

Ancillary Benefits and Costs²³:

- Potential increased reliability of electricity supply for CHP hosts, increased flexibility of supply.
- Central-station power plant cooling water savings

²³ Many of these additional benefits are adapted from those listed on page 2 of the WGA CDEAC EE report.

- Potential local air quality impacts (may be positive or negative)
- Saving consumers and businesses money on their energy bills
- Reducing dependence on imported fuel sources, and reducing vulnerability to energy price spikes
- Electricity (grid) system benefits: reduced peak demand, reduced capital and operating costs, improved utilization and performance of the electricity system, reduced pollutant emissions from power plants and related public health improvements
- Supporting local businesses (related to distributed generation/CHP sales, installation, and service) and stimulating economic development

Feasibility Issues:

None cited.

Status of Group Approval:

Completed.

Level of Group Support:

Unanimous.

Barriers to Consensus:

None cited.

RCI-7 Distributed Generation/Renewable Energy Applications

Policy Description:

Distributed generation sited at residences and commercial and industrial facilities, and powered by renewable energy sources, provides electricity system benefits and displaces fossil-fueled generation, thus reducing greenhouse gas emissions. Increasing the use of renewable distributed generation in Arizona can be achieved through a combination of regulatory changes and incentives.

Policy Design:

Customer-sited distributed generation powered by renewable energy sources provides electricity system benefits such as avoided capital investment and avoided transmission and distribution losses, while also displacing fossil-fueled generation and thus reducing greenhouse gas emissions. Customer-sited renewable distributed generation can include solar photovoltaic systems, wind power systems, biogas and landfill gas-fired systems, geothermal generation systems, and systems fueled with biomass wastes or biomass collected or grown as fuel. Policies to encourage and accelerate the implementation of customer-sited renewable distributed generation include direct incentives for system purchase, market incentives—including “net metering”—related to the pricing of electricity output by renewable distributed generation, state goals or directives, and favorable rules for interconnecting renewable generation systems with the electricity grid. Non-electric renewable energy applications also covered by this policy include solar water heat and solar space heat and cooling. It is suggested that Arizona should, at a minimum, set as its target the addition of customer-sited distributed renewable generation consistent with the overall generation capacity by year goals for renewable distributed generation in the West as expressed in the WGA CDEAC reports.

It is expected that implementing agencies will include Public Agencies (systems for state or other government buildings), the Arizona Corporation Commission²⁴, Arizona State Government, and Utilities.

Implementation Method(s):

- Information and education: Would include training and education programs and certification for building planners, builders/contractors, energy managers and operators, renewable energy contractors, and state and local officials on the incorporation of distributed renewable generation and solar space/water heat in building projects. Would also include programs for consumer and elementary/secondary education.
- Technical assistance: Assistance in siting, designing, planning renewable systems

²⁴ In addition to the ACC's influence on interconnection and pricing rules that will have a significant impact on the adoption of customer-sited distributed generation, decisions by the ACC on reserving a portion of the Environmental Portfolio Standard to be supplied by customer-sited DG systems will also have an impact on the future implementation of DG renewable energy.

- Funding mechanisms and or incentives: These might include low-interest loan programs, rebates on capital costs, tax incentives, attractive rates for power purchases/net metering, and other incentives.
- Voluntary and or negotiated agreements
- Codes and standards: Common interconnection rules and standards are needed. A national IEEE standard, IEEE #1547, has been adopted to facilitate DG installations. FERC has adopted a national standard interconnect standard for installation to transmission lines. In addition, States, including Texas, California, New Jersey, and New York, have adopted interconnect standards to facilitate DG installation²⁵.
- Market based mechanisms: Net metering for some renewable distributed generation systems, and possibly avoided-cost pricing rules for others²⁶.
- Pilots and demos, such as renewable systems in government buildings
- Research and development: Support for development of distributed renewable generation systems most germane to Arizona.
- Regulatory: Complete Environmental Portfolio Standard (EPS) process at the Arizona Corporation Commission, and complete Sustainable Energy process at the Salt River Project.²⁷

Related Policies/Programs in Place:

Salt River Project's Solarwise program; TEP and UES Sunshare PV buydowns; Arizona's state Solar and Wind Equipment Sales Tax Exemption; and existing Solar and Wind Energy Systems Tax Credits.

Types(s) of GHG Benefit(s):

- CO₂ reduction from avoided fossil-fueled electricity production.
- Modest reduction in emissions of CH₄ from avoided fuel combustion in electricity generation and avoided natural gas pipeline leakage. Likely small reductions in N₂O and Black Carbon emissions from avoided fuel combustion in electricity generation.

²⁵ Includes in part text provided by the Distributed Energy Association of Arizona.

²⁶ TWG members identified the need to coordinate with and support the ongoing ACC process on net metering as an important means toward achieving substantial use of distributed generation in Arizona. HB 2427 entitled "Tax Credit; Renewable Energy" creates new state income tax credits of 1.5 cents per kWh of electricity generation (and 1.1 cents per hp-hr of mechanical energy produced), beginning in 2007, for individual or corporate taxpayers who produce and sell power from "qualified energy resources", including solar, wind, closed-loop biomass, geothermal, small irrigation power, and combined heat and power. See http://www.azleg.state.az.us/FormatDocument.asp?inDoc=/legtext/47leg/2r/summary/h.hb2427_02-21-06_caucuscow.doc.htm

²⁷ Includes in part text provided by the Distributed Energy Association of Arizona.

Estimated GHG Savings and Costs per tCO₂e:

RCI-7	2010	2020	Units
GHG Emission Savings	0.1	2.1	MMtCO ₂ e
Net Present Value (2006-2020)		\$293	\$ million
Cumulative Emissions Reductions (2006-2020)		10	MMtCO ₂ e
Cost-Effectiveness		\$31	\$/tCO ₂ e

Discussion of Results: Net emissions reductions as calculated include consideration of avoided central station electricity generation, less modest net GHG emissions from additional fuel use (biomass, biogas, and landfill gas). Most of the costs and savings from this policy are from installation of solar PV systems; under current assumptions, a cumulative 850 MW of Solar PV are installed through 2020.

Data Sources, Methods, and Assumptions:

- **Data Sources:** Arizona "State Fact Sheet" from the Southwest Energy Efficiency Project's Report [Increasing Energy Efficiency in New Buildings in the Southwest: Energy Codes and Best Practices](#); USDOE/EIA document [2003 Commercial Buildings Energy Consumption Survey Detailed Tables](#); Worksheet "Solar Homes Summary table.xls", with calculations in support of the California Million Solar Homes Initiative, authored by XENERGY, Inc., and provided by M. Lazarus; [Arizona Consumer's Guide to Buying a Solar Electric System](#), from the Arizona Solar Center; sources with information on Photovoltaic costs.
- **Quantification Methods:** Projection of the number of new and existing homes, and new and existing commercial floor space, in Arizona through 2020 were coupled with an initial estimate for the penetration of solar PV panels and estimates of solar PV current and future costs to yield estimates of solar PV capacity and performance by year.
- **Key Assumptions:** Rates of growth of housing and commercial floor space; addition of residential and commercial PV systems at a penetration rate roughly consistent with that assumed for the "Million Solar Homes" initiative in California; annual solar capital cost reductions of about 5%, and addition of a total of 10 MW of new customer-sited biomass/landfill gas/biogas-fueled capacity per year by 2020.

See the document referenced on page G-3 of this Appendix for a more detailed listing of methods, data sources, and assumptions used in this analysis.

Key Uncertainties:

Future solar PV costs, solar PV penetration rates.

Ancillary Benefits and Costs²⁸:

- Increased flexibility of electricity supply for consumers hosting generation.
- Central-station power plant cooling water savings

²⁸ Some of these additional benefits are adapted from those listed on page 2 of the WGA CDEAC Energy Efficiency Task Force report.

- Potential local air quality impacts (may be positive or negative, depending on technology)
- Saving consumers and businesses money on their energy bills (and/or offering a new income stream)
- Reducing dependence on imported fuel sources, and reducing vulnerability to energy price spikes
- Where waste biomass fuels are used, possible reduction in disposal cost, reduction in environmental impacts related to disposal
- Electricity (grid) system benefits: reduced peak demand, reduced capital and operating costs, improved utilization and performance of the electricity system, reduced pollutant emissions from power plants and related health improvements
- Supporting local businesses (related to renewable system sales, installation, and service, and possibly biomass fuel supply) and stimulating economic development.

Feasibility Issues:

None cited.

Status of Group Approval:

Completed.

Level of Group Support:

Unanimous.

Barriers to Consensus:

None cited.

RCI-8 Electricity Pricing Strategies

Policy Description:

Adjustments in electricity pricing to reflect the true time-dependent cost and value of generation are suggested as means to both lower the overall costs and emissions from electricity system operation and to encourage the implementation of clean customer-sited combined heat and power and distributed generation.

Policy Design:

As with other energy and non-energy commodities, the pricing of electricity—including electricity from the grid used by consumers and electricity generated on the consumers' premises flowing to the grid—can have a significant impact on consumers' usage decisions. Proper and clear electricity tariffs and price signals can provide significant encouragement to distributed generation, energy conservation (in many forms), and reduction of electricity use during times of peak electricity demand. Creating such tariff structures may involve restructuring tariffs to provide incentives for “shoulder²⁹” and peak demand reduction—for example, through implementation of time-of-use energy charges—as well as setting net metering or other rules for sales from distributed generation to the grid that provide appropriate credit for the electricity generated during periods of high power demand³⁰. Changes in tariff structures are also needed that revise the balance between energy and demand charges and change the way that demand charges are fixed. These changes should be designed so as to provide improved incentives for end-users to adjust the timing of energy use so as to reduce greenhouse gas emissions as much as possible. The initiation of inverted block rates, where higher tariffs are charged once electricity use per household (for example) reaches a threshold level each month, is also recommended.

These tariff and pricing changes should be implemented by a set date in the future so as to remove barriers to and create incentives for customer-sited CHP and renewable generation as soon as possible. Note that it will likely not be possible to isolate the impacts of these tariff and pricing changes from policies such as RCI-1, RCI-2, RCI-6, and RCI-7, and as such the costs and impacts of these tariff and pricing policies will likely be taken into account in the quantification of costs and impacts other RCI policies (which RCI-8 policies support). To avoid double counting, then, the costs and impacts of tariff and pricing changes (with the exception of inverted block rates) will not be quantified separately³¹.

²⁹ “Shoulder” periods of electricity demand occur in the periods before and after the period of daily system peak power demand.

³⁰ A CCAG member noted that tariff changes that result in a shift in demand will not necessarily result in a reduction of carbon emissions from electricity generation, as emissions changes will depend on which generation units are affected by shifts in load.

³¹ A CCAG member suggested that those pricing strategies that result in a net reduction in electricity consumption might result in quantifiable savings, and suggested that “moderate importance” be placed on further investigating such strategies, and that the topic be addressed in the next RCI TWG meeting. The impacts of these strategies were subsequently quantified, as noted below.

Implementation Method(s):

Note that in the list of incentives below, rate designs, codes and standards, market-based mechanisms, and funding mechanisms and/or incentives (in that order) are considered by the TWG to be of primary importance, while other mechanisms are considered of secondary importance.

- Information and education: Would include programs for consumer education, information for distributed generation hosts.
- Technical assistance: Assistance to consumers/potential distributed generation hosts in economic analysis of potential systems
- Funding mechanisms and or incentives: Pricing incentives/TOU pricing
- Codes and standards: Common interconnection rules and standards are needed. A national IEEE standard, IEEE #1547, has been adopted to facilitate DG installations. FERC has adopted a national interconnect standard for installation to transmission lines. In addition, several States, including Texas, California, New Jersey, and New York, have adopted interconnect standards to facilitate DG installation³².
- Market based mechanisms: Net metering for some renewable distributed generation/CHP systems, avoided-cost pricing rules for others, TOU tariffs. Inverted block rates to spur conservation of electricity use by households using above-average quantities of electricity.
- Pilots and demos: Pilot TOU rate implementation, and pilot renewable and CHP systems in government buildings, with tracking of costs/income
- Research and development: Support for development of electricity pricing systems
- Rate Designs: Incorporate new rate designs in current DG Workshops and upcoming APS rate case. Legislative action may be needed requiring new Salt River Project standards be implemented.

Related Policies/Programs in Place:

APS Commercial Peak Reduction Campaign

Types(s) of GHG Benefit(s):

Policy contributes to:

- CO₂ reduction from avoided electricity production and avoided on-site fuel combustion less additional on-site CO₂ emissions from fuel used in CHP systems.
- Other gases: modest potential changes in emissions of CH₄: from avoided fuel combustion and avoided natural gas pipeline leakage, net of any additional on-site emissions or additional leakage from increased gas use, likely relatively small reductions in emissions of N₂O: from avoided fuel combustion, net of any increased on-site emissions, and also some possible small net changes in emissions of black carbon, depending on the balance between avoided and additional consumption of oil, coal, and biomass fuels, and of emission control equipment used on CHP and heating systems.

³² Portions of this description were adapted from text provided by the Distributed Energy Association of Arizona through TWG member Penny Allee Taylor.

Estimated GHG Savings and Costs per tCO₂e (quantified for inverted block rates only):

RCI-8	2010	2020	Units
GHG Emission Savings	1.1	1.5	MMtCO ₂ e
Net Present Value (2006-2020)		-\$985	\$ million
Cumulative Emissions Reductions (2006-2020)		16	MMtCO ₂ e
Cost-Effectiveness		-\$63	\$/tCO ₂ e

Data Sources, Methods, and Assumptions:

- **Data Sources:** For impacts of inverted block rate and similar tariff structures, the SWEEP “New Mother Lode” study provides one of the few available estimates, and is thus used here. Studies of similar programs in Utah and elsewhere may be used in the future to estimate the impacts of the inverted block rate element of this policy.
- **Quantification Methods:** Note that it will likely not be possible to isolate the impacts of these tariff and pricing changes from policies such as RCI-1, RCI-2, RCI-6, and RCI-7, and as such the costs and impacts of these tariff and pricing policies will likely be taken into account in the quantification of costs and impacts other RCI policies (which RCI-8 policies support). The net impacts of TOU rates may be positive or negative, but probably should be assessed as a part of other policies. To avoid double counting, then, the costs and impacts of tariff and pricing changes will likely not be quantified separately. Inverted block tariff structures, which may yield significant overall demand reduction, are quantified based on the estimated monthly savings from implementation of an aggressive, but revenue-neutral, tariff structure.
- **Key Assumptions:** Impact of suggested policies on uptake of consumer -sited CHP and renewable generation in Arizona; impact of TOU rates on utility load curves.

Key Uncertainties:

None cited.

Ancillary Benefits and Costs³³:

- Increased flexibility of electricity supply for consumers hosting generation.
- Central-station power plant cooling water savings
- Potential local air quality impacts (may be positive or negative, depending on technology)
- For pricing that induces new distributed generation, saving consumers and businesses money on their energy bills (and/or offering a new income stream)
- Some pricing structures may have negative impacts on low-income consumers—need to adopt rate designs or mitigating programs to address such impacts as a part of implementation strategies.

³³ Some of these additional benefits are adapted from those listed on page 2 of the WGA CDEAC Energy Efficiency Task Force report.

- Reducing dependence on imported fuel sources, and reducing vulnerability to energy price spikes
- Where waste biomass fuels are used, possible reduction in disposal cost, reduction in environmental impacts related to disposal
- Electricity (grid) system benefits: reduced peak demand, reduced capital and operating costs, improved utilization and performance of the electricity system, reduced pollutant emissions from power plants and related health improvements
- Supporting local businesses (related to renewable system sales, installation, and service, and possibly biomass fuel supply) and stimulating economic development

Feasibility Issues, if applicable:

None cited.

Status of Group Approval:

Completed.

Level of Group Support:

Unanimous.

Barriers to Consensus:

None cited.

RCI-9 Mitigating High Global Warming Potential (GWP) Gas Emissions (HFC, PFC)

Policy Description:

A combination of voluntary agreements with industries and of new specifications for key equipment is suggested to reduce the emissions of process gases that have high global warming potential.

Policy Design:

Based on a review of available options to further reduce high-GWP gas emissions in the RCI sectors, the TWG suggests further consideration of specifications for new commercial refrigeration equipment.³⁴ Such specifications and possible voluntary incentives—now under consideration and analysis by the California Air Resources Board—would: a) promote the use of low GWP refrigerants³⁵ in refrigerators in retail food stores, restaurants, and refrigerated transport vehicles (trucks and railcars); and/or b) require or provide incentives that centralized systems with large refrigerant charges and long distribution lines be avoided in favor of systems that use much less refrigerant and lack long distribution lines.³⁶ It is specifically recommended that the Governor explore working with California and other states in addressing HFC emissions from refrigeration.

While a focus on commercial refrigeration emerged from TWG discussions, participants also noted that maintaining momentum of voluntary industry-government partnerships (such as the semi-conductor industry agreement) should be a high priority.

Implementation Method(s):

These could consist of hybrid approach, combining market-based incentives and codes and standards (specifications).

Related Policies/Programs in Place:

- The Intel voluntary agreement noted above is producing significant reductions in PFC emissions from semiconductor manufacturing. Intel estimates that, in their Arizona

³⁴ Based on the current AZ emissions inventory and projection, GHG emissions from hydrofluorocarbons (HFCs) could grow from about 1 MMtCO₂e or <1% of Arizona GHG emissions in 2000 to over 7 MMtCO₂e or about 5% of state emissions by 2020. Most HFC emissions are expected to result from leaks in mobile air conditioning and refrigeration applications. Other sources of high Global Warming Potential (GWP) gases, which include the emission of perfluorocarbons (PFCs) and HFCs and from semiconductor manufacture and leakage of sulfur hexafluoride (SF₆) from electricity distribution equipment, contribute less to state emissions, and these emissions are expected to decline based on existing emission reduction efforts, such as the semiconductor industry's voluntary worldwide agreement.

³⁵ Examples include lower GWP HFCs, carbon dioxide, and hydrocarbons (propane or isobutene/propane blend).

³⁶ A CCAG member suggested following up in additional detail the specifications for using substitute for high-GWP gases now being discussed or in place in California, and which might be considered for Arizona. Another CCAG member noted that there are existing data on reduction of PFC use in the electronics industry that should be reviewed by the TWG. Also mentioned by the CCAG was the desire to consider progress in the reduction of SF₆ use in the electric utility sector.

operations, PFC emissions will be reduced 0.22 MMtCO₂e below 2000 levels by 2010. This estimate is reflected below.³⁷

Types(s) of GHG Benefit(s): This policy option would directly reduce HFC emissions. There is a possible rebound effect if substitute refrigerants are used and are less energy-efficient, which might increase CO₂ emissions from electricity production.

Estimated GHG Savings and Costs per tCO₂e:

Recent Actions (GHG Emissions Savings from semi-conductor industry voluntary agreement)	2010	2020	Units
Total	0.22	0.22	MMtCO ₂ e

Key Uncertainties:

None cited.

Ancillary Benefits and Costs:

None cited.

Feasibility Issues:

None cited.

Status of Group Approval:

Completed.

Level of Group Support:

Unanimous.

Barriers to Consensus:

None cited.

³⁷ The state inventory and forecast for PFC emissions is based on the national USEPA projections, which assume a significant drop in emissions by 2010 and 2020 due to the industry voluntary agreement. Therefore these reductions are likely already included in the forecast; they are reported here for transparency and future reference.

RCI-10 Demand-Side Fuel Switching

Policy Description:

Reductions in greenhouse gas emissions can be achieved in the residential, commercial and industrial end-use sectors when consumers switch to the use of less carbon-intensive fuels to provide key energy services.

Policy Design:

Fuel switching opportunities can include using natural gas in the place of electricity for thermal end-uses, natural gas in the place of coal for key industrial end-uses, biomass fuels in the place of electricity or natural gas for thermal end-uses, and solar thermal energy in the place of electricity or natural gas for thermal end-uses.

The three following options are proposed:

- Phase I: Promotion of switching from high-carbon fuels to lower-carbon fuels (such as from oil or coal to natural gas).
- Phase II: Promotion of “low or zero carbon” fuels via incentives.³⁸
 - The promotion of solar water heating through a combination of incentives and targeted research. These would build on incentives that already exist in the State.
 - The substitution of biodiesel for diesel in commercial and industrial equipment. Inventory estimates suggest that diesel/distillate fuel use in commercial and industrial sectors comprised 2-3% of the state’s emissions in 2003 (2.3 million MM_TCO_{2e}), thus the potential for emissions reductions could be quite significant.

Goals: Given the limited amount of coal use in the RCI sectors Arizona, and the site-specific issues (e.g. in cement production), goals for, and analysis of, switching among fossil fuels (Phase I) have not yet been developed. For the Phase II options, in order to develop a rough quantification, the CCS team used some simple placeholders for the biofuels and solar water heating options. These should not be viewed as specific recommendations, but rather a way to gauge emissions impacts and to kick-start further discussions.

- **Biofuels.** There are at least two possible approaches here: a) biofuels are blended and supplied statewide as the standard filling station fuel (engine modifications unlikely to be required); b) pure biofuels (such as 100% biodiesel) are purchased directly by consumers and used in engines or other applications with technical modifications, if and as needed. To get an order of magnitude estimate of potential

³⁸ CCAG members have noted the importance of considering the cost of fuel-switching alternatives on a cost per ton of carbon savings basis, as well as the need to consider incentive structures that allow the users of alternate-fuel systems to pay back incentives over time so as to reduce the cost burden on society as a whole. CCAG members also noted that there could be a tradeoff between new incentives provided for the use of low/no-carbon fuels and current incentives effectively in place for fossil fuels, as well as tradeoffs between the costs of action to reduce greenhouse gas emissions and the costs of inaction.

savings, we estimated emissions savings for a scenario in which biodiesel displaces 2% of diesel use by 2010 and rising to 20% by 2020.

- **Solar Water Heat.** For illustrative purposes we assume that solar water heaters could provide 70% of the energy needed in 5% of water heating applications (residential/commercial) by 2010, and in 25% of applications by 2020.

Implementation Method(s):

The following mechanisms could be implicated.

- Further tax or other financial incentives for solar water heating systems (see BAU policies).
- Targeted research at Arizona universities and research institutions to develop new and more cost-effective solar water heating technologies.
- Policies to promote the uptake of biofuels in commercial and industrial applications (See Transportation TWG)

Related Policies/Programs in Place:

- Arizona's Solar Energy Credit provides an individual taxpayer with a credit for installing a solar or wind energy device at the taxpayer's Arizona residence. The credit is allowed against the taxpayer's personal income tax in the amount of 25% of the cost of a solar or wind energy device, with a \$1,000 maximum allowable limit, regardless of the number of energy devices installed.
- Arizona provides a sales tax exemption for the sale or installation of "solar energy devices". A solar energy retailer may exclude from tax up to \$5,000 from the sale of each solar energy device, and a solar energy contractor may exclude up to \$5,000 of income derived from a contract to provide and install a solar energy device.

Types(s) of GHG Benefit(s):

Solar water heating will avoid CO₂ emissions from displaced fuel use (e.g. gas) or electricity generation. Biofuels will avoid CO₂ emissions from diesel and gasoline combustion; however, lifecycle emissions from the production of biofuels need to be considered, and these could involve N₂O emissions from crop production. Other emissions impacts are likely to be relatively insignificant.

Estimated Illustrative GHG Savings and Costs per tCO₂e:

RCI-10	2010	2020	Units
GHG Emission Savings	0.1	1.2	MMtCO ₂ e
Net Present Value (2006-2020)		\$0	\$ million
Cumulative Emissions Reductions (2006-2020)		7	MMtCO ₂ e
Cost-Effectiveness		Not Estimated	\$/tCO ₂ e

Other Key Results (RCI-10)	2010	2020	Units
GHG Emission Savings from Solar Water Heating	0.09	0.71	MMtCO ₂ e
GHG Emission Savings from Biodiesel	0.04	0.47	MMtCO ₂ e

Discussion: This analysis reflects a very rough estimate of impacts as noted above. As a result, costs are not estimated.

Data Sources, Methods, and Assumptions:

See the document referenced on page G-3 of this Appendix for a more detailed listing of methods, data sources, and assumptions used in this analysis. In summary:

- **Data Sources:** Key data sources include Argonne National Laboratory (life cycle biofuel CO₂e emissions), Lawrence Berkeley Laboratory and Public Service of New Mexico (to estimate electricity and gas used for water heating – no AZ data sources were found).
- **Quantification Methods:** The estimated emissions reductions are calculated in a straightforward manner based on multiplication of the various factors and assumptions noted here.
- **Key Assumptions:** See under “goals” above. It is assumed that most ethanol is provided from corn, and that by 2020, 20% of ethanol would be provided by cellulosic sources. Biodiesel is assumed to reduce the life-cycle GHG emissions of diesel by 78% on a tCO₂e/Btu basis.

Key Uncertainties:

None cited.

Ancillary Benefits and Costs:

- Potential local air pollution impacts (from switching from electricity to on-site fuels combustion, or from gas to other fuels)
- Potential local and state economic co-benefits [including rural employment] from using local biomass fuel supplies and installation of solar water heating systems.
- Biomass fuel supply/use may interact with land use, forestry, local air quality issues (from notes in the RCI TWG Policy Matrix).

Feasibility Issues:

None cited.

Status of Group Approval:

Completed.

Level of Group Support:

Unanimous.

Barriers to Consensus:

None cited.

RCI-11 Industrial Sector GHG Emissions Trading or Commitments

Note: This Option Is Moved to ES-4. During the May 16, 2006, CCAG meeting, it was agreed that further consideration of this option would be as part of Energy Supply option ES-4 (Cap and Trade Program). In Arizona, GHG emissions from power plants are likely to be over 10 times higher than emissions from industrial sources large enough to likely be included in a cap and trade program. Given that a common cap and trade program would likely apply to all sources (industrial and power supply), it was felt that the common discussions should occur within the ES group (with RCI participation).

Policy Description:

Industrial sector GHG emissions trading systems, with mandatory “caps” or voluntary emissions, are a means of limiting overall emissions while providing firms with choices as to how emissions limits will be achieved.

Policy Design:

Emissions cap and trade programs and/or voluntary emissions targets are options that have been considered for systematically addressing industrial sector GHG emissions. For example, a number of large industries (such as steel and cement) are included within the European emissions trading system, and have been proposed for inclusion in national legislation. Voluntary commitments have also been adopted within the US and internationally, exemplified by the US Climate Leaders program. This policy option specifically addresses how industrial sector sources would be addressed by trading systems and/or voluntary commitments.

The TWG suggests that an important first step would be to encourage the adoption of procedures to assist in the development of organizational GHG inventories, as would be enabled by a GHG registry.

RCI TWG members believe that emissions trading³⁹, in general, is a good idea. TWG members feel that a regional or national program approach would be preferable to a state level one. They feel that because the CCAG is a state-level advisory group, it may exceed the mandate of the CCAG to attempt development of a straw proposal; rather, an institution at a regional level or national level would best develop the concept and design elements. A recommendation for the CCAG to consider is a request that the governor explore a regional emissions trading program in a regional forum and/or advocate for development of national program.

³⁹ Some TWG members feel that reference to emissions trading should explicitly include consideration of an emissions cap. There was not full TWG consensus on this matter. Some CCAG members also felt that a cap on emissions, possibly even at the State level, should be considered, perhaps in a phased manner, with a (combined RCI and ES) cap system put in place first for utilities, with industrial sector emitters covered by the program in a later phase, although another CCAG member suggested that if industries make significant progress in reducing emissions on their own, a cap for industries may not be needed.

RCI-12 Solid Waste Management

Policy Description:

This policy option considers several options to increase recycling and reduce waste generation in order to limit greenhouse gas emissions associated with landfill methane generation and with the production of raw materials.

Policy Design:

In 2005, over 3 million residents in 39 Arizona communities had access to residential curbside recycling, representing slightly over 50% of the state's population. To further increase the diversion of waste from landfill and the amount of materials recycled, the State should aim to:

- Ensure that curbside recycling programs are provided in all communities over 50,000 in population;
- Increase the penetration of recycling programs in multi-family dwellings;
- Create new recycling programs for the commercial sector;
- Provide incentives for the recycling of construction materials;
- Develop markets for recycled materials;
- Increase average statewide participation/recovery rates for all existing recycling programs; and,
- Develop a statewide recycling goal.

Implementation Method(s):

Implementation options that should be considered include:

- **Expansion of ADEQ Waste Reduction Assistance (WRA) grants.** Grants can target projects that include new or expanded curbside recycling programs. Grants for new and expanded recycling programs to help overcome initial cost barriers faced by communities;⁴⁰
- **Mandatory source separation and recycling laws or ordinances in urban areas.** Municipalities in several states require households or businesses to use recycling containers or services for targeted materials (e.g. office paper, home recyclables).⁴¹ Some AZ solid waste experts feel that such measures may be needed if participation rates are to be increased, and suggest starting with banning of landfill disposal of consumer electronics (a toxics hazard) to evaluate feasibility;

⁴⁰ In 2006, four of the six awards were to communities for such projects.

⁴¹ For instance, participants using standard waste containers for targeted items may be issued warning notices and/or fines for non-compliance.

- **Tax breaks or other incentives** to make recycling financially attractive for private commercial sector waste haulers;
- **Full recycling as a contract requirement for state facilities;**
- **Government purchasing requirements for recycled content** of items purchased (paper, carpets, etc.);
- **Waste education campaign**, aiming at waste reuse and reduction, and targeting greenhouse gas reductions; and,
- **General awareness building**, e.g., working with community leaders to appreciate benefits and cost-effectiveness of curbside recycling.

Related Policies/Programs in Place:

See above.

Types(s) of GHG Benefit(s):

Waste prevention and recycling (including composting) divert organic wastes from landfills, thereby reducing the methane released when these materials decompose. Manufacturing goods from recycled materials typically requires less energy than producing goods from virgin materials. Waste reduction and reuse means less energy is needed to extract, transport, and process raw materials and to manufacture products.⁴²

Estimated GHG Savings and Costs per tCO₂e (for quantified actions):

RCI-12	2010	2020	Units
GHG Emission Savings	2.2	3.7	MMtCO ₂ e
Net Present Value (2006-2020)		\$0	\$ million
Cumulative Emissions Reductions (2006-2020)		36	MMtCO ₂ e
Cost-Effectiveness		Not Estimated	\$/tCO ₂ e

Note that about 15% of the above savings is estimated to be from avoided emissions from land filling (largely avoided methane release), and these savings should occur within the state. The other 85% is associated with avoided emissions related to the lower life cycle emissions of recycled compared with virgin products (wood harvesting, pulp and paper processing, transportation). To the extent that paper is manufactured outside the state, these emissions reductions will also occur outside the state.

Data Sources, Methods, and Assumptions:

- **Data Sources:** Key data sources include ADEQ (recycling amounts), USEPA studies (results from studies of life-cycle GHG emissions associated with managing waste materials)
- **Quantification Methods:** Assumes above efforts can increase amount of paper recycled by 600,000 short tons by 2010 and 1,000,000 short tons by 2020. Benefits from increased recovery of other materials not yet considered.

⁴² Adapted from USEPA. See website for further details:
<http://yosemite.epa.gov/OAR/globalwarming.nsf/content/ActionsWasteBasicInfoGeneral.html>

- **Key Assumptions:** Assumes national average landfill practices (methane recovery), transport distances, and waste composition (in a given category).

Key Uncertainties:

Key uncertainties are related to the feasibility and impact of the above recommendations.

Ancillary Benefits and Costs:

These could include:

- Reduction in environmental impacts related to disposal of wastes that are recycled and/or composted
- Income from sales of recycled materials, savings from avoided cost of landfill tipping fees
- Reduction of impacts related to manufacturing of new materials through recycling
- Local economic benefits from businesses engaged in recycling or reuse-related activities

Feasibility Issues:

None cited.

Status of Group Approval:

Completed.

Level of Group Support:

Unanimous.

Barriers to Consensus:

None cited.

RCI-13 Water Use and Wastewater Management

Policy Description:

A considerable amount of energy is used to pump, treat, and deliver water across the state. This policy options aims to reduce energy consumption by reducing overall water use and improving the efficiency of water supply and wastewater facilities.

Policy Design:

The State currently uses about 7.7 million acre-feet (MAF) of water, 77% of which is delivered to agricultural consumers, 18% to municipal consumers, and the remainder to industrial users. A significant amount of energy is used to pump this water from underground aquifers (3.6 MAF), from the Colorado River (2.6 MAF), and other sources (1.2 MAF), and to treat it in wastewater facilities after it is used.⁴³ Five specific recommendations are provided below:

1. Accelerate investment in water use efficiency: Implement best management practices and efficient water management practices, and provide incentives for implementation of water management improvement measures. Coordinate with the investments in energy efficiency (RCI-1). Start in the areas of the state with most energy-intensive water use cycles. Consider developing a statewide water and wastewater savings plan, based on a thorough assessment of water and wastewater options in all water using sectors.
2. Increase the energy efficiency of all water and wastewater treatment operations. Develop long-term programs to better mesh with the long-term investments in water and wastewater infrastructure. For example, for water pumping, in particular, two specific options are worth considering:⁴⁴
 - Pump Testing Program. A large amount of energy is likely expended by a small number of older well pumps that are often run until they failure, many years after it would be economic to replace them. Incentives combined with the provision of energy efficiency information through the existing DWR pump testing program could lead to significant energy savings.
 - Encouraging Pump Design/Planning/Maintenance Best Practices Study in Rapidly Growing Areas. Many municipalities, especially small but rapidly growing cities, lack the experience or resources to optimize the specifications of new pumps to reduce energy consumption. An effort to benchmark effective pump specification, management, and maintenance procedures across municipalities and to share best practices with emerging cities could yield large savings.

⁴³ Other sources include the Salt and Gila Rivers. For a good description of the state's water sources and uses, see http://www.tceq.state.tx.us/assets/public/compliance/R15_Harlingen/US-MX%20BGC%20Water%20table%20documents/US%20States/Arizona/bgc_resources_and_issues_presentation_final.ppt.

⁴⁴ Thanks go to Chico Hunter of SRP for valuable inputs on this option.

3. Increase energy production by water and wastewater agencies from renewable sources such as in-conduit hydropower and biogas. Add generation from solar and wind resources to water and wastewater projects where applicable.
4. Encourage and create incentives for technologies with the capability to reduce water use associated with power generation. Included would-be zero- or low-water-use technologies and renewable energy technologies, as well as energy efficiency technologies that reduce electricity consumption.
5. Ensure that power plants use the best management practices and economically feasible technology available to conserve water (via siting, evaluation, permitting or other processes).

Implementation Method(s):

Specific implementation strategies are to be determined.

Related Policies/Programs in Place:

The AZ Department of Water Resources maintains a number of water management programs and policies.⁴⁵

Types(s) of GHG Benefit(s):

GHG benefits (primarily CO₂) would result from avoided fuel and electricity consumption for pumping, treating, and delivering water.

Estimated Illustrative GHG Savings and Costs per tCO₂e:

RCI-13	2010	2020	Units
GHG Emission Savings	0.2	0.8	MMtCO ₂ e
Net Present Value (2006-2020)		\$0	\$ million
Cumulative Emissions Reductions (2006-2020)		6	MMtCO ₂ e
Cost-Effectiveness		Not Estimated	\$/tCO ₂ e

This analysis illustrates very roughly the magnitude of GHG savings that might result if state water use could be reduced by 10% compared with current usage levels by 2020 (i.e. by 0.8 MAF). Note that improvements in pump efficiency would provide GHG savings over and above this level; however, pump efficiency improvement potentials may already be partly taken into account in RCI-1 (for electric pumps only).

Data Sources, Methods, and Assumptions:

See the document referenced on page G-3 of this Appendix for a more detailed listing of methods, data sources, and assumptions used in this analysis. Sufficient information for cost-effectiveness assessment is not available. In summary:

- **Data Sources:** Arizona Department of Water Resources (water use levels) and California State Agencies (energy use and GHG emissions related to water use).

⁴⁵ See, for example, http://www.tceq.state.tx.us/assets/public/compliance/R15_Harlingen/US-MX%20BGC%20Water%20table%20documents/US%20States/Arizona/bcgwater_admin_overview.doc.

- **Quantification Methods:** The above estimate assumes a 10% water savings (relative to current levels) is achieved by 2020 (3% by 2010), and that 1 MtCO_{2e} could be avoided for each MAF saved (based on CA estimates).
- **Key Assumptions:** The key assumption is that a 10% water savings is achievable by 2020.

Key Uncertainties:

Key uncertainties are related to the feasibility and impact of the above recommendations.

Ancillary Benefits and Costs:

These could include:

- The ancillary benefits and costs described for other energy efficiency options (see RCI-1)
- Reduced cost of electricity for water pumping displaced fuels costs for users of landfill gas and captured gas from waste treatment facilities.
- Central-station power plant cooling water savings
- Reducing dependence on imported fuel sources, and reducing vulnerability to energy price spikes

Feasibility Issues:

None cited.

Status of Group Approval:

Completed

Level of Group Support:

Unanimous

Barriers to Consensus:

None cited.

- **Quantification Methods:** The above estimate assumes a 10% water savings (relative to current levels) is achieved by 2020 (3% by 2010), and that 1 MtCO_{2e} could be avoided for each MAF saved (based on CA estimates).
- **Key Assumptions:** The key assumption is that a 10% water savings is achievable by 2020.

Key Uncertainties:

Key uncertainties are related to the feasibility and impact of the above recommendations.

Ancillary Benefits and Costs:

These could include:

- The ancillary benefits and costs described for other energy efficiency options (see RCI-1)
- Reduced cost of electricity for water pumping displaced fuels costs for users of landfill gas and captured gas from waste treatment facilities.
- Central-station power plant cooling water savings
- Reducing dependence on imported fuel sources, and reducing vulnerability to energy price spikes

Feasibility Issues:

None cited.

Status of Group Approval:

Completed

Level of Group Support:

Unanimous

Barriers to Consensus:

None cited.



**APPENDIX H: ENERGY SUPPLY -
DETAILED POLICY DESCRIPTION/ANALYSIS**

Overview

The Energy Supply (ES) sector includes emissions mitigation opportunities related to electrical energy supply options, including the generation, transmission, and distribution of electricity, whether generated through the combustion of fossil fuels or by renewable energy sources, and whether generated in a centralized power station or distributed generation facilities. Arizona has little oil and gas production, so the CCAG made no oil and gas recommendations.

The CCAG recommends a set of eight ES policy options that offer significant potential emission reductions. Three options quantified under the RCI sector are noted below but are not included in the ES sector totals in order to avoid double-counting. Similarly, the CCAG recommended in ES-4 that Arizona should advocate for a GHG cap and trade program at the regional or national level; values shown for it reflect a range of results over four scenarios. ES-10, Metering Strategies, is an enabling policy for greater penetration of clean distributed generation and energy efficiency technologies, so its reductions are quantified under other CCAG policy options.

Three policies are quantified as ES options that Arizona can implement on its own, including ES-1, Environmental Portfolio Standard/Renewable Energy Standard and Tariff; ES-6, Carbon Intensity Targets; and ES-12, Integrated Resource Planning. Because the purpose of ES-12 would largely be accomplished by (i.e., overlap with) the activities that would be undertaken to satisfy ES-1 and ES-6, only the results from ES-1 and ES-6 are included in the totals. Further, because either ES-1 or ES-6 would exhaust all available wind, biomass, and geothermal generation capacity within Arizona, GHG reductions from these resources are included only in ES-6 in order to avoid double-counting.¹

In a further effort to eliminate possible double-counting, ES-1 and ES-6 were evaluated with respect to the reference case electricity demand forecast in order to take into account the fact that other ES and RCI measures (e.g., energy efficiency and distributed generation) will reduce the demand for grid electricity generation. Because the GHG reductions associated with ES-1 and ES-6 are directly related to total MWhs generated, GHG reductions for ES-1 and ES-6 were adjusted downward to reflect this lower demand. Specifically, GHG reductions achieved by the ES policies were reduced by the same percentage as the RCI policies reduced grid electricity generation in order to approximate the combined results of ES and RCI policies.

As summarized in the table below, these policy recommendations could lead to emissions savings from reference case projections of 17.9 MMtCO₂e per year by 2020 and cumulative savings of 120.6 MMtCO₂e from 2007 through 2020. The weighted average cost of saved carbon from the policy options for which quantitative estimates of both costs and savings were prepared was \$20.57 per metric ton of CO₂ equivalent.

¹ ES-6 was chosen for relative ease of calculation; wind, biomass, and geothermal could have been included in ES-1 instead.

Energy Supply Sector Summary of Results

#	Policy Name	Estimated 2010 GHG Savings (MMtCO ₂ e)	Estimated 2020 GHG Savings (MMtCO ₂ e)	Estimated Costs or Cost Savings Per Ton (\$/MMtCO ₂ e)	Cumulative 2007-2020 GHG Savings (MMtCO ₂ e)	Level of CCAG Support	
ES-1	Environmental Portfolio Standard / Renewable Energy Standard and Tariff	<i>The quantification below reflects the results provided by ES-1 when integrated into the comprehensive package of approved CCAG policy options.</i>				70.3	Majority
		3.0	8.7	\$3.54			
		<i>The quantification below reflects the results provided by ES-1 when isolated as a single, stand-alone policy option.</i>					
		4.19	16.4	\$6.48	116		
ES-3	Direct Renewable Energy Support (including Tax Credits and Incentives, R&D, and siting / zoning)	<i>This option is quantified under RCI-7, Distributed Generation / Renewable Energy Applications. Values are shown below for completeness, but not included in cumulative totals to prevent double-counting.</i>				10	Unanimous
		0.1	2.1	\$31			
ES-4	GHG Cap and Trade	<i>Quantification for an aggressive national cap and trade scenario (Cap-Trade 4) as it would apply to Arizona's power sector is shown below. These values reflect the results of this scenario were it to be integrated into the comprehensive package of approved CCAG policy options.</i>				63.2	Unanimous
		0.12	12.2	\$18.45			
		<i>Four national cap and trade scenarios were modeled as they would apply to Arizona's power sector in order to gauge their impact if implemented as an isolated, single, stand-alone policy option. Ranges of results are shown below. These values are not included in cumulative figures.</i>					
		-0.28 – 0.18	2.0 – 18.5	\$7.29 – \$18.52	7 – 88		

ES-6	Carbon Intensity Targets	<i>The quantification below reflects the results provided by ES-6 when integrated into the comprehensive package of approved CCAG policy options.</i>				Majority
		0.0	9.2	\$44.33	50.3	
		<i>The quantification below reflects the results provided by ES-6 when isolated as a single, stand-alone policy option.</i>				
		0.0	14.0	\$44.56	70	
ES-9	Reduce Barriers to Renewables and Clean DG	<i>This option is quantified under RCI-6, Distributed Generation / Combined Heat and Power. Values are shown below for completeness, but not included in cumulative totals to prevent double-counting.</i>				Unanimous
		0.4	2.7	-\$25	16	
ES-10	Metering Strategies	<i>ES-10 is an enabling policy for RCI-6 and RCI-7; its quantification is incorporated into those options.</i>				Unanimous
ES-11	Pricing Strategies	<i>This option is quantified under RCI-8, Electricity Pricing Strategies. Values are shown below for completeness, but not included in cumulative totals to prevent double-counting.</i>				Unanimous
		1.1	1.5	-\$63	16	
ES-12	Integrated Resource Planning	<i>The quantification below reflects the results ES-12 would provide if implemented as a single, stand-alone policy option. When integrated into the comprehensive package of CCAG-approved policy options, however, it would target the same activities as ES-1 and ES-6, so its reductions and savings would not be included in order to avoid double-counting.</i>				Unanimous
		0.06	5.4	-\$2.50	28	
Total All Options		3.0	17.9	\$20.57	120.6	<i>Note: Total includes only ES-1 and ES-6.</i>

ES-1 Environmental Portfolio Standard / Renewable Energy Standard and Tariff (REST)

Policy Description:

An environmental portfolio standard (EPS) is a requirement that electric utilities must supply a certain percentage of electricity from environmentally friendly sources. An EPS differs from a Renewable Portfolio Standard (RPS) in that an EPS can include more options than renewables for meeting this requirement. Utilities can meet their requirements by purchasing or generating environmentally friendly electricity or by purchasing clean energy credits. By giving utilities the flexibility to purchase clean energy credits, a market in these credits would emerge that would provide an incentive to companies that are best able to generate clean energy, either through energy efficiency or renewables. Other options for meeting the requirement are possible, depending on how the EPS is structured. A provision could be included, for example, allowing funding for research and development to be applied toward meeting a utility's commitment.

Policy Designs:

The ES TWG analyzed five policy designs:

ES-1a(0): The likely changes by the Arizona Corporations Commission (ACC) to the EPS applied only to ACC-jurisdictional utilities: 5% in 2015, 15% in 2025; starting in 2007, 5% of the total renewable requirement must be from distributed renewables, increasing to 30% by 2011 and remaining at 30% in future years. Renewable Energy Credit (REC) trading is allowed, provided that all other associated attributes are retired when applying RECs to the Annual Renewable Energy Requirement. Out-of-state resources can be used provided that the necessary transmission rights are obtained and utilized.

ES-1a(1): The ACC's likely changes to the EPS, with the Salt River Project (SRP) continuing with its proposed renewable investments. The SRP has set a target to generate 15% of its electricity from renewable resources by 2025.

ES-1a(2): The ACC's likely changes to the EPS extended statewide.

ES-1b: Alternative scenario for ACC jurisdictional utilities: Starting with the current 1% target in 2005, increase 1% each year to 26% in 2025. Allow out-of-state renewables and REC trading.

ES-1c: Alternative scenario extended statewide.

- **Goal levels:** As noted above.-
- **Timing:** As noted above.
- **Parties:** Utilities as noted above.
- **Other:** Apply a least-cost approach, reflecting resource availability constraints, to determine which renewable energy resources and technologies would be used to meet the EPS (beyond the specific requirements laid out in the proposals).

Implementation Method(s):

- An EPS is usually implemented through a regulatory requirement (mandate) on the applicable utilities.

Related Policies/Programs in Place:

In the existing EPS, utilities (not including SRP) must generate a specified percentage of their total retail sales from renewable energy:

- Started in 2001 at 0.2% and increased annually to 1% in 2005; will increase to 1.1% in 2007. Expires in 2012.
- 2001–2003: 50% of EPS requirement must be solar electric; remainder can be other environmentally friendly technologies including no more than 10% R&D.
- 2004–2012: 60% of resources must be solar electric.
- Environmental Portfolio Surcharge of \$0.000875 per kWh with caps by customer class.

Type(s) of GHG Benefit(s):

- CO₂: By creating a substantial market in renewable generation, an EPS can reduce fossil fuel use in power generation, correspondingly reducing CO₂ emissions.
- Black Carbon: To the extent that generation from coal and oil is displaced by renewables, black carbon emissions would decrease.

Estimated GHG Savings and Costs per tCO₂e:

Initial estimates were calculated – using the data sources, quantification methods, and key assumptions indicated below – as follows for CCAG review:

#	Policy	Scenario	Reductions (MMtCO ₂ e)			NPV (2006–2020) \$ millions	Cost-Effectiveness \$/tCO ₂
			2010	2020	Cumulative Reductions (2006 - 2020)		
ES-1	RE/Std/Tariff, ES-1a(0)	ACC Proposal alone	0.80	4.4	26	331	13
ES-1	RE/Std/Tariff, ES-1a(1)	ACC Proposal + SRP program	1.39	8.0	47	366	8
ES-1	RE/Std/Tariff, ES-1a(2)	ACC Proposal Statewide	1.42	7.7	46	538	12
ES-1	RE/Std/Tariff, ES-1b	Alternative Proposal for ACC Utilities	2.31	9.2	65	281	4
ES-1	RE/Std/Tariff, ES-1c	Alternative Proposal Statewide	4.19	16.4	116	752	6

The CCAG ultimately chose ES-1c, *Alternative Proposal Statewide*, as its recommendation for this policy option, and the steps described in the final report were taken to eliminate any potential overlap with other CCAG recommendations, because this could result in double-counting of costs and benefits. After eliminating potential overlaps, the following values were reported to the CCAG:

#	Policy	Scenario	Reductions (MMtCO ₂ e)			NPV (2006–2020) \$ millions	Cost-Effectiveness \$/tCO ₂
			2010	2020	Cumulative Reductions (2006 - 2020)		
ES-1	RE/Std/Tariff, ES-1c	Alternative Proposal Statewide	3.0	8.7	70.3	249	3.54

Data Sources, Methods, and Assumptions:

- **Data Sources:** CDEAC, WECC, EIA, EPA, Arizona Solar Energy Center, "Assessment of Parabolic Trough and Power Tower Solar Technology Cost and Performance Forecasts" by Sargent & Lundy.
- **Quantification Methods:** A simple capacity expansion model was developed in Excel specifically for this policy option. A trajectory of MWhs needed to satisfy the REST requirement was calculated, both for central renewable generation and distributed renewables. Renewable and fossil technologies were characterized in terms of cost

and operating profiles, and available resources in the State were also defined. Technologies include three classes of wind, concentrating solar power, geothermal, biomass, landfill gas, distributed solar PV, distributed solar thermal, conventional coal, integrated gasification combined cycle with carbon capture and storage (IGCC with CCS), natural gas combined cycle (NGCC), and natural gas combustion turbines (NGCT). It was assumed that 75% of the Renewable Energy Standard and Tariff (REST) requirement would be met through REC trading. It was also assumed that corresponding CO₂ reductions would be bundled with the RECs and count toward the emission reduction performance of this policy. A \$5 per MWh REC price was assumed, which is consistent with available low-cost wind and other renewable resources in the West and is consistent with REC price assumptions in Integrated Resource Plans by various western utilities as reported in *Balancing Cost and Risk: The Treatment of Renewable Energy in Western Utility Resource Plans* (August 2005, Lawrence Berkeley National Laboratory). The model found the least-cost mix of renewables, constrained by available resources, to satisfy 25% of the central renewable requirement. An assumption that the distributed renewable requirement will be met by 50% solar PV and 50% solar thermal was made. Each renewable was also defined by the share of generation it displaces from NGCT, NGCC, and coal. The model then determines how many MWhs of NGCT, NGCC and coal would be displaced and the corresponding CO₂ emissions. The model also tracks the cost of generation for renewables and the displaced fossil; the present value of the difference is reported above.

- **Key Assumptions:** Cost and performance characteristics of generating technologies; resource availability; no demand response as a result of policy; no transmission and distribution modeled.

Key Uncertainties:

- As with any assessment of the future, this analysis has many uncertainties. Key uncertainties are, first, related directly to the key assumptions listed above. If those assumptions are incorrect, then the results would change. Other uncertainties include the forecast of the price of fossil fuels and the growth in the demand for electricity.

Ancillary Benefits and Costs:

- Reductions in overall energy consumption and the shift from fossil fuel generation resulting from an EPS would lead to reductions in criteria air pollutants and, consequently, lower health impacts and costs associated with those pollutants.
- Water use may be reduced through renewable versus combustion technologies.
- While much of the EPS requirement would come from low-cost renewables such as wind and biomass, meeting the requirement may lead to a moderate increase in direct costs to utilities implementing the EPS policy and a small increase in overall electricity system cost for Arizona. At the same time, investment in new technologies resulting from the EPS may spur economic development and corresponding job growth, and to the extent the renewable energy is derived from Arizona-based capital projects, generate additional local tax revenues.

Feasibility Issues:

- None cited.

Status of Group Approval:

Completed.

Level of Group Support:

Majority.

Barriers to Consensus:

Virtually all CCAG members concur with the idea of an EPS, but some felt that the majority option might be too aggressive. Some members of the CCAG affiliated with entities regulated by the ACC were not in a position to publicly support EPS requirements which depart from those being pursued by the ACC.

ES-3 Direct Renewable Energy Support (including Tax Credits and Incentives, R&D, and siting/zoning)

Policy Description:

The purpose of this suite of policies is to encourage investment in renewables by providing direct financial incentives and by removing siting and zoning barriers to renewable energy facilities. Funding R&D also encourages development of new renewable technologies.

Direct renewable energy support can take many forms including: 1) direct subsidies for purchasing/selling renewable technologies given to the buyer/seller; 2) tax credits or exemptions for purchasing/selling renewable technologies given to the buyer/seller; 3) tax credits or exemptions for operating renewable energy facilities; 4) feed-in tariffs, which are direct payments to renewable generators for each kWh of electricity generated from qualifying renewable facilities; and 5) tax credits for each kWh generated from a qualifying renewable facility.

R&D funding can be targeted toward a particular technology or group of technologies as part of a State program to build an industry around that technology and/or to set the stage for adoption of the technology in the State. R&D funding can also be made available to any renewable or other advanced technology through an open bidding procedure (i.e., driven by bids received rather than by an effort to develop a particular technology). Funding can also be provided for demonstration projects to help commercialize technologies that have already been developed but are not yet in widespread use.

Many renewable energy technologies – particularly wind power – face siting and zoning obstacles. Often the best wind resources are also in scenic areas, which can spur opposition to development. Further, they may not be near existing transmission lines. Policies can be developed to help overcome these barriers.

Policy Design:

This policy was identified by both ES and RCI TWGs. In order to avoid duplicative effort, it was analyzed under RCI-7, Distributed Generation/Renewable Energy Applications.

- **Goal levels:** As noted above.
- **Timing:** As noted above.
- **Parties:** A state agency would administer the direct subsidies, and individuals, commercial enterprises, and industrial enterprises would receive them. Utilities would administer a feed-in tariff under supervision of a state agency, and independent power producers operating qualifying renewable facilities would receive the payments. A state agency would administer R&D funding through a public-private partnership with companies and research institutions.

Note that a source of funds to cover subsidies or other support would have to be determined.

Implementation Method(s):

- Funding mechanisms and or incentives
- Pilots and demos
- Research and development

Related Policies/Programs in Place:

- Personal income tax credit for renewables, amounting to 25% of the cost of installation up to a maximum of \$1,000.
- Sales tax exemption for up to \$5,000 of the cost of a renewable installation.

Type(s) of GHG Benefit(s):

- CO₂: By providing a financial incentive for renewable generation and helping overcome siting and zoning barriers facing renewables, more renewable facilities would be installed and more electricity from renewables would be generated. This low-carbon generation would displace generation from fossil fuels and reduce carbon emissions. By funding R&D, new or improved renewable technologies would be developed or commercialized, leading to even more installations of renewables and a corresponding reduction in carbon emissions in the long term.
- Black Carbon: To the extent that generation from coal and oil would be displaced by renewables, black carbon emissions would decrease.

Estimated GHG Savings and Costs per tCO₂e:

- This option is quantified under RCI-7, Distributed Generation/Renewable Energy Applications

Data Sources, Methods, and Assumptions:

- See RCI-7, Distributed Generation/Renewable Energy Applications.

Key Uncertainties:

- See RCI-7, Distributed Generation/Renewable Energy Applications.

Ancillary Benefits and Costs:

- Reductions in overall electricity consumption and the shift from fossil fuel generation as a result of new renewables would lead to reductions in criteria air pollutants and, consequently, health costs associated with those pollutants.
- Water use may be reduced through renewable versus combustion technologies.
- Renewable resources may be less risky than fossil resources because they are not subject to unexpected changes in the price of fossil fuels.
- The operating costs of renewable generation – primarily maintenance – are spent locally and are a direct boost to local and state economies, whereas the primary cost of operating fossil fuel plants – fossil fuels – may go out of state and not contribute to the local or state economy.

Feasibility Issues:

- None cited.

Status of Group Approval:

Completed.

Level of Group Support:

Unanimous.

Barriers to Consensus:

None cited.

ES-4 GHG Cap-and-Trade Program

Policy Description:

A cap-and-trade system is a market mechanism in which CO₂ emissions are limited or capped at a specified level, and those participating in the system can trade permits (a permit is an allowance to emit one ton of CO₂) in order to reduce the costs of compliance. For every ton of CO₂ released, an emitter must hold a permit. Therefore, the number of permits issued or allocated is, in effect, the cap. The government can give permits away for free (according to any of many different criteria) to those participating in the system or even to those who are not, auction them, or a combination of the two. Participants can range from entities within a single sector to the entire economy and can be implemented upstream (at the level of fuel extraction or import) or downstream (at the points where fuel is consumed).

Policy Design:

The CCAG recommendation is to encourage the governor to explore development of a regional or national, economy-wide cap-and-trade program.

Some CCAG members also expressed interest in exploring a cap-only program for Arizona, but implementation of such a program would have effectively echoed other policy options considered, such as an EPS/REST (ES-1).

The ES TWG's investigation primarily concerned electric sector impacts of an economy-wide GHG cap-and-trade program implemented on a regional (multi-state) or preferably a national basis. The TWG considered existing studies of such programs to infer what the impact in Arizona may be. The TWG also considered the comparative costs of reaching a given cap on a national or a regional basis.

Other issues cited by the TWG as important in the design of a GHG cap-and-trade system include:

- Applicability (i.e., sources and sectors included)
- Gases included
- Permit allocation rules (method; options for new market entrants)
- Generation-based or load-based; leakage concerns
- Linkage to other trading systems
- Banking and borrowing; early reduction credits
- Inclusion of emission offsets (within or outside covered sector(s) or geography)
- Incentive opportunities (e.g., interaction with other pollution regulations like Pennsylvania's EDGE program).

For illustration of the potential impact of various levels of a national cap-and-trade program, four national cap-and-trade scenarios (described below under Goal Levels) were

considered.² The GHG reductions and costs reported further below reflect regional power-sector results that have been scaled to approximate what would occur in Arizona.

- **Goal levels:**

Case Name	Carbon Intensity (CI) Reduction Goal (% per year)		Safety-Valve Price (2004 dollars per tCO ₂ e)		Other
	2010-2019	2020-2030	2010	2030	
Cap-Trade 1	2.4	2.8	\$ 6.16	\$ 9.86	Greenhouse gas cap-and-trade system with safety valve.
Cap-Trade 2	2.6	3.0	\$ 8.83	\$ 14.13	
Cap-Trade 3	2.8	3.5	\$ 22.09	\$ 35.34	
Cap-Trade 4	3.0	4.0	\$ 30.92	\$ 49.47	

- **Timing:** As noted above.
- **Parties:** Economy-wide.

Implementation Method(s):

- A market-based mechanism with underlying regulatory obligation.
- Arizona cannot implement a regional or national cap-and-trade program on its own, but it can work with other jurisdictions and federal officials toward this outcome.

Related Policies/Programs in Place:

- No GHG cap-and-trade system is in place in Arizona.

Type(s) of GHG Benefit(s):

- **CO₂:** A cap-and-trade system is a direct limit on CO₂ emissions. The level of the cap determines reductions.
- **Black Carbon:** To the extent that electric generation from coal and oil would decline under a cap-and-trade system, black carbon emissions would also decrease.

² These scenarios were consistent with scenarios identified and published by the U.S. Energy Information Administration (EIA) in March 2006.

Estimated GHG Savings and Costs per tCO₂e:

Arizona doesn't have the authority alone to implement a national or regional cap-and-trade program. However, the CCAG wanted to have some awareness of what the impacts of such a program might be in Arizona. Accordingly, the ES TWG investigated power-sector GHG reductions and costs under the four EIA cap-and-trade scenarios noted above. This investigation yielded the following results:

#	Policy	Scenario	Reductions (MMtCO ₂ e)			NPV (2006– 2020) \$ millions	Cost- Effective- ness \$/tCO ₂
			2010	2020	Cumulative Reductions (2006-2020)		
ES-4	Cap - Trade 1	2.4%–2.8% CI, \$6.16–\$9.86 safety valve	-0.28	4.4	7	51	7
ES-4	Cap - Trade 2	2.6%–3.0% CI, \$8.83–\$14.13 safety valve	0.17	2.0	9	85	10
ES-4	Cap - Trade 3	2.8%–3.5% CI, \$22.09–\$35.34 safety valve	-0.20	16.5	63	1096	17
ES-4	Cap - Trade 4	3.0%–4.0% CI, \$30.92–\$49.47 safety valve	0.18	18.5	88	1630	19

Data Sources, Methods, and Assumptions:

- Data Sources:** Data for the electricity modeling done for this analysis comes from the U.S. Energy Information Administration (EIA) and can be found within the National Energy Modeling System (NEMS). Data in NEMS includes representation of the existing generation, transmission and distribution system down to the unit level. NEMS also includes data that characterizes new plants that the model can choose to build to meet projected demand growth. EIA's publication entitled *"Assumptions to the Annual Energy Outlook"* details key assumptions in the current version of the model. EIA also publishes NEMS model documentation.
- Quantification Methods:** The modeling presented here was done by the Energy Information Administration in a Congressional Service Report from March 2006 entitled *"Energy Market Impacts of Alternative Greenhouse Gas Intensity Reduction Goals."* The scenarios are listed above and reflect national cap-and-trade policies. Impacts were scaled to approximate the results in Arizona for the four scenarios presented here in the same way as for the NEMS modeling conducted specifically for this process. For the cap-and-trade scenarios, the cost of the policies was approximated by multiplying CO₂ reductions by one-half of the market price for CO₂ allowances. (The allowance price is the marginal price of allowances needed to produce the reported emission reductions; the actual cost of each ton of reductions ranges from zero up to the price of allowances. For simplicity, the actual cost is assumed to be an average of the high (the market clearing price) and low (zero) cost of reductions, which equals one-half of the market clearing price). Costs are reported as a net present value of the stream of costs from 2006 to 2020. The number of tons reduced was determined by calculating the difference between the emissions in

the policy case and those from a reference case NEMS run. Because the NEMS model is a national model with multi-state regions (Arizona is within the Rocky Mountain Power Area), the results for Arizona were derived from results in the region. Regional emissions and cost results were assigned pro rata according to the share of Arizona generation within the region.

- **Key Assumptions:** Any analysis of state-level policies using the National Energy Modeling System (NEMS) from the U.S. Energy Information Administration should be weighed carefully. NEMS is a national model that consists of 13 regions. State policies cannot be implemented explicitly within NEMS, and the State-specific impacts cannot be known explicitly. Assumptions must be made about the impact of policies at the State level by assigning shares of regional results. In reality, the State-level changes resulting from the policies implemented may differ substantially from the change in the region overall.

Key Uncertainties:

- As with any assessment of the future, this analysis has many uncertainties. Key uncertainties are related directly to the key assumptions and quantification methods listed above. If those assumptions were changed, then the results would change. Other uncertainties include the forecast price of fossil fuels and future growth in demand for electricity.

Ancillary Benefits and Costs:

- The shift from fossil fuel generation as a result of a cap-and-trade system would lead to reductions in criteria air pollutants and, consequently, health impacts and costs associated with those pollutants.
- Water use may be reduced through renewable versus combustion technologies.
- Allowing “offsets” from outside the capped sector can create the incentive to quantify and reduce GHG emissions from sources in other sectors.
- The shift in fossil fuel resources as a result of a cap-and-trade system could have unintended consequences, including increased cost of natural gas and need for additional natural gas infrastructure.

Feasibility Issues:

- None cited, apart from the far greater feasibility of a national or regional cap-and-trade system.

Status of Group Approval:

Completed.

Level of Group Support:

Unanimous.

Barriers to Consensus:

The CCAG’s explicit preference was for a cap-and-trade program a) implemented at the national level, and b) covering the widest spectrum of economic sectors possible. Consensus would have been unlikely regarding an Arizona-only cap-and-trade program.

ES-6 Carbon Intensity Targets

Policy Description:

Rather than a fixed cap on carbon emissions, a carbon intensity target is a limit on the ratio of carbon emissions to a measure of output. Absolute emissions can increase as output increases. Measures of output are clear for some sectors – like electricity generation (e.g., MWh) – but can be difficult for other sectors (e.g., manufacturing). One measure of output for other sectors could be dollars equal to the value of the output.

Policy Design:

Under this policy, Arizona would implement a mandatory carbon intensity target that begins in 2010 (i.e., equal to carbon intensity in 2010) and that declines by 3% annually through 2025. The annual carbon intensity target would be translated into a cap, and trading would be allowed under that cap.

- **Goal levels:** As noted above.
- **Timing:** As noted above.
- **Parties:** Utilities and electric generators.

Implementation Method(s):

- A market based mechanism with underlying regulatory obligation.

Related Policies/Programs in Place:

- No carbon intensity target is currently in place in Arizona.

Type(s) of GHG Benefit(s):

- **CO₂:** A carbon intensity target may or may not reduce absolute CO₂ emissions. A stringent intensity target is more likely to lead to reductions than a lenient target. A less stringent target may curb growth in emissions, but not reduce absolute emissions.
- **Black Carbon:** To the extent that generation from coal and oil would decline under a carbon intensity target, black carbon emissions would also decrease.

Estimated GHG Savings and Costs per tCO₂e:

Using the data sources, quantification methods, and key assumptions described below, initial estimates were calculated:

#	Policy	Scenario	Reductions (MMtCO ₂ e)			NPV (2006– 2020) \$ Millions	Cost- Effective- ness \$/tCO ₂
			2010	2020	Cumulative Reductions (2006-2020)		
ES-6	Carbon Intensity Target	Intensity improvement of 3%/year 2010-2025	0.00	14.0	70	3119	44

The CCAG ultimately selected this policy option as one of its recommendations. The steps described in the final report were then taken to eliminate any potential overlap with other CCAG recommendations, because this could result in double-counting of costs and benefits. After eliminating potential overlaps, the following values were reported to the CCAG:

#	Policy	Scenario	Reductions (MMtCO ₂ e)			NPV (2006– 2020) \$ Millions	Cost- Effective- ness \$/tCO ₂
			2010	2020	Cumulative Reductions (2006-2020)		
ES-6	Carbon Intensity Target	Intensity improvement of 3%/year 2010-2025	0.00	9.2	50.3	2231	44.33

Data Sources, Methods, and Assumptions:

- Data Sources:** CDEAC, WECC, EIA, EPA, Arizona Solar Energy Center, "Assessment of Parabolic Trough and Power Tower Solar Technology Cost and Performance Forecasts" by Sergeant & Lundy.
- Quantification Methods:** A simple capacity expansion model was developed in Excel specifically for this policy option. Renewable and fossil technologies were characterized in terms of cost and operating profiles, and available resources in the State were also defined. Technologies include three classes of wind, concentrating solar power, geothermal, biomass, landfill gas, conventional coal, integrated gasification combined cycle with carbon capture and storage (IGCC with CCS), natural gas combined cycle (NGCC), and natural gas combustion turbines (NGCT). The reference case forecast of electricity generation was the starting point for this analysis. It was assumed that existing resources would continue to operate in the State over the analysis period. Generation from existing resources was subtracted from the reference forecast of total generation to provide a new generation forecast. The model then found the least-cost mix of new generation needed, subject to the constraint that resulting CO₂ emissions not exceed the limit imposed by the carbon intensity target. The model tracks cost and CO₂ emissions associated with this new generation. The model was also run without constraints in order to develop a reference case. The difference in CO₂ emissions and total cost of generation between the policy case and the reference case was then calculated. These results are reported above.

- **Key Assumptions:** Cost and performance characteristics of generating technologies now and in the future; resource availability; no demand response as a result of policy; no transmission and distribution modeled.

Key Uncertainties:

- As with any assessment of the future, this analysis has many uncertainties. Key uncertainties are, first, related directly to the key assumptions listed above. If those assumptions were changed, then the results would change. Other uncertainties include the forecast price of fossil fuels and growth in the demand for electricity.

Ancillary Benefits and Costs:

- The shift from fossil fuel generation as a result of a carbon intensity target would lead to reductions in criteria air pollutants and, consequently, health impacts and costs associated with those pollutants.

Feasibility Issues:

- Although no significant hurdles to the effective adoption of this policy are evident, Arizona would be among the first states to implement such a program.

Status of Group Approval:

Completed.

Level of Group Support:

Majority.

Barriers to Consensus:

Some CCAG members were concerned that a carbon intensity regulatory program has little precedent elsewhere in the U.S. and thus represents relatively uncharted ground. Further, members of the CCAG affiliated with entities regulated by the ACC were not in a position to publicly support requirements which depart from those being pursued by the ACC.

ES-9 Reduce Barriers to Renewables and Clean Distributed Generation (DG)

Policy Description:

Remove barriers to renewables and clean distributed generation (DG) including: commercialization barriers; price distortions; failure of the market to value the public benefits of renewables; failure of the market to value the social cost of fossil fuel technologies; and market barriers such as inadequate information, institutional barriers, high transaction costs because of small projects, high financing costs because of lender unfamiliarity and perceived risk, "split incentives" between building owners and tenants, and the fact that transmission costs are often higher for renewables.

Policy Design:

This policy was identified by both ES and RCI TWGs. In order to avoid duplicative effort, it was analyzed under RCI-6, Distributed Generation/ Combined Heat and Power.

Policies to remove these barriers include: standard interconnection policies; procurement policies (e.g., state power purchases, loading order requirements, long-term contracting for clean DG resources, etc.); environmental disclosure, etc.

- **Goal levels:** Depends on specific policies to remove barriers.
- **Timing:** Depends on specific policies to remove barriers.
- **Parties:** Depends on specific policies to remove barriers.

Implementation Method(s):

- Varies depending on specific policies to remove barriers.

Related Policies/Programs in Place:

- None cited.

Type(s) of GHG Benefit(s):

- **CO₂:** By removing barriers to renewables and clean DG, more clean generation would enter the energy supply mix, displacing fossil fuel generation, and thereby reducing CO₂ emissions.
- **Black Carbon:** To the extent that removing barriers to renewables and clean DG lead to displacement of generation from coal and oil, black carbon emissions would decrease.

Estimated GHG Savings and Costs per tCO₂e:

- This option is quantified under RCI-6, Distributed Generation/Combined Heat and Power

Data Sources, Methods, and Assumptions:

- See RCI-6, Distributed Generation/Combined Heat and Power.

Key Uncertainties:

- See RCI-6, Distributed Generation/Combined Heat and Power.

Ancillary Benefits and Costs:

- Renewables and clean DG typically keep energy dollars in state, contributing more to employment, fuel diversity and security, and price stability for the state. Water use may be reduced through renewable versus combustion technologies.

Feasibility Issues:

- None cited.

Status of Group Approval:

Completed.

Level of Group Support:

Unanimous.

Barriers to Consensus:

None cited.

ES-10 Metering Strategies

Policy Description:

There are two common metering strategies or policies: net metering and advanced metering. Net metering allows owners of grid-connected distributed generation resources (i.e., generating units on the customer side of the meter) to generate excess electricity and sell it back to the grid, effectively “turning the meter backward.” This policy allows for low transaction costs (e.g., no need to negotiate contracts for the sale of electricity back to the utility) and is attractive to DG owners because they are compensated equal to the full cost of purchased electricity (i.e., the sum of wholesale generation, transmission and distribution, and utility administration costs) rather than just the utility’s avoided costs.

Advanced metering technologies allow electricity consumers much greater opportunity to manage their electricity consumption. For example, consumers could set their meter to turn off or turn down air conditioning during the day while they are away. Coupled with pricing strategies that match prices to reflect actual costs during peak times, advanced metering could be set to automatically adjust demand by turning off lighting or appliances when real-time power prices reach a threshold set by the consumer. A policy could be put into place to encourage the use of advanced metering by subsidizing the meters or by mandating their installation.

Policy Design:

Net metering and advanced metering are enabling policies to encourage clean, distributed generation as opposed to reduction policies per se. Accordingly, the GHG reductions and costs associated with this policy option are automatically incorporated under RCI-6, Distributed Generation/Combined Heat and Power and RCI-7, Distributed Generation/Renewable Energy Applications.

- **Goal levels:** Not applicable.
- **Timing:** Not applicable.
- **Parties:** Utilities and utility customers.

Implementation Method(s):

- Information and education
- Technical assistance
- Funding mechanisms and or incentives
- Market-based mechanisms

Related Policies/Programs in Place:

- None cited.

Type(s) of GHG Benefit(s):

- CO₂: By encouraging more clean distributed generation through net metering, and lower demand through advanced metering, there would be less demand for CO₂-intensive central generation, leading to reductions in CO₂ emissions.
- Black Carbon: To the extent that net metering and reduced demand lead to less generation from coal and oil, black carbon emissions would decrease.

Estimated GHG Savings and Costs per tCO₂e:

- GHG reductions and costs for this enabling option are incorporated into the reductions reported under RCI-6, *Distributed Generation/Combined Heat and Power* and RCI-7, *Distributed Generation/Renewable Energy Applications*.

Data Sources, Methods, and Assumptions:

- Not applicable.

Key Uncertainties:

- None cited.

Ancillary Benefits and Costs:

- To the extent that metering strategies reduces fossil fuel generation, reductions in criteria air pollutant emissions and, consequently, health impacts and costs associated with those pollutants, would also occur.
- Water use may be reduced through renewable versus combustion technologies.

Feasibility Issues:

- None cited.

Status of Group Approval:

Completed.

Level of Group Support:

Unanimous.

Barriers to Consensus:

None cited.

ES-11 Pricing Strategies

Policy Description:

Pricing strategies can take many forms including: *real-time pricing* in which utility customer rates are not fixed, but reflect the varying costs that utilities themselves pay for power; *“time-of-use” rates*, which are fixed rates for different times of the day and/or for different seasons; *“increasing block” rates* that are defined by blocks of consumption; *green pricing* whereby customers are given the opportunity to purchase electricity with a renewable or cleaner mix than the standard supply mix offered by the utility; and *advanced metering* to allow electricity consumers much greater opportunity to manage their electricity consumption.

Policy Design:

This policy was identified by both ES and RCI TWGs. In order to avoid duplicative effort, it was analyzed under RCI-8, Electricity Pricing Strategies.

- **Goal levels:** Not applicable.
- **Timing:** Depends on the specific policies.
- **Parties:** Utilities and utility customers.

Implementation Method(s):

- Market-based mechanisms

Related Policies/Programs in Place:

- See RCI-8, *Electricity Pricing Strategies*.

Type(s) of GHG Benefit(s):

- **CO₂:** By encouraging less electricity consumption through pricing strategies, generation should be reduced, thereby reducing CO₂ emissions. Some pricing strategies, however, may have the impact of increasing CO₂ emissions.
- **Black Carbon:** To the extent that pricing strategies lead to less generation from coal and oil, black carbon emissions would decrease.

Estimated GHG Savings and Costs per tCO₂e:

- This option is quantified under RCI-8, *Electricity Pricing Strategies*.

Data Sources, Methods, and Assumptions:

- See RCI-8, *Electricity Pricing Strategies*.

Key Uncertainties:

- See RCI-8, *Electricity Pricing Strategies*.

Ancillary Benefits and Costs:

- See RCI-8, *Electricity Pricing Strategies*.

Feasibility Issues:

- See RCI-8, *Electricity Pricing Strategies*.

Status of Group Approval:

Completed.

Level of Group Support:

Unanimous.

Barriers to Consensus:

None cited.

ES-12 Integrated Resource Planning

Policy Description:

Integrated Resource Planning (IRP) is a process that diverges from traditional utility least-cost planning. Rather than simply focusing on supply-side options to meet a forecasted growth in electricity demand, IRP integrates technology and policy options on the demand side with supply-side options to satisfy the anticipated demand. Demand-side measures include energy efficiency, distributed generation, and peak-shaving measures. IRP typically also takes into account a broader array of costs, including environmental and social costs.

Policy Design:

IRP is an involved process that, by its nature as a bottom-up planning methodology at the utility level, does not lend itself to setting implementation levels per se. Quantifying CO₂ reductions under a policy mandating IRP would require, in effect, conducting integrated resource planning for all utilities in the State, which is beyond the scope of the CCAG process. However, a value can be assigned to emissions for use in the planning process. In the context of a climate-driven Arizona IRP, a “shadow price” per ton would be assigned to CO₂ emissions. In making decisions about which resources to use to satisfy demand for energy services, utilities would be required to apply this “shadow price” as a CO₂ adder in their evaluation of technologies and approaches. Utilities would not actually be required to pay this sum.

To quantify this option, the ES TWG applied a “shadow price” for CO₂, implemented in the fashion described below.

- **Goal levels:** Implement IRP with a CO₂ adder shadow price of \$15 per ton of CO₂ emitted.
- **Timing:** Varies by individual utility generation profiles.
- **Parties:** Utilities and the ACC.

Implementation Method(s):

- Codes and standards

Related Policies/Programs in Place:

- No mandated IRP process is in use at this time in Arizona.

Type(s) of GHG Benefit(s):

- CO₂: IRP is a planning process that attempts to factor in the external cost of emissions, including CO₂; lower-emitting technologies are favored as a result. It also treats demand-side efficiency options as equal to supply-side options in the planning process, so fewer or smaller fossil fuel plants may be needed. The end result can be potentially significant CO₂ savings.
- Water use may be reduced through renewable versus combustion technologies.

- Black Carbon: To the extent that generation from coal and oil is reduced under IRP, black carbon emissions would also be reduced.

Estimated GHG Savings and Costs per tCO₂e:

#	Policy	Scenario	Reductions (MMtCO ₂ e)			NPV (2006– 2020) \$ millions	Cost- Effective-ness \$/tCO ₂
			2010	2020	Cumulative Reductions (2006-2020)		
ES-12	Integrated Resource Planning	\$15/ton CO ₂ adder	0.06	5.4	28	-70	-2

The CCAG ultimately selected this policy option as one of its recommendations. The steps described in the final report were then taken to eliminate any potential overlap with other CCAG recommendations, because this could result in double-counting of costs and benefits. After considering what actions utilities would take in response to IRP with a \$15 carbon adder, the ES TWG recommended and the CCAG determined that the same steps would already be driven by ES-1, *EPS/REST* and/or ES-6, *Carbon Intensity Targets*. Accordingly, all of the GHG reductions and cost savings provided by this policy would represent double-counting, and thus have not been counted in the overall GHG reduction or cost tallies of the ES TWG.

Data Sources, Methods and Assumptions:

- **Data Sources:** Data for the electricity modeling done for this analysis comes from the U.S. Energy Information Administration (EIA) and can be found within the National Energy Modeling System (NEMS). Data in NEMS includes representation of the existing generation, transmission and distribution system down to the unit level. NEMS also includes data that characterizes new plants that the model can choose to build to meet projected demand growth. EIA's publication entitled "*Assumptions to the Annual Energy Outlook*" details key assumptions in the current version of the model. EIA also publishes NEMS model documentation.
- **Quantification Methods:** As a proxy for the outcome of an IRP process, a tax of \$15 per ton of CO₂ emitted was applied to electricity generators at the national level. CO₂ reductions were found by comparing emissions from the policy case to emissions from a reference case. Costs were estimated by comparing policy and reference case new generating capacity investments, operating and maintenance costs for all generation, fuel costs for all generation, and transmission and distribution costs for all generation. The reported cost for the policy is the net present value of the difference in the above costs between the policy and reference cases. Because the NEMS model captures the CO₂ tax in the price of fuel, the reference case price of fuel was simply substituted for the policy case price of fuel, which reflects the CO₂ tax. By making this assumption, the CO₂ tax is treated as a shadow price, i.e., the tax revenues are ignored, but investment and operating decisions are made as if there were a CO₂ tax in place. Because the NEMS model is a national model with multi-state regions (Arizona is within the Rocky Mountain Power Area), the results for Arizona were derived from results in the region. Regional emission and cost results were pro-rated according to the share of Arizona generation within the region.
- **Key Assumptions:** Any analysis of state-level policies using the National Energy Modeling System (NEMS) from the U.S. Energy Information Administration should be

weighed carefully. NEMS is a national model that consists of 13 regions. State policies cannot be implemented explicitly within NEMS, and the State-specific impacts cannot be known explicitly. Assumptions must be made about the impact of policies at the State level by assigning shares of regional results. In reality, the State-level changes resulting from the policies implemented may differ substantially from the change in the region overall.

Key Uncertainties:

- Key uncertainties are related directly to the key assumptions and quantification methods listed above. Other uncertainties include the forecast of the price of fossil fuels and the growth in the demand for electricity.

Ancillary Benefits and Costs:

- IRP attempts to take into account social costs including the impact on the economy as well as health impacts and costs related to criteria air pollution.

Feasibility Issues:

- None cited.

Status of Group Approval:

Completed.

Level of Group Support:

Unanimous.

Barriers to Consensus:

None cited.

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Feasibility Issues:

- None cited.

Status of Group Approval:

Completed.

Level of Group Support:

Unanimous.

Barriers to Consensus:

None cited.



**APPENDIX I: TRANSPORTATION AND LAND USE -
DETAILED POLICY DESCRIPTION/ANALYSIS**

Overview

The Transportation and Land Use sector includes GHG mitigation opportunities related to vehicle technologies, fuel choices, transit options, and demand for transportation services. The CCAG recommends a set of 13 policy options for the TLU sector that offer the potential for major GHG emissions reductions from the reference projection. As summarized in the table below, these 13 policy recommendations could lead to emissions savings from reference case projections of 14.5 MMtCO_{2e} per year by 2020 and cumulative savings of 91 MMtCO_{2e} from 2007 through 2020. The weighted average cost of saved carbon from the policy options for which quantitative estimates of both costs and savings were prepared was minus \$32 per metric ton of CO₂ equivalent, meaning that there is a net savings to the Arizona economy in implementing these options.

For each recommended TLU policy, this technical appendix provides details on design, analysis, quantification of impacts, and other related information. (See Appendix E for explanation of the general methods applied.) When these TLU policies were quantified, some policies were considered to have overlapping impact. To avoid double-counting of GHG emission reductions, the following steps were taken:

- **Light-duty sector:** Implementation of the light-duty measures would cause overlap with each other. For example, the State Clean Car Program (TLU-1) reduces per-vehicle CO₂ emissions while the Smart Growth Bundle (TLU-2) reduces the overall Vehicle-miles Traveled (VMT) from the light-duty sector. Thus, the VMT that should be applied to TLU-1 is reduced by TLU-2 while the per-mile CO₂ reduction for TLU-2 would be reduced by TLU-1. The sum of the product of the fraction of emissions remaining after each individual measure (TLU-1, TLU-2, TLU-9, and TLU-10) was applied to the reference case projected emissions showed the total fraction of the reference case emissions that would be expected to remain with these four measures applied in combination. In 2020, these four measures provide a total reduction to the light-duty CO₂ emissions of 37% when applied individually. When applied in combination and accounting for the overlap, they reduce 2020 reference case projected light-duty CO₂ emissions by 33%.
- **Freight sector:** Implementation of the biodiesel option (TLU-12) would overlap with the idling reduction option (TLU-4) and the reduced speed limit for commercial vehicles option (TLU-14). It was assumed that a portion of the fuel conserved in TLU-4 and TLU-14 would be biodiesel fuel, in the same proportion as described in the biodiesel option; e.g., 1.5% of the fuel conserved through 2014 and 10% of the fuel conserved from 2015 through 2020 (in terms of B100). Since a 78% reduction in CO₂ emissions was already applied to these fuel quantities in the biodiesel option, the base CO₂ emissions from these fuel quantities were reduced by an additional 22% rather than the complete 100% reduction (as applied to the diesel portion of the fuel) from conserving these fuel quantities in TLU-4 and TLU-14.

Transportation and Land Use Sector Summary of Results

#	Policy Name	Estimated 2010 GHG Savings (MMtCO _{2e})	Estimated 2020 GHG Savings (MMtCO _{2e})	Estimated Costs or Cost Savings Per Ton (\$/tCO _{2e})	Cumulative 2007–2020 GHG Savings (MMtCO _{2e})	Level of CCAG Support
TLU-1	State Clean Car Program	0.3	5.6	-\$90	32.5	Unanimous
TLU-2	Smart Growth Bundle	1.5	4.0	\$0 (Net savings)	26.7	Unanimous
TLU-3	Promoting Multimodal Transit	Not available (included in TLU-2)				Unanimous
TLU-4	Reduction of Vehicle Idling	0.7	1.3	-\$22	11.8	Unanimous
TLU-5	Standards for Alternative Fuels	Not available (enabling policy for TLU-12 and A-3)				Unanimous
TLU-7	Hybrid Promotion and Incentives	Not available (included in TLU-1)				Unanimous
TLU-8	Feebates	Not available				Super-majority
TLU-9	Pay-As-You-Drive Insurance	0	2.8	\$0 (Zero Net cost)	12.3	Unanimous
TLU-10	Low Rolling Resistance Tires	0.0	0.8	Not available	4.8	Unanimous

TLU-11	Accelerated Replacement/ Retirement of High-emitting Diesel Fleet	0.2	0.03	Not available	1.2	Unanimous
TLU-12	Biodiesel Implementation	0.1	1.1	\$0 (Zero Net cost)	6.2	Unanimous
TLU-13	State Lead-By-Example (via Procurement and SmartWay)	0.03	0.04	\$0 (Zero Net cost)	0.4	Unanimous
TLU-14	60 mph Speed Limit for Commercial Trucks	0.3	0.5	\$35	5.2	Supermajority
Accounting for Policy Overlaps		-0.01	-1.5		-9.8	
Total All Options		3.1	14.5	\$ -32 (weighted average)	91.0	

The savings in fuel, measured in barrels and dollars, associated with TLU policy recommendations are presented in the table below.

FUELS SAVINGS FROM TLU OPTIONS				
GASOLINE SAVINGS	2010	2020	Cumulative Barrels	NPV (million \$)
Barrels of Gasoline Reduced	4,422,311	30,079,892	171,856,457	
Aggregate of TLU-1,3,9,10				
Gasoline Cost Savings (million \$)	\$393.8	\$2,743.0		\$9,647.3
Aggregate of TLU-1,3,9,10				
DIESEL SAVINGS	2010	2020	Cumulative Barrels	NPV (million \$)
Barrels of Diesel Reduced				
TLU-4 Idling Reduction	1,728,519	3,102,881	29,617,707	
TLU-12 Biodiesel Implementation	335,603	3,213,032	20,086,318	
TLU-14 Reduced Speed Limit	808,463	1,161,024	12,258,875	
Total	2,872,585	7,476,936	61,962,900	
Diesel Cost Savings (million \$)				
TLU-4 Idling Reduction	\$174.2	\$312.8		\$2,068.0
TLU-12 Biodiesel Implementation	\$0.0	\$0.0		\$0.0
TLU-14 Reduced Speed Limit	\$81.5	\$117.0		\$871.2
Total	\$255.7	\$429.8		\$2,939.2
TOTAL FUEL SAVINGS	2010	2020	Cumulative Barrels	NPV (million \$)
Barrels of Fuel Reduced	7,294,895	37,556,828	233,819,357	
Fuel Cost Savings (million \$)	\$649.6	\$3,172.8		\$12,586.5

TLU-1 State Clean Car Program

Policy Description:

Adopt the “State Clean Car Program” (also known as the “Pavley” standards or “California GHG emission standards”) in order to reduce the net emissions of GHGs from passenger vehicle operation.

Policy Design:

New cars and light trucks in all states must comply with Federal emission standards, and, generally speaking, states have the choice of adopting a stronger set of standards applicable in California. In 2005, California finalized a set of standards that would require reductions of GHG emissions of about 30% from new vehicles, phased in from 2009 to 2016, through a variety of means. The standards must still be approved by US EPA, and face a court challenge.

Implementation Method(s):

Standards take effect in Model Year 2011 (calendar year 2010).

Related Policies/Programs in Place:

Federal regulation of tailpipe emissions and fuel economy.

Types(s) of GHG Benefit(s):

Overwhelmingly CO₂ reductions.

Estimated GHG Savings and Costs per tCO₂e:

	2010	2020	Units
GHG Emission Savings	0.3	5.6	MMtCO ₂ e
Net Present Value (2006–2020)		-\$2,944	\$million
Cumulative Emissions Reductions (2006–2020)		32.5	MMtCO ₂ e
Cost-Effectiveness		-90	\$/tCO ₂ e

Data Sources, Methods, and Assumptions:

- **Data Sources:** Diane Brown and Elizabeth Ridlington, Cars and Global Warming: Policy Options to Reduce Arizona’s Global Warming Pollution from Cars and Light Trucks, AZ PIRG Education Fund: February 2006, www.arizonapirg.org/AZ.asp?id2=22371 . CCS, Arizona Greenhouse Gas Inventory and Reference Case Projections, 1990–2020, March 2006.
- **Quantification Methods:** The AZ PIRG report used a model of light-duty vehicle fleet comparing the difference between base case emissions and emissions with fleet penetration over time of vehicles that meet lower GHG emissions standards consistent

with the California regulations. The AZ PIRG model calculated light-duty vehicle fuel use and emissions based upon scientifically valid methods. (See extended discussion in AZ PIRG report, pp. 22–26.)

CCS compared the AZ PIRG model results to results for the New England states and California that were obtained using comparable modeling methods. CCS found that while all three modeling efforts were scientifically valid and comparable, some of the AZ PIRG model assumptions and methods were relatively conservative, while the California and New England modeling results were relatively optimistic. CCS further refined the AZ PIRG model results consistent with a middle range scenario that produced results less conservative than the AZ PIRG results and less optimistic than the California and New England results. While AZ PIRG projected a 13.7% reduction in light duty vehicle emissions with this policy, the CCS refinement estimates a 15.5% reduction in emissions. CCS applied this refined percentage reduction in emissions to the CCAG approved reference case scenario to obtain a net estimated reduction of 5.6 MMtCO_{2e} in 2020.

This analysis assumes the program will start with the 2011 model year. Some 2011 model year vehicles will be on the market in calendar year 2010, and so there are some small emissions reductions that are foreseeable for that first year of sales/implementation.

- **Key Assumptions:** The three modeling efforts have established a generally acceptable scientific method of projecting GHG emissions reductions from this policy. The CCS comparison of the three modeling methods provides some independent professional validation of the models and their results. The key assumption of the emissions reduction projected by CCS is that the most likely scenario for emissions reductions is one that would fall between the more conservative scenario projected by the AZ PIRG model and the more optimistic scenario projected by the California and the New England models.

Key Uncertainties:

Fleet turnover rates for light-duty vehicles and future patterns of consumer purchase choices between passenger cars and light-duty trucks (i.e., SUVs).

Ancillary Benefits and Costs, if applicable:

Some reduction in criteria pollutants is likely.

Feasibility Issues, if applicable:

Light-Duty Vehicle GHG emissions standards can be met with existing 'off-the-shelf' automotive technologies that are already in the marketplace.

Level of Group Support:

Unanimous.

Barriers to Consensus:

None cited.

TLU-2 Smart Growth Bundle

Policy Description:

This bundle of options encompasses four components related to reducing GHG emissions through land use practices and policies. These policies contribute to GHG emission reductions by reducing vehicle trips and total vehicle miles traveled.

Policy Design:

Smart growth actions include the following programs and program elements:

- **Infill and Brownfield redevelopment.** Shifting housing and commercial development toward location efficient sites, such as infill and brownfields projects, and away from location inefficient sites, such as greenfields, reduces overall travel demand and expands lower emitting mode choices. Brownfields are commercial or industrial properties that are abandoned or are not being fully used because of actual or perceived environmental contamination. These properties have potential for redevelopment, but the uncertainty and risk of environmental liability and the cost of investigation and cleanup keep them from being redeveloped. Former industrial properties, abandoned gas stations, and vacant warehouses are all examples of brownfields. Redevelopment of these properties creates jobs, revitalizes neighborhoods, increases property and sales tax revenues, decreases urban sprawl, and reduces potential health risks to the local community. Infill development can also revitalize neighborhoods, increase tax revenues, and decrease urban sprawl.
- **Transit-oriented development (including multi-modal transit proposals previously covered under option TLU-3)** includes a shift to lower emitting mode choices by building compact development (including employment) around transit stops. Helps people meet daily needs by foot, bicycle, or transit.
- **Smart growth planning, modeling, and tools** includes a number of practices that allow, support, and encourage location efficient growth in communities that are proximate to household amenities (such as jobs, shopping, school, services, entertainment, etc.) as opposed to growth in areas that are not proximate and require greater travel distance and have less mode choice. Smart growth allows for mixed land uses within a project with a range of housing opportunities and multiple transportation options including pedestrian/bike access.
- **Targeted open space protection** includes programs designed to protect and conserve State lands and other open spaces, and develop and improve neighborhood, community, and regional parks in ways that encourage location-efficient growth and broader mode choice.

Goal levels: Target a reduction in growth in VMT from passenger vehicles of 2 to 11% in the years 2007–2020 through a combined approach utilizing a number of programs that fall under those listed above.

Implementation Method(s):

Specific policy measures would include:

- Promote use of authority under Growing Smarter/Plus by counties to impose development fees consistent with municipal development fee statutes.
- Promote smart growth principles in new development by requiring bidders to include defined smart growth principles in bid packages.
- Promote use of authority under Growing Smarter/Plus by cities to create infill incentive districts and plans that could include expedited process incentives.
- Promote use by cities of a fee waiver system, similar to the Phoenix Infill Housing Program, to encourage development of single-family owner-occupied housing on vacant, orphaned, or underutilized land located in the mature portions of Arizona cities.
- Provide technical assistance to communities that want to pursue Smart Growth and disseminate lessons learned in cities such as Phoenix and Tucson.
- Provide Smart Growth information tools that identify the qualitative (e.g., improved quality of living) and quantitative benefits (e.g., reduced vehicle operation costs) of these Smart Growth communities.
- Encourage lenders to apply location-efficient mortgage principles, so transportation cost savings are recognized when calculating a household's borrowing ability.
- Encourage cities to review (and update where appropriate) their engineering plans and standards to make new road and sidewalk infrastructure more supportive of transit, bikes, and pedestrians.
- Promote and support telecommuting.¹
- Promote and support affordable housing in new developments.
- Carefully review land swaps for potential to produce undesirable development patterns.
- Implement the vision set forth in the MoveAZ report.

Related Policies/Programs in Place:

Arizona and various counties and cities have been pursuing a variety of policies related to Smart Growth (e.g., Growing Smarter legislation and actions by Phoenix and Tucson). In addition, in 2004, the Arizona Department of Transportation completed a long-range transportation plan for the State entitled MoveAZ (www.moveaz.org). Adopted by the State Transportation Board, MoveAZ provides policy directions, performance-based evaluations of capital transportation projects, and tools for ADOT to use in planning and implementing a vibrant multi-modal transportation system for the State. If successful, these efforts will complement the other actions in the Smart Growth bundle and help it achieve VMT reductions more toward the upper range of estimates for that option.

Types(s) of GHG Benefit(s):

CO₂ reductions

¹ There was also a suggestion of hybrid access to HOV lanes, but this will be discussed in Hybrid Incentives (TLU-, and is not part of Smart Growth.

Estimated GHG Savings and Costs Per tCO₂e:

	2010	2020	Units
GHG Emission Savings	1.47	4.0	MMtCO ₂ e
Net Present Value (2006–2020)		0 (Net savings)	\$ million
Cumulative Emissions Reductions (2006–2020)		26.7	MMtCO ₂ e
Cost-Effectiveness		0 (Net savings)	\$/tCO ₂ e

Data Sources, Methods, and Assumptions:

- **Data Sources:** CCS, Arizona Greenhouse Gas Inventory and Reference Case Projections, 1990–2020, March 2006. Extensive Smart Growth literature.
- **Quantification Methods:** Modified Arizona reference cast forecast for 2008–2020 using 2–11% reduction in VMT.
- **Key Assumptions:** The value used for reduction in VMT. To be conservative, assumes “de minimus” increases in GHG emissions from increased use of alternate transit modes. Assumes that infrastructure savings offset other costs.

Key Uncertainties:

Sensitivity of VMT growth to policy shifts.

Ancillary Benefits and Costs, if applicable:

Benefits include reduced infrastructure costs, avoided health care costs from reduced air pollution and increased walking/biking, and other quality-of-life aspects. There will be front-end costs of program development and implementation for brownfields, infill, and transit-oriented development programs. A successful program requires dedicated resources to ensure that desired development is achieved. There are grants available from the EPA that assist with the initial establishment of a program or to fund environmental activities for a specific project; however, successful local and State brownfields programs have a dedicated source of funds for the program. Financial resources are required to fund staff (at least one full-time employee is typical), administrative expenses, promotion, education, etc., on an annual basis, which has averaged approximately \$200,000 per year for the City of Phoenix.

Many successful programs have used financial incentives to jump-start private sector investment. As the market increasingly embraces Smart Growth, these may become less necessary. Most federal brownfields programs are not available directly to the private sector; therefore, the most effective programs nationwide provide local or state financial assistance. In the City of Phoenix, capital improvement bond funds are used to provide financial assistance directly to the private sector and to encourage the use of brownfields for public facilities. Phoenix secured \$3.4 million from the 2000 Phoenix Bond Program and recently obtained \$4 million from the 2006 program for brownfields redevelopment.

Feasibility Issues, if applicable:

Smart Growth developments sell at a premium.

Level of Group Support:

Unanimous.

Barriers to Consensus:

None cited.

TLU-3 Promoting Multi-Modal Transit

Policy Description:

Arizona should promote multi-modal transit options.

Policy Design:

Arizona should enable and support shifts in passenger transportation mode choice (auto, bus, rail, bike, pedestrian, etc.) to lower emitting choices. This includes: making optimal use of CMAQ funds; expanding transit infrastructure (rail, bus, BRT); improving transit service, promoting and marketing transit (including tax-free and employer-paid commuter benefits); improving bike and pedestrian infrastructure; exploring commuter rail using existing rail corridors; considering re-establishing train service between Phoenix and Tucson; reviewing all proposed transportation projects for multi-modal flexibility (e.g., add BRT or light rail, if feasible); and conducting research into new transportation technologies and urban planning techniques.

Implementation Method(s):

Implement in concert with TLU-2, Smart Growth.

Related Policies/Programs in Place:

None cited.

Estimated GHG Savings and Costs Per tCO₂e:

Not quantified.

Data Sources, Methods, and Assumptions:

Quantified as part of TLU-2.

Key Uncertainties:

None cited.

Ancillary Benefits and Costs:

None cited.

Feasibility Issues:

None cited.

Level of Group Support:

Unanimous.

Barriers to Consensus:

None cited.

TLU-4 Reduction of Vehicle Idling

Policy Description:

Reduce idling from diesel and gasoline heavy-duty vehicles, buses, and other vehicles through the combination of a statewide anti-idling ordinance and by promoting and expanding the use of technologies that reduce heavy-duty vehicle idling, including: automatic engine shut down/start up system controls; direct fired heaters (for providing heat only); auxiliary power units; and truck stop electrification.

Policy Design:

Currently, only Maricopa County has an anti-idling ordinance. This ordinance has not been enforced due to a lack of enforcement funding and enforcement authority. This policy would build off of the Maricopa County ordinance, strengthen it, and make it applicable statewide by the end of 2008. The statewide ordinance should be designed to be easily enforceable by the appropriate state and local agencies. It is critical that a dedicated State-funding stream for enforcement is needed for this measure to be successful in reducing vehicle idling and to obtain the predicted reductions in GHG emissions. The ordinance would also need to limit exemptions as much as possible, to make it easier to enforce. However, idling that occurs for public health and safety reasons (such as emergency vehicles) should be exempted from this rule.

This measure will also reduce idling from heavy-duty vehicles through programs aimed at increasing voluntary adoption of idle reduction technologies. ADEQ and the county agencies would collaborate on outreach and education beginning in the year 2008, to coincide with the implementation and enforcement of a statewide anti-idling ordinance. The State would also seek funding for pilot projects and demonstrations from CMAQ (Congestion Mitigation Air Quality) funds, as well as funds available through EPA, DOE, and DOT. These pilot programs could be used to evaluate the effectiveness of various idle reduction technologies prior to more widespread use throughout the State. Pilot projects could include truck stop electrification as well as an expanded school bus pilot program. The outreach materials should emphasize the benefits of reducing idling, including a reduction in fuel costs, GHG emissions, and toxic emissions.

- **Goal levels:** Implement a statewide vehicle idling restriction ordinance that can be enforced and that minimizes allowable exemptions, and provide the necessary resources for enforcing the ordinance. Develop and pilot the truck stop electrification programs. Target an overall reduction in idling of 80% by 2010 and 100% by 2020.
- **Timing:** Have ordinance in place by 2008.
- **Parties:** Industry, ADEQ, counties, school districts, and truck stop owners.

Implementation Method(s):

Information and education: Provide general public, trucking industry, and bus companies with information indicating when and where idling is prohibited, and under what circumstances it is permitted. Indicate the benefits of reducing idling, including fuel savings,

toxic emission reductions, and GHG reductions. Provide a hotline number to call to report violations. Encourage trucking companies to do their own policing of measure. Reach out to busing companies, school districts, and truck stop owners to help bus and truck drivers be more aware of idling restrictions. Ensure that signs are also posted in venues associated with bus idling (e.g., sporting events, shows, etc.). Emphasize the fuel savings benefits, reductions in toxic emissions, and reduced engine wear associated with reducing idling.

Provide information to fleet carriers, shippers, retailers, bus companies, school districts, and others involved in the diesel fleet industry indicating the economic benefits, as well as the environmental benefits, of applying idle reduction technologies. Identify best practices within the industry and recognize companies with these best practices in place within Arizona to encourage companies to select these carriers for their shipments. Develop outreach materials with cost benefits information and toxic diesel health impacts. Outreach materials should also be geared toward making the general public aware of the GHG, toxics, and fuel-saving benefits of eliminating idling on personal vehicles, as well as on trucks and buses. Expand school bus idling program based upon the pilots currently being conducted.

Technical assistance: Coordinate with anti-idling product manufacturers to organize workshops/outreach programs to regulated communities to let them know of technological options that provide alternatives to the need for idling including products for cabin comfort, power for other functions (e.g., refrigerated trucks) and engine warm-up.

Funding mechanisms and or incentives: Propose legislation to partially fund idling technology loan grants for truck stop electrification and other idle reduction technologies in the State, focusing grants on high idling areas. Determine a dedicated funding stream that can be used to fund enforcement of anti-idling ordinance as well as for continued education and outreach. Funding the enforcing agency with an adequate share of the revenue from using the idling reduction facilities could be an option. CMAQ funds and federal money may be available for idle reduction programs. A plan needs to be developed to apply for the funds.

Voluntary and or negotiated agreements: Work with regulated entities to promote voluntary compliance assistance through distribution of materials, staff training, etc. Encourage participation in EPA's SmartWay Transport Partnership (or similar programs).

Codes and standards: Include proper language in ordinance so that the agency with enforcement responsibilities is clearly delineated and has full authority to enforce the ordinance. The language of the statewide ordinance should also make enforcement straightforward (e.g., such that any exemptions to the idling policy can be easily observed). In developing the statewide anti-idling ordinance, EPA's recent Model State Idling Law should be reviewed for potential ordinance language. For example, the EPA model rule contains the following language exempting vehicles used for emergency and public safety purposes: "A police, fire, ambulance, public safety, military, other emergency or law enforcement vehicle, or any vehicle being used in an emergency capacity, idles while in an emergency or training mode, and not for the convenience of the operator."

Pilots and demonstrations: Coordinate with product developers to help them promote their technologies. Investigate availability of funds for pilot or demonstration projects on idle reduction technologies from EPA, DOE, and DOT. If funding is available, develop a pilot program to evaluate the effectiveness of various idle reduction technologies, including implementation of truck stop electrification and expanded school bus idling program. Evaluate the effectiveness of the pilot programs before implementing on a broader scale.

Reporting: Develop a system for tracking violations so that the State can eventually determine compliance rates and benefits achieved from the ordinance.

Enforcement: Phase enforcement program to initially conduct outreach (Phase 1), provide warnings for a limited period of time (Phase 2), then issuance of tickets (Phase 3).

Related Policies/Programs in Place:

Idling restrictions are currently in place in Maricopa County. House Bill 2538, (2001 regular session) requires counties containing portions of [Area A²](#) to implement and enforce ordinances limiting maximum idling time for Heavy Duty Diesel Vehicles weighing over 14,000 pounds gross vehicle weight rating (GVWR). Other counties in Arizona also have the option of adopting an ordinance. The Maricopa County ordinance states “No owner or operator of a vehicle shall permit the engine of such vehicle to idle for more than five (5) consecutive minutes except as provided in Section 4 (Exemptions) of this ordinance.” Violators are subject to a civil penalty of \$100 for the first violation and \$300 for a second or any subsequent violation, and can be enforced by any law enforcement officer on private/public property. Truck stop/distribution center owners/operators are required to erect signs indicating the maximum idling time in Maricopa County is 5 minutes. Exemptions are allowed under a number of conditions. To date, however, no violators of this ordinance have been fined. (Maricopa County Ordinance can be found at www.maricopa.gov/aq/rules/docs/fin-VIRO.pdf.)

ADEQ School Bus Idling program. A number of school districts are participating with ADEQ in their School Bus Idling Pilot project. Key elements of this project include having drivers turn off buses upon reaching a school or other location and not turn on the engine until the vehicle is ready to depart; parking buses at least 100 feet from a school air intake system; and posting appropriate signage advising drivers to limit idling near the school. This program could be expanded throughout the State.

Idle reduction programs are currently being used by some shippers/carriers/retailers in Arizona. As an example, Swift Transportation is a charter member of EPA’s SmartWay Transport program. This company maintains a modern fleet with an average vehicle age of less than 3 years old. Idle strategies used include optimized idle and other technologies as well as driver training.

Types(s) of GHG Benefit(s):

Reducing idling will reduce black carbon emissions, as well as all other GHG exhaust emissions (CO₂, CH₄, N₂O) through reduced fuel consumption. However, it is important to also ensure that any technologies used to reduce idling have lower emissions than the diesel truck idling emissions they are replacing.

² See www.azdeg.gov/enviro/air/vej/images/areaa.html.

Estimated GHG Savings and Costs per tCO₂e:

	2010	2020	Units
GHG Emission Savings	0.7	1.3	MMtCO ₂ e
Net Present Value (2006–2020)		-\$258	\$million
Cumulative Emissions Reductions (2006–2020)		11.8	MMtCO ₂ e
Cost-Effectiveness		-\$22	\$/tCO ₂ e

Data Sources, Methods, and Assumptions:

- **Data Sources:**

American Transportation Research Institute, “Idle Reduction Technology: Fleet Preferences Survey,” February 2006 for technology costs.

EPA SmartWay Transportation Partnership (www.epa.gov/otaq/smartway/idlingtechnologies.htm#truck-mobile) for technology costs.

“Analysis of Technology Options to Reduce the Fuel Consumption of Idling Trucks,” ANL/ESD-43, Argonne National Laboratory, Transportation Technology R&D Center, June 2000 for information on technology impacts.

Data from EPA’s MOBILE6 model were used to estimate the proportion of CO₂ emissions attributable to Class 8 trucks.

Data from USDOE/EIA *Annual Energy Outlook 2005* were used to estimate the amount of fuel consumed annually per truck.

“Model State Idling Law,” EPA420-S-06-001, U.S. Environmental Protection Agency, Office of Transportation and Air Quality, Transportation and Regional Programs Division, March 2006.

- **Quantification Methods:** The estimated reduction in CO₂ emissions from reduced idling was calculated based on estimating the portion of emissions and fuel consumption in the Arizona inventory that were attributable to Class 8 diesel trucks, estimating the portion of the total fuel consumption that would be consumed during idling, and applying a targeted reduction of 80% to this amount starting in 2008 and a reduction of 100% starting in 2015.

- **Key Assumptions:**

This analysis assumes idle reductions are achieved only by Class 8 diesel truck population; these trucks idle for an average of 6 hours per day; they consume 0.8 to 1.2 gallons of diesel per hour during idling; and that an 80 or 100% reduction of diesel idling from these Class 8 trucks is achieved.

The cost analysis assumes a 5-year lifetime for idling technology equipment, applied to 80% of Class 8 vehicles starting in 2008 and 100% of Class 8 vehicles starting in 2015, at a cost of \$6,000 per vehicle and a \$2.40 per gallon diesel cost savings.

Program administration costs, enforcement costs, fines, and reduced vehicle maintenance costs have not been factored into the cost analysis.

Key Uncertainties:

Buses, as well as other diesel trucks and gasoline vehicles and trucks that have not been quantified here, could achieve a small additional reduction in idling emissions. The distribution of technologies that would be selected by these trucks or fleets to reduce their emissions is highly uncertain. This will have a significant impact on the overall cost/cost savings of this measure. The use of these technologies will also cause a slight decrease in the CO₂ and fuel consumption reductions achieved. The use of truck stop electrification would increase emissions from electricity generation. Equipment cost and lifetime will vary by technology employed. The cost value selected was based on cost data summarized by American Transportation Research Institute, representing the capital costs of a variety of idle reduction technology. The cost of \$6,000 per vehicle represents a mix of higher and lower technology costs. The cost analysis does not take into account the number of vehicles that have already installed idle reduction technologies. The fuel cost assumed here is based on long-term projected fuel costs. Increases in this assumed fuel cost will lead to greater cost savings for this measure.

Ancillary Benefits and Costs:

Reductions in idling will also reduce emissions of toxics, NO_x, and PM. California estimates that 70% of toxic risk comes from diesel engines.

Idle emission reductions will reduce fuel consumption, thus leading to a cost benefit from reduced operating costs.

Additional costs are associated with on-board idle reduction technologies, but fuel savings over time typically lead to a net savings.

Providing idling reduction technologies (electrification/portable power units) at mandatory truck stops, such as Port-of-Entries/weigh stations, could prevent idling in other locations throughout the State. Providing central warehousing infrastructure may avoid idling required for refrigeration or other critical needs. Providing any new infrastructure requires funding.

Feasibility Issues:

Ability to enforce remains critical.

Level of Group Support:

Unanimous.

Barriers to Consensus:

None cited.

TLU-5 Standards for Alternative Fuels

Policy Description:

Develop and enforce standards for ethanol, biodiesel, and other alternative fuels in order to ensure fuel quality and reduce performance problems with these fuels, and to enable more widespread acceptance of these fuels.

Policy Design:

Develop and enforce a state standard for neat biodiesel (B100), biodiesel blends, and ethanol blends. For biodiesel blends, the biofuel portion and the petroleum diesel portions of the fuel are separately regulated through American Society for Testing and Materials (ASTM) standards; however, no standard is currently in place for the blended biodiesel. Similarly, for ethanol blends, E85 and the gasoline portion of ethanol blends are regulated by ASTM standards.

Arizona currently has legislation pending that would also regulate the ethanol portion of ethanol blends. (Note: This bill was enacted by the State Legislature in April 2006.) This measure is intended to support the bill. The base gasoline for ethanol blends must meet the standards for gasoline sold in that area. Enforcement of the standard should be designed to ensure that fuel taxes are being paid and that blenders are registered with the State. To reduce fraud, the measure should ensure fuel that is delivered is as advertised, and eliminate consumer problems. Enforcement of this standard would be led by the Arizona Department of Weights and Measures. Certain exemptions might be acceptable (e.g., a school district blending biodiesel for use in its own school buses and not for outside sale).

These standards should be in place by the end of 2008. Increased funding and resources are needed for enforcement of this measure. Through the National Energy Act, growth in alternative fuels is expected in the near term. This measure will ensure that these alternative fuels sold in Arizona meet quality standards. This measure would also be broadened to include other alternative fuels that may be sold in Arizona.

- **Goal levels:** Adopt ASTM D5798-99 as the standard for E85.
Adopt ASTM D6751 as the standard for biodiesel.
- **Timing:** Standards should be in place by the end of 2008 to encourage the use of biofuels within the State.
- **Parties:** AZDWM, ADOT, ADEQ, local jurisdictions, and school districts.

Implementation Method(s):

Information and education: Information and education will be used to disseminate information to industry and public

Codes and standards: Support the provisions of HB2590: HB2590 is the E85 bill. The current bill does several things: it adopts ASTM D5798-99 as the standards for E85; it sets standards for the equipment that will be dispensing E85 to ensure compatibility with the corrosive nature of E85; it establishes reporting requirements that will track product quality

and amount of E85 produced; and it requires that the gasoline portion of the E85 must be Cleaner Burning Gasoline (CBG) in the CBG Covered Area. This is a consistent approach with how EPA deals with E85 in ReFormulated Gasoline (RFG) areas. Recommend that EVR at retail be required for E85 (or parallel to approach CARB is currently being investigated). (Note: this bill was enacted by the State Legislature in April 2006.)

Currently under A.R.S. 41-2083(K) through (N), the Department of Weights and Measures regulates the quality of biodiesel. The current law requires that biodiesel must meet the specifications in ASTM D6751 and that the diesel portion of the biodiesel must meet ASTM D975. This should help protect the consumer. Again, as in the proposed legislation, the current law requires reporting to track volumes and help ensure the quality of the product.

Enforcement: Increased funding and resources for enforcement. Currently, the Department, under A.R.S. 41-266, has the authority to enter a facility, take samples, seize evidence, and take products off the shelf if it is found not to conform to State standards. State inspectors currently inspect fueling facilities throughout the State and check fuel quality and compliance with our regulations. These powers and duties are also codified in the department rules under R20-2-104. These rules will need to be clarified to indicate where the standards will be enforced and the fines that will be levied for violations.

Related Policies/Programs in Place:

National CO₂ requirements for increased use of biofuels.

Types(s) of GHG Benefit(s):

Reduced CO₂ emissions.

Estimated GHG Savings and Costs per tCO₂e:

Not quantified.

Data Sources, Methods, and Assumptions:

Not quantified.

Key Uncertainties:

None cited.

Ancillary Benefits and Costs:

Reduced criteria pollutants, but could increase NO_x.

Feasibility Issues:

None cited.

Level of Group Support:

Unanimous.

Barriers to Consensus:

None cited.

TLU-7 Hybrid Promotion and Incentives

Policy Description:

A combination of public education and information and financial incentives to promote the sales of light-duty vehicles with hybrid gasoline-electric power trains.

Policy Design:

- **Goal levels:** An increase in the hybrid share of the light-duty vehicle fleet for the period 2007 – 2020.
- **Timing:** 2007 – 2020.
- **Parties:** Industry, ADEQ, and the Arizona Department of Revenue.

Implementation Method(s):

Hybrid promotion and incentive programs would be implemented from the years 2007 through 2020. This covers the time period between the near-term years when production is limited and the medium-to-long-term years when expansion of production capabilities makes it more likely that promotion and incentive policies will have a significant effect on consumer choices. Some promotion programs could include public education and information and partnership programs. Some incentive programs could include financial incentives such as reduction in fees and taxes for owners of newly purchased hybrid vehicles or giving preferential infrastructure access to hybrids on carpool lanes or metered parking spaces. A modest level of incentive is unlikely to spur a higher hybrid share than that likely to occur due to the State Clean Car Program (TLU-1). The State should study further the level and design of incentives necessary to achieve higher market shares for hybrids.

In the near term (2006–2008), the hybrid vehicle sales are constrained on the producer side by an inability of automobile manufacturers to keep up with already-existing consumer demand. In the medium-to-long term (2009 forward for Arizona), automobile manufacturers are likely to increase production capabilities for hybrid power train vehicles, and provide consumers with many more choices of hybrid cars. As a result, hybrid promotion and incentive programs are likely to have some incremental positive net effect on consumer purchase behavior.

Related Policies/Programs in Place:

Current law provides for a Federal income tax credit up to \$3,400 for purchase of a hybrid.

Estimated GHG Savings and Costs Per tCO₂e:

Not quantified (included in TLU-1).

Data Sources, Methods, and Assumptions:

Not quantified.

Key Uncertainties:

There are numerous uncertainties about what influences consumer demand for different

types of automobiles. While some consumer education and incentive programs have been shown to have positive impact (e.g., most notably, Energy Star programs), the degree of success of hybrid vehicle promotion and incentive programs is uncertain.

Ancillary Benefits and Costs:

None cited.

Feasibility Issues:

None cited.

Level of Group Support:

Unanimous.

Barriers to Consensus:

None cited.

TLU-8 Feebates

Policy Description:

"Multi-State LDV GHG Fee and Rebate Study and Pilot Program." The State of Arizona would participate in funding a multi-state study of "feebate" program benefits and costs, including the neighboring states of California and New Mexico. Feebate proposals usually have two parts: 1) a fee on relatively high emissions/lower fuel economy vehicles; and 2) a rebate or tax credit on low emissions/higher fuel economy vehicles.

Policy Design:

The "Multi-State LDV GHG Fee and Rebate Study and Pilot Program" would consider the expected impacts of individual state feebate programs as well as coordinated or consistent multi-state programs. Ideally, such a multi-state study would include a number of western states in order to assess boundary issues as well as coordination issues. Initial analysis suggests that the Arizona new car market, which represents approximately 2% of the United States market, may be too small a share of the market to have an effect on the types of vehicles that manufacturers put into the marketplace. A consistent set of feebate programs across multiple states may include a large enough share of the U.S. market to have a more significant effect on supply side decisions made by automobile manufacturers. The study would also identify and assess the actual benefits and costs of a pilot feebate program to be implemented at the county or metropolitan level in the western United States.

Economic analyses of these proposals have found that feebate programs would work on two levels. First, the feebates would directly affect consumer choices for vehicle purchases as a result of the financial incentives. Second, the feebates could indirectly affect the types of vehicles that automobile manufacturers choose to put into the marketplace.

While feebate proposals have been described in academic studies, there has been no implementation of a full feebate program to date in the United States. While there are individual 'gas guzzler tax' and tax incentives for hybrid vehicle purchases, there is not yet any history of an on-the-ground example of an implemented feebate program.

Both the United States Department of Energy and the Canadian Transport Ministry have studied the potential impacts of national level feebate programs in recent years. While these studies have informed the debate about the advantages and disadvantages of national feebate programs, there remains considerable uncertainty about the potential benefits and costs of state or multi-state level feebate programs.

There is an important need for a greater understanding of the potential effects of single state or multi-state feebate programs on the types of vehicles that manufacturers put into the marketplace. Since existing analysis shows that 90% of the benefits of feebate programs are likely to arise from the manufacturing (supply side) response rather than the consumer (demand side) response, it is important to develop a better understanding of where the threshold for manufacturer response lies and the degree of impact of single state and multi-state programs. Some political issues also may arise relating to the potential perception of the fee portion of these programs as additional taxes on motor vehicles.

Implementation Method(s):

The State of Arizona would fund a cost-shared study with other western states. The study would be jointly funded and administered by the environment agencies and energy agencies of the states that choose to cooperate in this study.

Related Policies/Programs in Place:

None cited.

Estimated GHG Savings and Costs Per tCO₂e:

Not quantified.

Data Sources, Methods, and Assumptions:

CCS conducted a review of the most relevant research and analysis on feebate proposals. CCS made three findings:

- there has been significant conceptual development of the feebate idea, especially at the national level;
- there is a need for a greater understanding of potential benefits and costs of state level and multi-state coordinated feebate programs; and
- there has not been sufficient pilot testing of feebate programs in the United States to provide implementation experience.

CCS assessed recent studies of potential GHG emission reductions from a national feebate program based on modeling work conducted by the U.S. Department of Energy's Oak Ridge National Laboratory (ORNL). CCS also reviewed other relevant recent studies and analyses of feebates conducted by the Canadian government, the State of California, and PIRG. The ORNL and other studies assume a national feebate rate high enough to produce responses from both consumers and manufacturers. ORNL's estimate of the national potential for reduction in carbon dioxide emissions is approximately 11 MMtCO₂e in 2010 and 66 MMtCO₂e in 2020.

Some attempts have recently been made to estimate the GHG emissions reduction potential from individual state feebate programs, including programs proposed for the states of Arizona and California. For example, a recent PIRG analysis suggests that a single state feebate program for Arizona would result in an estimated 0.1 MMtCO₂e GHG emissions reductions in 2020. These recent estimates of the potential impacts of individual state programs are contingent upon assumptions and analytical methods that have not undergone thorough peer review. Therefore, the results of these analyses are preliminary and should be interpreted with some caution. Further analysis and study of the potential benefits and costs of individual state and multi-state feebate programs would greatly increase confidence in projected results.

Key Uncertainties:

The results of a feebate program depend on manufacturer and consumer response, which are uncertain at this time.

Ancillary Benefits and Costs, if applicable:

Feebates would reduce criteria pollutants along with GHG emissions.

Feasibility Issues, if applicable:

Requires multi-state cooperation.

Level of Group Support:

Supermajority.

Barriers to Consensus:

None cited.

TLU-9 Pay-As-You-Drive Insurance

Policy Description:

Pay-As-You-Drive (PAYD) insurance program (changing part of vehicle insurance payments from fixed charges to per-mile charges).

Policy Design:

Arizona would change insurance regulations to allow PAYD insurance, and initiate and promote an aggressive pilot of PAYD in 2008. Assuming this pilot is successful, market penetration could increase to 100% by 2020. This could happen either through competitive pressure (increasing numbers of companies offer it in order to stay competitive) or through a change in state policy mandating PAYD at some point after it has been shown to work.

Pay-as-You-Drive Insurance has been promoted by a variety of groups for reasons that include emissions reduction and safety (through decreased driving), and fairness (by changing insurance costs to more closely track the portion of individuals' risk that is created by miles driven). Some key questions and answers are presented below.

Q: Would PAYD penalize rural residents because they drive further than average?

A: Rates can be set—as most insurance rates are—for classes. PAYD rates would be charged within classes, so that a driver in that class (for example, "rural") traveling the average distance would pay the same under PAYD as before.

Q: Does the technology exist to support PAYD?

A: Yes. The necessary equipment for remote mileage readings is standard on GM OnStar-equipped vehicles. Add-on equipment to relay mileage automatically has been added in several pilot projects for several hundred dollars. All MY1996 vehicles and newer have OBD (on-board diagnostics) that already electronically monitor mileage that can be quickly downloaded via transponder. Also, current odometers are sufficiently tamper-proof to support yearly mileage readings with no additional technology.

Q: Is there any on-the-ground experience with PAYD?

A: Yes. Several companies around the world offer PAYD today. In English-speaking countries:

- 1) Progressive Insurance ran an initial 5,000-car pilot in Texas, which saw reductions in driving of ~20%. A subsequent pilot in Minnesota filled up its 4,800 spots quickly, and Progressive is now rolling it out in other states.
<https://tripsense.progressive.com/>
- 2) GMAC Insurance and OnStar have announced a PAYD program.
- 3) The British insurance company Norwich Union offers PAYD in Britain.
www.norwichunion.com/pay-as-you-drive/index.htm.
- 4) North Central Texas Council of Governments and King County Metro (Seattle) have both recently concluded Requests for Proposals to conduct PAYD pilots
www.nctcog.org/trans/air/programs/payd/index.asp). There are no available results as yet.

Any of these pilots could be useful sources of models for an Arizona pilot project.³ See also the discussion in the AZ Public Interest Research Group (PIRG) report, below.

Implementation Method(s):

Authorization and pilot project, followed by evaluation and promotion.

Related Policies/Programs in Place:

None cited.

Types(s) of GHG Benefit(s):

CO₂ reductions.

Estimated GHG Savings and Costs Per tCO₂e:

	2010	2020	Units
GHG Emission Savings	0	2.8	MMtCO ₂ e
Net Present Value (2006–2020)		No net cost	\$million
Cumulative Emissions Reductions (2006–2020)		12.3	MMtCO ₂ e
Cost-Effectiveness		No net cost	\$/tCO ₂ e

Data Sources, Methods, and Assumptions:

CCS examined an Arizona PIRG report⁴ and compared its model results for estimated reductions in vehicle miles of travel with other studies of PAYD policies, including those produced by the Economic Policy Institute and Resources for the Future (RFF). Arizona PIRG conducted an analysis of the potential GHG reductions from a PAYD automobile insurance policy. CCS found that the AZ PIRG estimates were comparable with other estimates, which ranged from 8 to 20%. As a result, the Arizona PIRG results for estimated reductions in vehicle miles of travel and greenhouse gas emissions reductions fell within the lower range of the comparable estimates. That is, the emissions reduction estimates are conservative.

AZ PIRG's analysis assumed that insurers are required to offer mileage-based insurance for certain elements of vehicle insurance, including collision and liability. AZ PIRG assumes the PAYD policy is required, phased in over time, and that all drivers in Arizona are eventually covered. (That is, AZ PIRG's analysis assumes a different path to 100% penetration than does CCS, but both assume that penetration reaches 100% by 2020.)

To calculate GHG savings, Arizona PIRG converted Arizona state automobile collision and liability insurance expenditures to an insurance cost per mile (6.4 cents per mile). Assuming insurance consumers pay 80% of their collision and liability insurance on a per-mile basis, drivers would be assessed about a 5.1-cent charge per mile. This per-mile insurance charge would reduce vehicle-miles traveled by about 8%, and light-duty vehicle carbon dioxide

³ For additional information see: Kevin Maney, "For a price, would you let car insurer along for the ride?", *USA Today*, 8/3/05. www.usatoday.com/money/industries/technology/maney/2005-08-03-car-monitoring_x.htm; Todd Litman, "Pay-As-You-Drive Vehicle Insurance: Converting Vehicle Insurance Premiums Into Use-Based Charges" www.vtqi.org/tdm/tdm79.htm; Dean Baker, "Insurance By the Mile", *Harper's Magazine*, June, 2006. harpers.org/bb-insurance-by-the-mile-2838238.html; Ian W.H. Parry, "Is Pay-As-You-Drive Insurance: a Better Way to Reduce Gasoline than Gasoline Taxes?," Resources for the Future (www.rff.org/Documents/RFF-DP-05-15.pdf), 2005.

⁴ AZ Public Interest Research Group, "A Blueprint for Action," <http://www.arizonapirg.org/reports/BlueprintForAction.pdf>

emissions by about 4%. (See AZ PIRG, “A Blueprint for Action.”). To put this charge in context, at 20 mpg, 5.1 cents/mile = ~\$1/gallon of gasoline.

Key Uncertainties:

The specifics of the PAYD insurance programs are to be determined, and the actual effects of PAYD insurance on driver behavior are subject to some significant uncertainty.

Ancillary Benefits and Costs:

Reductions in criteria air pollutants, and reductions in crashes.

Feasibility Issues:

The CCAG raised questions and potential concerns regarding disproportionate impacts on rural drivers.

Level of Group Support:

Unanimous.

Barriers to Consensus:

None cited.

TLU-10 Low Rolling Resistance Tires

Policy Description:

Improve the fuel economy of the light-duty vehicle (LDV) fleet by setting minimum energy efficiency standards for replacement tires and requiring that greater information about Low-Rolling Resistance (LRR) replacement tires be made available to consumers at the point of sale.

Policy Design:

- **Goal levels:** Require that replacement tires be LRR tires achieving an average 3% gain in fuel economy.
- **Timing:** The requirement would begin in 2008.
- **Parties:** Industry, AZDWM, ADOT, and ADEQ.

Implementation Method(s):

Manufacturers currently use LRR tires on new vehicles, but they are not easily available to consumers as replacement tires. When installing original equipment tires, carmakers use low rolling resistance tires as a way to contribute to meeting the federal automobile fuel economy (CAFE) standards. When replacing the original tires, consumers often purchase less efficient tires. Currently, tire manufacturers and retailers are not required to provide information about the fuel efficiency of replacement tires. In addition, there is no current minimum standard for fuel efficiency that all replacement tires must meet. The rolling resistance of the various tires consumers can purchase have significant variations depending on tread design, composition, cross-section geometry, and inflation pressure.

The program would include consideration of the technical feasibility and cost of such a program, the relationship between tire fuel efficiency and tire safety, potential effects upon tire life, and impacts on the potential for tire recycling. In addition, the program would exempt certain classes of tires that sell in low volumes, including specialty and high performance tires.

An appropriate State agency would initiate a fuel efficient tire replacement program. The program could include consumer education, product labeling, and minimum standards elements. These programs would be developed under a rule development process that would incorporate the best scientific information, including the results from tests of tires conducted by the tire manufacturers, the California Energy Commission, and other data reviewed by the National Academy of Sciences.

The minimum standard is likely to be less stringent than the energy efficiency of original tires provided by the automobile manufacturers on new purchase vehicles. Such a regulation would improve the fuel efficiency of the overall LDV fleet, but not necessarily the fuel efficiency of all tires since consumers would still make choices in the marketplace. The replacement tires in the future would be on average more fuel efficient than those historically purchased, but are likely to be on average not as fuel efficient as the tires included as original equipment by the automobile manufacturers.

Related Policies/Programs in Place:

In October of 2003, California adopted the world's first fuel-efficient replacement tire law. AB 844 is a "first-of-its-kind" law requiring energy efficient tires. AB 844 directed the California Energy Commission (CEC) to develop a State Efficient Tire Program. Specifically, AB 844 requires the CEC to: 1) develop a consumer education program, 2) require that retailers provide labeling information to consumers at the point of sale, and 3) promulgate through a rule development process a minimum standard for the fuel efficiency of replacement tires sold. The California rule development process is scheduled to begin in January 2007.

Estimated GHG Reductions and Costs Per tCO_{2e}:

	2010	2020	Units
GHG Emission Reductions	~0	0.8	MMtCO _{2e}
Net Present Value (2006–2020)		Not quantified	\$million
Cumulative Emissions Reductions (2006–2020)		4.8	MMtCO _{2e}
Cost-Effectiveness		Not quantified	\$/tCO _{2e}

Data Sources, Methods, and Assumptions:

- **Data Sources:** Studies by National Research Council, California Energy Commission, and Arizona PIRG.
- **Quantification Methods:** CCS evaluated and compared a series of existing assessments, as follows:

At the request of the United States Congress, the National Research Council of the National Academy of Sciences (NRC/NAS) conducted a study of the feasibility of reducing rolling resistance in replacement tires. The 2006 NRC/NAS study made the following conclusions:

“Reducing the average rolling resistance of replacement tires by a magnitude of 10 percent is technically and economically feasible.

Tires and their rolling resistance characteristics can have a meaningful effect on vehicle fuel economy and consumption.

Although traction may be affected by modifying a tire's tread to reduce rolling resistance, the safety consequences are probably undetectable.

Reducing the average rolling resistance of replacement tires promises fuel savings to consumers that exceed associated tire purchase costs, as long as tire wears life is not shortened.”

A 2003 study commissioned by the California Energy Commission found that about 300 million gallons of gasoline per year can be saved in that state with lower rolling resistance tires. A set of four low rolling resistance tires would cost consumers an estimated \$5 to \$12 more than conventional replacement tires. The efficient tires would reduce gasoline consumption by 1.5 to 4.5%, saving the typical driver \$50 to \$150 over the 50,000-mile life of the tires. Consumers would save more than \$470 million annually at current retail prices or approximately \$1.4 billion over the 3-year lifetime of a typical set of replacement tires.

The Arizona PIRG report, “A Blueprint for Action,” presents estimates for potential carbon dioxide emission reductions from a low-rolling resistance replacement tire program. The AZ PIRG estimate for GHG reductions from a fuel efficient tire program is 0.7 MMtCO_{2e} in 2020. PIRG calculates an estimated 2.4% reduction in greenhouse gas emissions from the PIRG-calculated baseline. (See AZ PIRG, “A Blueprint for Action,” pp. 22-23, 54)

The PIRG analysis uses a base case scenario that is different from the approved Arizona CCAG reference case scenario. As a result, the CCS quantification method used was to apply the 2.4% estimate of the emissions reductions to the CCAG reference case scenario, producing an emissions reduction that is higher than the 0.7 MMtCO_{2e} estimated by AZ PIRG. The resulting CCS estimate for emissions reductions from fuel-efficient replacement tires is 0.8 MMtCO_{2e} in 2020.

- **Key Assumptions:** The amount of greenhouse gas emissions reductions from this policy depends upon what the average fuel efficiency of replacement tires would be under such a policy and the rate at which consumers will replace their existing tires with more fuel-efficient tires.

Key Uncertainties:

The low rolling resistance fuel efficient tires program is based upon existing off-the-shelf technologies and products that already exist in the consumer marketplace. These tires are already available in the marketplace, and are comparable with the tires included as original equipment on new purchase light-duty vehicles.

Ancillary Benefits and Costs, if applicable:

Some reduction in criteria pollutants.

Feasibility Issues, if applicable:

Some members of the group raised questions about potential safety and performance compared to conventional tires.

Level of Group Support:

Unanimous.

Barriers to Consensus:

None cited.

TLU-11 Accelerated Replacement/Retirement of High-Emitting Diesel Fleet

Policy Description:

Reduce GHG black carbon emissions from heavy-duty diesel vehicles by developing and implementing an incentives program in Arizona to accelerate the replacement and/or retirement of the highest-emitting diesel vehicles.

Policy Design:

Starting with the 2007 model year, the emission standards for new heavy-duty diesel vehicles will be significantly tightened. In conjunction with these more stringent emission standards, the sulfur content of diesel fuel will be lowered from 500 parts per million (ppm) to 15 ppm. These measures will combine to significantly reduce GHG black carbon emissions from heavy-duty diesel trucks and buses. However, a large number of older, more-polluting diesel vehicles will remain in the fleet for a number of years. This measure is aimed at developing methods to incentivize the owners of these older vehicles to retire their vehicles early and replace them with vehicles meeting the 2007 emission standards.

- **Goal levels:** Target 25% of vehicles from model years 1990 through 2006 (e.g., vehicles that still have over 4 years of expected useful life and do not meet the 2007 emission standards) for early retirement/replacement.
- **Parties:** Industry, ADEQ, local jurisdictions, and school districts.

Implementation Method(s):

Information and education: An information and education component will be needed to provide truck and bus owners, school districts, and municipal organizations with information regarding the significant GHG black carbon emission reductions that could be achieved by retiring certain truck or bus engines with high annual emissions and replacing them with vehicles meeting the new emission standards. Provide information on potential funding partners, grants, or loans available from a number of organizations for this purpose.

Tools: Develop a database tool to show the lifetime emission reductions that would be achieved from retiring specific truck and bus models as well as calculate to estimate the cost of purchasing a new vehicle on an accelerated schedule.

Funding mechanisms or incentives: Develop policies to incentivize truck and bus owners with high annual emissions to retire their vehicles on an accelerated basis.

Voluntary and/or negotiated agreements: The program could be set up on a strictly voluntary basis.

State lead-by-example: The State of Arizona could lead-by-example by replacing their older/dirtier vehicles. Target fleet owners of older vehicles within the State for a pilot program aimed at replacing a number of that fleet's vehicles.

Related Policies/Programs in Place:

None cited.

Types(s) of GHG Benefit(s):

This program will reduce black carbon emissions.

Estimated GHG Savings and Costs Per tCO₂e:

	2010	2020	Units
GHG Emission Savings	0.2	0.03	MMtCO ₂ e
Net Present Value (2006–2020)		Not quantified	\$million
Cumulative Emissions Reductions (2006–2020)		1.2	MMtCO ₂ e
Cost-Effectiveness		Not quantified	\$/tCO ₂ e

Note that reductions in 2020 are lower than reductions in 2010 due to natural fleet turnover (e.g., fewer vehicles in fleet not meeting the 2007 emission standards by 2020).

Data Sources, Methods, and Assumptions:

- **Data Sources:**

CCS, Arizona Greenhouse Gas Inventory and Reference Case Projections, 1990–2020, March 2006.

Data from EPA’s MOBILE6.2 model were used to estimate the mix of Class 8 Heavy Duty Diesel Vehicle (HDDV) VMT, PM₁₀ emissions, and number of vehicles by model year.

“RIA Local Mobile Measures Methodology,” EPA memo on the estimation of potential local control measures, May 2006.

- **Quantification Methods:** The 2002 PM₁₀ and black carbon emissions estimates prepared for Arizona’s greenhouse gas emissions inventory by CCS were used as the baseline emissions. These were scaled by Arizona diesel fuel use and fleet average PM₁₀ exhaust emission rates to 2010 and 2020 to estimate 2010 and 2020 statewide PM₁₀ emissions from Class 8 HDDVs. Data from EPA’s MOBILE6.2 emission factor model were used to estimate the mix of vehicles types and ages in the fleet. The mix of model years expected to be candidates for this measure (1990 through 2006 model years) and reductions from replacing engines with new 2007 model year engines were based on EPA’s assumptions by model year (EPA, 2006), providing a 90 to 98% PM reduction. PM₁₀ exhaust emission reductions were then scaled to black carbon and CO₂ equivalent emission reductions.

- **Key Assumptions:** A replacement rate of 25% of vehicles from eligible model years.

Key Uncertainties:

Actual attainable replacement rates.

Ancillary Benefits and Costs:

This program will also reduce emissions of PM, NO_x, and toxics.

Feasibility Issues:

None cited.

Level of Group Support:

Unanimous.

Barriers to Consensus:

None cited.

TLU-12 Biodiesel Implementation

Policy Description:

Increase market penetration of biodiesel fuels in Arizona by a mixture of policies (voluntary and/or mandatory) to achieve feasible goals.

Policy Design:

Increase market penetration of biodiesel fuels in Arizona. (Ethanol reductions are accounted for in the agriculture sector.) Conduct a review of any technical impediments to biodiesel use, and, if these are not significant, proceed to policies and measures that significantly increase biodiesel use and substitution for conventional diesel fuel. Target programs to the best possible applications where they are most likely to be successful and with a certainty of obtaining significant GHG emission reductions. This measure will help to ensure that Arizona is actively pursuing and meeting or exceeding the alternative fuel penetration goals specified in the Energy Security Act of 2005.

- **Goal levels:** 75% B2 penetration by 2010 (e.g., 1.5% total penetration of biodiesel). Review the program success by 2015 and determine whether further penetration of biodiesel fuel is desirable. This review should take into consideration the interactions of biodiesel blends with the ultra-low sulfur diesel to be sold nationally by 2010 and the implementation of new diesel vehicle emission standards starting in 2007. If the program is determined to be successful at that point, and if supply of biodiesel is not an issue, set a goal of at 50% B20 penetration by 2020 (e.g., 10% total penetration of biodiesel).
- **Timing:** See above.
- **Parties:** Industry, AZDWM, ADOT, ADEQ, local jurisdictions, and school districts.

Implementation Method(s):

Information and education: An information and education component will be needed to let consumers know of product availability and associated performance issues, as well as the potential benefits of using these fuels.

Voluntary and/or negotiated agreements: A program could be set up on a voluntary basis to target certain fleet segments. For example, a B20 biodiesel program (20% biodiesel blended with 80% petroleum diesel) in a truck fleet with older vehicles (e.g., without diesel particulate filters) should achieve success. Emergency vehicles and snow removal vehicles should not be included in such programs.

Codes and standards: In order for this program to be successful, the standards and enforcement recommended under policy TLU-5 (Standards for Alternative Fuels) should be in place first. The State could impose a mandatory biodiesel use requirement for fuel vendors that goes beyond the biofuels requirement in the Energy Security Act of 2005.

Pilots and demos: Have the State of Arizona lead by example. Where practical, have State diesel vehicles begin using B10 and B20 fuel and report on experience to industry.

Related Policies/Programs in Place:

HR 6, the Energy Security Act of 2005, established a Renewable Fuel Standard that requires that 4 billion gallons of ethanol and/or biodiesel be used in 2006 nationally and increasing to at least 7.5 billion gallons in 2012.

Types(s) of GHG Benefit(s):

This measure will reduce emissions of CO₂ by 78% when compared to CO₂ emissions from diesel fuel on a full life cycle basis.

Estimated GHG Savings and Costs Per tCO₂e:

	2010	2020	Units
GHG Emission Savings	0.10	1.1	MMtCO ₂ e
Net Present Value (2006–2020)		Zero net cost	\$million
Cumulative Emissions Reductions (2006–2020)		6.2	MMtCO ₂ e
Cost-Effectiveness		Zero net cost	\$/tCO ₂ e

Data Sources, Methods, and Assumptions:

- **Data Sources:**

“Final Arizona Greenhouse Gas Inventory and Reference Case Projections 1990–2020,” The Center for Climate Strategies, June 2005.

“Documentation of Inputs to Macroeconomic Assessment of the Climate Action Team Report to the Governor and Legislature,” California Climate Action Team, January 2006.

A Life Cycle Inventory of Biodiesel and Petroleum Diesel for Use in an Urban Bus, Sheehan et al. May 1998.

- **Quantification Methods:** The quantity of diesel fuel projected to be used in Arizona in the Arizona GHG inventory was multiplied by the penetration rate of biodiesel fuel (0.02*0.75 for 2010, 0.20*0.5 for 2020). Emission reductions from this option were quantified based on multiplying the biodiesel fuel penetration by the baseline projected CO₂ emissions and then applying a 78% reduction in CO₂ to account for the biodiesel CO₂ reduction. (Sheehan, et al, May 1998). A biodiesel fuel economy penalty of 4.6% was applied.
- **Key Assumptions:** This analysis assumes a 78% reduction in CO₂ emissions from biodiesel fuel and resolution of barriers to market penetration.

Key Uncertainties:

GHG benefits will depend on biodiesel feedstock and production process used. Benefits may differ for older trucks versus those meeting 2007 emission standards. The effect of biodiesel on engines meeting new pollution standards with low sulfur diesel is questioned by some in the industry.

Ancillary Benefits and Costs:

The use of biodiesel will also reduce emissions of PM, SO₂, CO, and HC in older vehicles (emission reduction potential reduced with new technology engines equipped with catalyts

and diesel particulate filters). EPA has reported that the use of B20 biodiesel can lead to a 21% reduction in HC, 11% reduction in CO, and a 10% reduction in PM emissions. Toxic emission reductions can also be significant. However, biodiesel can lead to increased exhaust emissions of NOx and some air toxics, depending on feedstock and blend level. EPA reports a 2% increase in NOx emissions for B20 blends. Effects on newer diesel vehicles are likely to be different. An increased penetration of biofuels reduces our foreign fossil fuel dependency. Biodiesel reduces energy content which reduces fuel economy: 0.9–2.1% reduction for B20 and 4.6–10.6% reduction for B100. Biodiesel typically costs more than diesel (EPA estimates a 30 to 40 cents per gallon increase.)

Feasibility Issues:

Some members of the group were concerned that biodiesel use could lead to operational problems, particularly at low temperatures, and could also lead to operational problems on new technology engines equipped with diesel particulate filters. Others felt that these issues have been resolved and would not impact future biodiesel use.

Level of Group Support:

Unanimous.

Barriers to Consensus:

None cited.

TLU-13 State Lead-By-Example (Procurement and SmartWay)

Policy Description:

Arizona state agencies could “lead by example” by enacting procurement policies and or joining the EPA SmartWay program that result in adoption of lower emitting vehicle fleets. There are three primary components of the program: creating partnerships, reducing all unnecessary engine idling, and increasing the efficiency and use of rail and intermodal operations.

Policy Design:

Goals, levels, timing, and participation in procurement or voluntary standards programs were not specifically considered, and need to be developed in the future.

Implementation Method(s):

There are numerous activities Arizona could pursue to participate fully in enacting procurement policies or programs such as SmartWay. For example:

State agencies with vehicle fleets could sign on as SmartWay carrier partners. They would then measure their environmental performance with the FLEET model and come up with a plan to improve that performance. The partnership provides information and suggested strategies to improve fuel economy and environmental performance of vehicle fleets.

State agencies that buy transportation services, or ship goods could sign on as SmartWay shippers. As shipper partners, state agencies would seek to select SmartWay partners when they purchased the services of carriers. One way that the State could help would be to add SmartWay certification to the list of factors that they may consider when selecting carriers. Alternatively, they could encourage the carriers that they do business with to join the partnership. Shippers can also implement direct strategies, for instance, developing no-idle policies for their loading areas.

State agencies could sign onto SmartWay as affiliates. As affiliates, they would help to distribute information on the program to interested parties. This could be as easy as putting a link on their web site, or it could involve a more active role.

Related Policies/Programs in Place:

There are three Arizona based carriers in the program now: Knight Transportation, Inc., McKelvey Trucking Company, and Swift Transportation Co.

Types(s) of GHG Benefit(s):

CO₂, black carbon.

Estimated GHG Savings and Costs Per tCO₂e:

	2010	2020	Units
GHG Emission Savings	0.03	0.04	MMtCO _{2e}
Net Present Value (2006–2020)		Zero net cost	\$million
Cumulative Emissions Reductions (2006–2020)		0.4	MMtCO _{2e}
Cost-Effectiveness		Zero net cost	\$/tCO _{2e}

Data Sources, Methods, and Assumptions:

To roughly approximate what an aggressive State program could accomplish, CCS examined data on gasoline and diesel fuel use by the six largest State fleets.⁵ CCS estimated the GHG reductions associated with reducing this fuel use by 85 percent. This could be accomplished by some combination of use of E85 fuels, biodiesels, ZEVs, and other alternative fuels. The analysis assumed that the 85 reduction occurred in 2010 and continued through 2020, with fleet VMT growing at the same 2.5%/year as the private LDV fleet. Similar to other options dealing with biofuels, the analysis assumed that these alternatives would be competitive in price and would result in zero net cost.

Key Uncertainties:

None cited.

Ancillary Benefits and Costs:

Some reduction in criteria pollutants.

Feasibility Issues:

None cited.

Level of Group Support:

Unanimous.

Barriers to Consensus:

None cited.

⁵ Arizona Department of Administration, *Use of Alternative Fuels in the State Motor Vehicle Fleet*, June 30, 2005.

TLU-14 60 MPH Speed Limit for Commercial Trucks

Policy Description:

Reduce speed limit for commercial trucks to 60 mph.

Policy Design:

- **Goal levels:** Reduce Class 8 commercial diesel truck traffic traveling above 60 mph on interstates, freeways, and major arterials by 50%.
- **Timing:** Begin enforcement of measure by 2008.
- **Parties:** ADOT, and state police.

Implementation Method(s):

Education/outreach: Provide information to the trucking industry and the general public about the fuel economy benefits obtained when reducing speeds from 70 mph to 60 mph. Emphasize fuel savings and safety aspects.

Codes/standards: Have all interstates, freeways, and major arterials signed with a maximum speed of 60 mph for Class 8 commercial trucks. Significant enforcement resources will be needed to ensure the success of this measure.

Related Policies/Programs in Place:

Current speed limits are as high as 75 mph, depending on the highway segment.

Types(s) of GHG Benefit(s):

CO₂, black carbon

Estimated GHG Savings and Costs Per tCO₂e:

	2010	2020	Units
GHG Emission Savings	0.3	0.5	MMtCO ₂ e
Net Present Value (2006–2020)		\$179	\$million
Cumulative Emissions Reductions (2006–2020)		5.2	MMtCO ₂ e
Cost-Effectiveness		\$35	\$/tCO ₂ e

Data Sources, Methods, and Assumptions:

- **Data Sources:**
U.S. Department of Labor, Bureau of Labor Statistics, “Establishment Data; Hours and Earnings,” Table B-14 and “Employer Costs for Employee Compensation–December 2005,” Table 10.

U.S. Environmental Protection Agency, Office of Transportation and Air Quality, Smartway Transport Partnership, "A Glance at Clean Freight Strategies: Reducing Highway Speed," EPA420-F-04-007, February 2004.

U.S. Environmental Protection Agency, Office of Transportation and Air Quality, MOBILE6 model, documented in "User's Guide to MOBILE6.1 and MOBILE6.2: Mobile Source Emission Factor Model," EPA420-R-03-010, August 2003.

Ang-Olson, Jeffrey and William Schroeer, "Energy Efficiency Strategies for Freight Trucking: Potential Impact on Fuel Use and Greenhouse Gas Emissions," *Transportation Research Record 1815*, Transportation Research Board of the National Academy of Sciences, Washington, DC, 2002.

- **Quantification Methods:** The diesel fuel consumption from Class 8 diesel trucks was multiplied by 80% to account for the amount of fuel estimated to be consumed at speeds above 60 mph. This fuel consumption was then multiplied by 50% to account for the expected penetration rate of this measure. This quantity was then multiplied by the percentage increase in fuel economy. The ratio of reduction in fuel consumption was then multiplied by the baseline CO₂ emissions to estimate the reduction in CO₂ from this measure. Costs were calculated by multiplying the per unit fuel cost by the number of gallons reduced and subtracting this from the product of the increased time required for traveling the same distances at 60 mph rather than 70 mph multiplied by the hourly trucking industry cost.

- **Key Assumptions:**

80% of Class 8 diesel truck travel (fuel consumption) is spent at speeds above 60 mph, assumed to be at 70 mph on average. Fifty percent of this truck travel is assumed to be reduced to 60 mph (Ang-Olson and Schroeer).

Each one mile per hour reduction of speed from 70 mph to 60 mph yields a fuel economy increase of 0.1 miles per gallon (EPA).

A fuel cost of \$2.40/gallon is assumed.

Average hourly truck transportation wage is \$17.22/hour (BLS), with an industry average overhead rate of 1.48 (BLS).

Base fuel economy assumed to be 6.42 mpg (EPA MOBILE6 model); assumed to increase to 7.42 mpg with this measure.

Key Uncertainties:

The ability to enforce a speed limit significantly lower than current policy is uncertain. The fuel cost assumed here is based on long-term projected fuel costs. Increases in this assumed fuel cost will lead to lower overall costs or a cost savings for this measure.

Ancillary Benefits and Costs:

This measure will lead to a reduction in fuel consumption from Class 8 commercial trucks. Some reduction in criteria pollutant emissions would also be expected to occur. There will be an increase in travel time required for the vehicles affected by this measure. The increased costs of speed enforcement are not included here. This measure should lead to increased driver safety which may decrease operating costs. Reducing speed is also likely to reduce truck maintenance costs. These costs have not been factored into this analysis.

Feasibility Issues:

None cited.

Level of Group Support:

Supermajority.

Barriers to Consensus:

None cited.

Feasibility Issues:

None cited.

Level of Group Support:

Supermajority.

Barriers to Consensus:

None cited.



**APPENDIX J: AGRICULTURE AND FORESTRY -
DETAILED POLICY DESCRIPTION/ANALYSIS**

Overview

The Agriculture and Forestry (AF) sector includes emissions and mitigation opportunities related to use of biomass energy, protection, and enhancement of forest and agricultural carbon sinks, control of agricultural methane emissions, production of renewable fuels, and reduction of transport emissions from imported agricultural commodities. The CCAG recommends a set of 11 policy options for the AF sector that offer the potential for major GHG emissions reductions from the reference projection. As summarized in the table below, these 11 policy recommendations could lead to emissions savings from reference case projections of 5.9 MMTCO₂e per year by 2020 and cumulative savings of 51 MMTCO₂e from 2007 through 2020. The weighted average cost of saved carbon from the policy options for which quantitative estimates of both costs and savings were prepared was -\$0.5 per metric ton of CO₂ equivalent.

For each recommended AF policy, this technical appendix provides details on design, analysis, quantification of impacts, and other related information. (See Appendix E for explanation of the general methods applied). GHG reductions associated with biomass energy utilization from biomass supply quantified from options F3a and F3b will overlap with GHG reductions achieved by commercializing biomass gasification/combined cycle technology in option F4 (since the biomass energy from F3a and F3b will serve as input to F4). Therefore, GHG reductions have been quantified under F3a and F3b only.

Agriculture and Forestry Sector Summary of Results

#	Policy Name	Estimated 2010 GHG Savings (MMtCO _{2e})	Estimated 2020 GHG Savings (MMtCO _{2e})	Estimated Costs or Cost Savings Per Ton (\$/tCO _{2e})	Cumulative 2007-2020 GHG Savings (MMtCO _{2e})	Level of CCAG Support
A-1	Manure Management – Manure Digesters	0.2	0.5	\$1	3.8	Unanimous
A-2	Biomass Feedstocks for Electricity or Steam/Direct Heat	0.05	0.1	-\$8	4.5	Unanimous
A-3	Ethanol Production and Use	0.5	4.0	\$0	28	Unanimous
A-7	Convert Land to Forest or Grassland	Not Quantified	Not Quantified	Not Quantified	Not Quantified	Unanimous
A-8	Reduce Permanent Conversion of Farm and Rangelands to Developed Uses	0.1	0.2	\$65	1.6	Unanimous
A-9	Programs to Support Local Farming / Buy Local	0.01	0.02	\$6	0.1	Unanimous
F-1	Forestland Protection from Developed Uses	0.3	0.3	\$17	3.7	Unanimous
F-2	Reforestation/Restoration of Forestland	0.02	0.1	\$44	0.7	Unanimous
F-3a	Forest Ecosystem Management – Residential Lands	0.5	0.5	-\$21	6.4	Unanimous
F-3b	Forest Ecosystem Management – Other Lands	0.2	0.2	-\$21	2.9	Unanimous

F-4	Improved Commercialization of Biomass Gasification and Combined Cycle	Not quantified ^a	Not quantified ^a	Unanimous
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^a Not quantified due to overlap of biomass energy resource with Option F3a and F3b.

The energy savings (measured in MMcf of natural gas, MWh of electricity, and MMgal of gasoline and diesel, and measured in dollars) associated with AF policy recommendations are presented in the table below.

Option No.	Option Name	2020 Cumulative Energy/Fuel Savings		Cost Savings (\$1,000)
		Amount	Units	
F1	Forestland Protection from Developed Uses	not quantified		not quantified
F2	Reforestation/Restoration of Forested Lands	not quantified		not quantified
F3a	Forest Ecosystem Management - Residential Lands	127,112	MMcf Nat.Gas	979,577
F3b	Forest Ecosystem Management - Other Lands	56,836	MMcf Nat.Gas	438,006
F4	Commercialization of Biomass Gasification/Combined Cycle	not quantified		not quantified
A1a	Manure Energy Utilization - Dairies	498,383	MWh Elect.	18,802
A1b	Manure Management - Land Application	not quantified		not quantified
A2	Biomass Feedstocks for Electricity or Steam Production	22,921	MMcf Nat.Gas	149,516
A3	Ethanol Production (high end of estimated benefit)	4,373	MMGal Gasoline	0 ^a
A4	Change Livestock Feedstocks	NA		NA
A5	Reduce Nonfarm Fertilizer Use	not quantified		not quantified
A6	Grazing Management	not quantified		not quantified
A7	Convert Agricultural Land to Grassland or Forest	not quantified		not quantified
A8	Reduce Permanent Conversion of Ag & Rangeland to Developed Uses	not quantified		not quantified
A9	Programs to Support Local Farming/Buy Local	15	MMGal Diesel	44,449
Totals				1,630,350

^a No savings are estimated to the consumer. Retail gasoline-equivalent gallon of ethanol is assumed to be equal to gasoline.

A-1 Manure Management - Manure Digesters

Policy Description:

Reduce CH₄ emissions from livestock manure through the use of manure digesters installed at dairies. Energy from the manure digesters is used to create heat or power, which offsets fossil fuel-based energy production and associated CO₂ and black carbon emissions.

Policy Design:

- **Goal levels:** Manage dairy manure using anaerobic digesters and energy capture technology (e.g., electricity generators) covering 25% of the state-wide dairy population by 2010. Increase this level to 75% of the dairy population by 2020. Because use of manure digesters at beef feedlots are not as far along in development as dairy applications, implement at least three demonstration projects at large beef feedlots (>5,000 head) by 2010. This represents about 5% of the current feedlot population. Expand the use of digesters or other energy production technology at beef feedlots to 50% of the feedlot population by 2020.
- **Timing:** See discussion under goal levels above.
- **Parties:** Arizona Department of Agriculture, universities, Arizona Department of Environmental Quality, industry associations, and dairies.

Implementation Method(s):

Funding Mechanisms – Funding mechanisms (grant programs, low interest loans) might be needed to reduce the capital costs and provide net savings to livestock producers.

Research and Development – Additional research should be performed to identify the best technologies suited for energy development at Arizona dairies/feedlots. For at least one of the feedlot demonstration projects, investigate the potential of a combined manure digester and ethanol production plant. In these projects, the spent grain from the ethanol process would be used as feed for the cattle. Heat and electricity produced from the manure digester is used in the ethanol plant to reduce fossil-based energy use.

Related Policies/Programs in Place: None identified.

Types(s) of GHG Benefit(s):

- **CO₂:** Use of methane captured in manure digesters to generate electricity displaces fossil fuel use and associated CO₂.
- **CH₄:** Manure digesters collect and combust the CH₄ produced from anaerobic decomposition during manure storage.
- N₂O emissions from manure management are not likely to be affected by this policy option. N₂O emissions from fossil fuel-based electricity will be offset.
- **Black Carbon:** Use of methane captured in manure digesters to generate electricity displaces fossil fuel use and associated BC emissions.

Estimated GHG Savings and Costs per tCO₂e (for quantified actions):

- GHG potential in 2010, 2020: 2010 Dairies = 0.16 MMtCO₂e; 2020 Dairies = 0.49 MMtCO₂e; Feedlots 2010 = 0.0005 MMtCO₂e; 2020 Feedlots = 0.005 MMtCO₂e.
- Net Cost per tCO₂e: Dairies = \$1; Feedlots = \$580

Based on the high costs and low GHG reductions for feedlots, only the benefits and costs for dairies are included in the policy summary at the beginning of this document.

Data Sources, Methods, and Assumptions (for quantified actions):

- **Data Sources:** Data from the GHG inventory and forecast report on methane emissions and dairy/feedlot populations were used as the starting point. It is important to note that the TWG did not want to assume any growth in either the dairy or feedlot cattle populations in future years. Hence, they were kept at 2004 levels. Methane emissions at feedlots are much lower than those at dairies due to the differences in manure management and storage at these different operations. Consistent with the policy design, manure digesters are assumed to be implemented at dairies covering 25% of the state population by 2010. By 2020, 75% of the dairy cattle population is assumed to be covered. For feedlots, 5% of the feedlot cattle are covered in 2010 and 50% are covered by 2020.

For each facility that installs a manure digester or other energy capture/utilization technology, it is assumed that 75% of the methane emissions are collected (due to inefficiencies in the manure collection process). This methane is converted to electricity using a heat rate of 17,100 Btu/kWh. The annual kWh produced were used to estimate both the costs offset (through avoided electricity consumption), as well as GHGs offset (from grid power). The 2010 grid power emission factor used was 1.607 lb CO₂e/kWh. For 2020, this value was 2.223 lb CO₂e/kWh (which factors in a higher level of coal-based power production in 2020). These values were taken from the AZ GHG Inventory & Forecast Report.

The CO₂e reduction benefits were calculated as the sum of the methane emissions reduced, plus the GHG offset from grid-based power. Costs were estimated using data on capital costs from EPA's Methane to Markets report¹ and a recent dairy manure digester application in central California. These data indicate a range of capital costs from about \$190 to \$450 per head. An annual operating cost of \$38/head was also estimated from the central California project.² An electricity offset cost of \$0.04/kWh was also used. High and low annualized costs were estimated using the high and low estimates of capital costs. The reported costs for the policy are the mid-range of these estimates. A 15-year project life was assumed along with a 5% interest rate to determine the capital recovery factor.

- **Quantification Methods:** See discussion above.
- **Key Assumptions:** No further growth in dairy and feedlot operations in Arizona (data indicate nearly 5% annual growth in the dairy herd since 1990).

Most applications of manure digesters in the U.S. have been conducted at dairies with liquid (slurry) manure management systems. For livestock operations that manage manure primarily in solid form, there could be major differences in energy technology

¹ http://www.methanetomarkets.org/resources/ag/docs/animalwaste_prof_final.pdf, accessed March 2006.

² Williams, Douglas, Valley Air Solutions, presentation "Joseph Gallo Farms Dairy Manure Digester", January 18, 2006.

selected (e.g., for solid manure, biomass gasification might be a better alternative). These different technology choices could carry higher or lower costs than those used here for anaerobic lagoon digesters combined with an engine and electricity generator. CCS believes that the range of costs considered in this analysis represents, on the low end, manure energy projects implemented for a group of farms (e.g., regional digesters/energy plants) to high end costs, where the digester/energy plant is implemented at a single facility.

Key Uncertainties:

The effects of the no-growth assumption above. This could lead to a significant underestimate of future benefits. The costs associated with anaerobic digester/energy plant application at Arizona dairies and their representativeness to the energy technology actually selected.

Ancillary Benefits and Costs, if applicable:

- Reduction of ammonia, VOC emissions, and odor.
- Reduction of fossil fuel-based energy consumption.
- Could enhance the value of manure through higher demand for manure overall and potentially higher quality of digested manure.

Feasibility Issues, if applicable:

- In the U.S., about 7% of greenhouse gas emissions are from agriculture, with the major source of agricultural emissions being nitrous oxide from agricultural soils. About 25% of agricultural emissions come from waste management activities and about 25% from enteric fermentation. We have a lot of interest in developing domestic energy sources, especially in rural areas where electricity is more difficult and expensive to obtain. We would like to focus on making some of these technologies more affordable (e.g., high initial cost of anaerobic digesters compared to other management methods).
- Need to identify methods for integrating this form of distributed power into the power grid in Arizona.
- Due to the current high costs and relatively low benefit associated with energy utilization at feedlots, the TWG recommends limiting this option to dairies only. For feedlots, the TWG recommended additional research and pilot projects to assess the future viability of energy recovery projects.

Level of Group Support:

Unanimous consent.

A-2 Biomass Feedstocks for Electricity or Steam Production

Policy Description:

Displace fossil fuel usage through the use of agricultural waste (e.g., orchard trimmings, and other crop residue) as a feedstock for electricity, steam, or space heat production.

Policy Design:

- **Goal levels:** Program goal of using 50% of available agricultural biomass residue for energy use by 2020.
- **Timing:** 20% of available biomass used by 2010, 50% by 2020.
- **Parties:** Arizona Department of Agriculture, Agricultural Cooperative Extension Offices, Arizona Department of Environmental Quality, Arizona Growers Association, and crop producers.
- **Other:** For the purposes of quantifying the costs and benefits of this option, biomass energy was assumed to be pelletized and used for commercial or residential space heating or steam production. The benefits were estimated by quantifying the amount of fossil fuel displaced (assumed to be natural gas).

Implementation Method(s):

Pilots and Demonstrations – Pilot projects on the use of different residues for energy production are needed.

Research and Development – Research is needed on techniques for collecting and processing crop residues, as well as markets for these materials.

Market-Based Mechanisms – Incentives (e.g., preferential tax rates) may be needed to spur the use of biomass energy.

Related Policies/Programs in Place:

None identified.

Types(s) of GHG Benefit(s):

- **CO₂:** Savings occur as a result of displacing fossil fuel use in the production of electricity or steam.
- **CH₄:** Not applicable (savings only occur if it can be demonstrated that biomass combustion produces less methane than fossil-based combustion).
- **N₂O:** Not applicable (savings only occur if it can be demonstrated that biomass combustion produces less methane than fossil-based combustion).
- **HFC's, SFC's:** Not applicable.
- **Black Carbon:** Likely to be a reduction in BC emissions to the extent that coal-based combustion is offset (if electricity is generated from any of the biomass utilized).

Estimated GHG Savings and Costs per tCO₂e (for quantified actions):

- GHG potential in 2010, 2020: 0.05 MMtCO₂e in 2010, 0.13 MMtCO₂e in 2020
- Net Cost per tCO₂e: -\$8

Data Sources, Methods, and Assumptions (for quantified actions):

- **Data Sources:** Harvested acres for corn grain, sorghum, barley, oats, winter wheat, and durum wheat, and orchards were obtained from USDA NASS³. Per acre crop residue yields for grain crops were taken from a joint study by the USDA and US DOE⁴. An estimate of biomass yields from orchard trimmings was taken from a report from the National Renewable Energy Laboratory⁵. Estimates of the energy content in kWh/ton for switchgrass pellets (used to estimate crop residue) were obtained from Resource Efficient Agricultural Production Canada⁶. The energy content for wood pellets was taken from a wood pellet brochure⁷. The delivered costs for biomass pellets were obtained from Resource Efficient Agricultural Production Canada⁸. A comparison of the biomass resources available using the above data to the Western Governors' Association's Clean and Diversified Energy Advisory Committee's (CDEAC) report on regional biomass resources⁹ yielded very similar results (301,000 dry tons of residue compared to the CDEAC estimate of 317,000).
- **Quantification Methods:** Acreage data and the tons of crop residue (or orchard trimmings) per acre were used to estimate the total amount of available biomass from existing crops. Estimates of the energy content for switchgrass pellets (19.3 MMBtu/ton for crop residues) and wood pellets (16.4 MMBtu/ton for orchard trimmings) were used to estimate the total energy that could be generated using biomass pellets. The amount of CO₂e avoided by burning biomass instead of natural gas was estimated by subtracting the biomass emission factor (14.96 lbs CO₂e/MMBtu) from the residential natural gas emission factor (116.7 lbs CO₂e/MMBtu). No adjustments were made for the potential differences in efficiencies between the natural gas fired and biomass fired equipment.
- **Key Assumptions:** Crop acreage for grains was assumed to remain constant for 2005–2020 and orchard acreage was assumed to remain constant for 2002–2020. The energy content and pelletizing costs for Arizona crop residue were assumed to be the same as for an analysis of pelletized switchgrass conducted in Canada.

Key Uncertainties:

- **Benefits:** The values for crop residue yields are based on National values, and may differ for crops in Arizona. It is uncertain whether all types of AZ crop residues can be economically recovered for energy use (additional research needed). The energy content of Arizona crop residue may differ from that of switchgrass. Another uncertainty is the acreage of potential biomass crops in 2010 and 2020. The benefits are quantified as the amount of fossil fuel (natural gas) offset with biomass energy for space heating. Full

³ AZ State Agriculture Overview – 2005, http://www.nass.usda.gov/Statistics_by_State/Ag_Overview/AgOverview_AZ.pdf

⁴ Biomass as Feedstock for a Bioenergy and Bioproducts Industry: The Technical Feasibility of a Billion-Ton Annual Supply, 2004, http://www.ethanolrfa.org/objects/documents/92/billion_ton_vision.pdf

⁵ Lessons Learned from Existing Biomass Plants, NREL, 2000, <http://www.nrel.gov/docs/fy00osti/26946.pdf>

⁶ Grass Biofuel Pellets, http://www.reap-canada.com/bio_and_climate_3_2.htm

⁷ http://www.energycentre.info/pdf/dokumentarkiv/brochure_about_wood_pellets.pdf

⁸ Grass Biofuel Pellets, http://www.reap-canada.com/bio_and_climate_3_2.htm

⁹ 2005. WGA Clean and Diversified Energy Advisory Committee (CDEAC) Biomass Supply Report - <http://www.westgov.org/wga/initiatives/cdeac/Biomass-supply.pdf>.

life-cycle GHG benefits (i.e., embedded energy) for the production of pelletized biomass and natural gas were not incorporated into this analysis.

- **Costs:** The costs of production and transport of pellets made from crop residue and orchard trimmings may differ from that of switchgrass.

Ancillary Benefits and Costs, if applicable:

- Increased costs associated with collecting and transporting biomass.
- Increased emissions associated with collection and transport.
- Decrease in emissions in some cases – e.g., situations where open burning of residue is replaced by controlled combustion.

Feasibility Issues, if applicable:

None were identified.

Level of Group Support:

Unanimous consent.

A-3 Ethanol Production and Use

Policy Description:

Provide incentives for the production of ethanol from crops, agricultural waste, or other materials. Use of the ethanol will offset fossil fuel use (gasoline). Different incentive programs will be needed for crop (starch-based) ethanol production versus agricultural waste (cellulosic) ethanol production processes.

Policy Design:

- **Goal levels:** Three production goal options were assessed. The first involved production of enough ethanol to support the use of E10 (10% ethanol by volume in gasoline) year round in areas that currently use it during the winter season (Maricopa, northern Pinal, and Pima Counties). Year round use would more than double the current usage levels of ethanol in Arizona. The second option involved producing enough ethanol to support alignment with the New Mexico CCAG goal of 20% ethanol usage by volume in gasoline by 2012. The third option was alignment with the New Mexico CCAG goal of 40% ethanol by 2040.
- **Timing:** The timing for the first option is by 2010. This would require the production of 207 MMgal/yr. The second option is to be achieved by 2020, and it would require the production of 858 MMgal/yr at that time. The third option would require production of 3,450 MMgal/yr by 2050. Note: production from the new Pinal County facility (55 MMgal/yr capacity) is included in the forecasted goals.
- **Parties:** Arizona Department of Environmental Quality, Arizona Department of Agriculture, and various industries and industry associations which produce feedstock for ethanol production (growers, solid waste, forest products, etc.).

Implementation Method(s):

Pilots and Demonstrations – Incentives are needed to attract investment in commercial cellulosic ethanol production plants;

Research and Development – Additional research is needed to identify the availability of appropriate feedstocks for ethanol production. The new Pinal Energy Plant is expected to take up a significant fraction of the potential corn production in the state. Additional feedstocks for starch-based production are probably limited in AZ. Cellulosic feedstocks should be identified for commercial application;

Market-Based Mechanisms – This policy option focuses strictly on the production of ethanol for use in transportation. Programs are needed to assure sufficient in-state demand for ethanol (e.g. a renewable fuels standard). The demand-side issues are handled by the Transportation and Land Use TWG.

Related Policies/Programs in Place:

None identified.

Types(s) of GHG Benefit(s):

- **CO₂:** CO₂ emissions are reduced by offsetting the use of petroleum-derived gasoline and diesel. Energy requirements of producing ethanol need to be compared to the energy requirements of producing gasoline to completely assess the CO₂ benefit. While both starch-based and cellulosic ethanol production processes produce GHG benefits, the benefits from cellulosic ethanol are much higher and were used to estimate the benefits for this option. See the discussion below.
- **Black Carbon:** Differences in BC emissions between gasoline and ethanol-blended gasoline are probably negligible.

Estimated GHG Savings and Costs per tCO₂e (for quantified actions):

Option 1:

- GHG potential in 2010, 2020: 0.49 MMtCO₂e; 0.64 MMtCO₂e.
- Net Cost per tCO₂e: \$0

Option 2:

- GHG potential in 2020, 2050: 4.03 MMtCO₂e; 8.46 MMtCO₂e
- Net Cost per tCO₂e: \$0

Option 3:

- GHG potential in 2050: 18.4 MMtCO₂e

Data Sources, Methods, and Assumptions (for quantified actions):

- **Data Sources:** Production volumes for each scenario in each year are based on forecasted gasoline consumption (from the Arizona Inventory & Forecast), current and planned ethanol production in the State, and the volume of gasoline to be offset in each year. Costs for all ethanol production are based on estimates for cellulosic technology¹⁰ and do not include the costs for the new starch-based Pinal Energy Plant. Life-cycle emission CO₂e emission factors from a General Motors sponsored¹¹ were used to estimate the emission reductions associated with offsetting gasoline consumption with varying in-state production volumes. In this study, emission factors were developed using Argonne National Laboratory's (ANL) Greenhouse gases, Regulated Emissions, and Energy use in Transportation (GREET) model. This study is included as an appendix to this report.
- **Quantification Methods:** Well-to-wheels CO₂e emission factors from a recent Argonne National Laboratory Study were used to estimate the benefits of offsetting conventional gasoline with starch-based ethanol (from the Pinal Energy Plant) and cellulosic ethanol for all incremental production needed to fulfill the policy goals. Well-to-wheels emission factors take into account the energy required to produce, process, and transport each fuel type (i.e., starting with the oil well for gasoline and the crop for starch-based

¹⁰ Charles Bensinger, Sunbelt Biofuels, personal communication with S. Roe, CCS. Costs based on cellulosic plants in the 7 to 11 MMgal/yr production range. Plants use either manure or municipal solid waste as feedstock. Plants are profitable at ethanol prices of \$1.90/gal (current price is \$2.70/gal). Costs to produce cellulosic ethanol range from \$1.28 - \$1.40/gal.

¹¹ *Well-to-Wheels Analysis of Advanced Fuel/Vehicle Systems— A North American Study of Energy Use, Greenhouse Gas Emissions, and Criteria Pollutant Emissions*, General Motors, Argonne National Lab, and Air Improvement Resource, Inc., May 2005.

ethanol). These emission factors are output from ANL's GREET Model (all based on an average fuel economy of 21 mi/gal):

Reformulated gasoline = 552 g CO₂e/mi;

Corn (starch) ethanol = 451 g CO₂e/mi;

Cellulosic ethanol = 154 g CO₂e/mi.

As shown in these emission factors, use of corn (starch-based) ethanol results in a CO₂e reduction of about 18% relative to the use of reformulated gasoline. Cellulosic ethanol consumption results in a CO₂e reduction of about 72%. Although the TWG did not recommend that this policy should target only incentives to cellulosic ethanol production, benefits of this option were estimated assuming that additional ethanol production capacity in Arizona (beyond the Pinal Energy Plant) would come from cellulosic ethanol.

The costs to produce cellulosic ethanol were taken from recent analyses of a member of the New Mexico Climate Change Advisory Group.¹⁸ Costs for the Pinal Energy Plant were not included in the assessment. Based on the current costs to produce cellulosic ethanol and the wholesale price of ethanol, these plants can be profitable (estimates are that a plant can be profitable at an ethanol price of \$1.90/gallon, while the current wholesale price is around \$2.70/gallon). Starch-based ethanol plants are being built or planned in many areas of the country due to these favorable economics (costs to produce starch-based ethanol were not identified). Due to the apparent profitability of either type of plant, a net zero cost is assumed for this option.

- **Key Assumptions:** These include: future ethanol production in Arizona will come from cellulosic ethanol plants; production volumes are set at one of the selected scenarios; current costs for cellulosic ethanol production are accurate and not expected to change considerably over the policy period (thru 2020); and current ethanol prices will not fall substantially to the point of making near-term cellulosic plants economically infeasible.

Key Uncertainties:

Representativeness of ANL's GREET model emission factors to starch-based and cellulosic ethanol production associated with Arizona-specific feedstocks and production facilities; future costs of cellulosic ethanol production (plants in the near future are likely to use enzymatic processes that have lower costs than today's acid hydrolysis technology).

Ancillary Benefits and Costs, if applicable:

- Gasoline-ethanol blends may increase or decrease emissions of some criteria and toxic air pollutants (decrease in aromatic hydrocarbons, such as benzene, toluene, and xylenes; increases in aldehydes, like formaldehyde and acetaldehyde).
- In-state job growth.
- Creates markets for current waste products (e.g., municipal solid waste, forestry and crop residues, and manure).

Feasibility Issues, if applicable:

The current wholesale ethanol pricing makes cellulosic ethanol plants very attractive. A sharp drop (e.g., below \$1.90/gallon) will have a strong negative effect on private investment. Enzymatic processes for cellulosic ethanol production are expected to be commercially-available within the next 5 to 10 years.

Status of Group Approval:

Completed.

Level of Group Support:

Unanimous consent.

Members of the group expressed the need to reiterate that this option was not meant to favor cellulosic ethanol production exclusively, and that Arizona should further investigate additional production potential for starch-based ethanol.

A-7 Convert Agricultural Lands to Grasslands or Forests

Policy Description:

Increase carbon sequestration in agricultural land by converting marginal land used for annual crops to permanent cover (grassland or forests).

Policy Design:

No data were identified to assess the location and acreages of marginal agricultural land in AZ. Further, it is not clear whether significant marginal agricultural lands exist beyond those that are already included in the Federal Conservation Reserve Program (CRP). Finally, unless the marginal agricultural lands are located in higher elevation areas of the state that receive adequate precipitation, the incremental carbon benefits are likely to be negligible.

- **Goal levels:** Program goal of converting X acres of marginal agricultural land to grassland or forest. Information on the native land cover associated with these marginal lands (forest, grassland) or their location can also be factored in to the assessment of above and below ground carbon change.
- **Timing:** Acres of land converted to grassland or forest by 2010, 2020 and 2050.
- **Parties:** Not determined.
- **Other:**

Implementation Method(s):

Not determined.

Related Policies/Programs in Place:

Federal Conservation Reserve Program.

Types(s) of GHG Benefit(s):

- CO₂: Loss of carbon to the atmosphere from tillage and fallow land is reduced by converting land to permanent cover. This increases soil carbon content. Above ground carbon stocks are increased by converting to cover with a greater ability to sequester carbon (i.e. higher biomass).

Estimated GHG Savings and Costs per tCO₂e (for quantified actions):

- GHG potential in 2010, 2020: Not quantified.
- Net Cost per tCO₂e: Not quantified

Data Sources, Methods, and Assumptions (for quantified actions):

- **Data Sources:** See discussion under Policy Description above.
- **Quantification Methods:**
- **Key Assumptions:**

Key Uncertainties:

None identified.

Ancillary Benefits and Costs, if applicable:

None identified.

Feasibility Issues, if applicable:

See discussion under Policy Description above.

Status of Group Approval:

Completed

Level of Group Support:

Minority

Members noted the lack of data to quantify benefits and costs for this option (i.e., availability of marginal agricultural lands in AZ that could be converted to native cover that were not already covered by the Conservation Reserve Program).

A-8 Reduce Permanent Conversion of Farm and Rangelands to Developed Uses

Policy Description:

Reduce the rate at which existing crop and rangelands are converted to developed uses. The carbon sequestered in soils and above-ground biomass is higher in crop and rangelands than in developed land uses.

Policy Design:

- **Goal levels:** Program goal of reducing the rate of crop and rangeland loss to 50% of the loss rate from 1982 to 1997 by 2020.
- **Timing:** 20% reduction in loss rate by 2010, 50% by 2020.
- **Parties:** County Governments, non-government organizations (land trusts), and Arizona State Land Department.

Implementation Method(s):

Information and education; technical assistance; voluntary or negotiated agreements; funding mechanisms or incentives.

Related Policies/Programs in Place:

None identified.

Types(s) of GHG Benefit(s):

- **CO₂:** Conservation of agricultural lands retains the ability of the land to sequester carbon in soil and biomass. Agricultural lands tend to hold more carbon than developed uses. These direct benefits were quantified below. Retention of agricultural lands also indirectly reduces CO₂ emissions by encouraging less suburban sprawl and the associated transportation-related emissions.

Estimated GHG Savings and Costs per tCO₂e (for quantified actions):

- GHG potential in 2010, 2020: 0.08 MMtCO₂e; 0.20 MMtCO₂e.
- Net Cost per tCO₂e: \$65

Data Sources, Methods, and Assumptions (for quantified actions):

- **Data Sources:** The number of acres that moved from cropland, pasture, and rangeland categories to developed uses between 1982 and 1997 was obtained from the USDA Natural Resource Inventory (NRI). Agricultural land soil carbon data was taken from a study in *Soil Science* that compiled data for cultivated and uncultivated land with various soil types¹². Estimates of soil carbon on Arizona rangeland was obtained from the STATSGO/SSURGO SOC database.

¹² Mann, L.K. 1986. Changes in soil carbon storage after cultivation. *Soil Science* 142(5):279-288.

Costs for agricultural land can vary widely from as low as \$200/acre in rural areas without significant water supply to as much as \$100,000/acre in prime locations with high development potential.¹³ Costs were estimated for this option using a cost of \$2,000/acre for conservation easement. This cost represents the nationwide average determined by the American Farmland Trust.¹⁴

- **Quantification Methods:** The number of acres of cropland, pasture, and rangeland converted to developed uses between 1982 and 1997 was divided by 15 years to give the average number of acres lost each year. The number of acres to be saved in 2010 and 2020 were estimated by multiplying the average rate for 1982–1997 by 20% and 50%, respectively. The amount of CO₂ emissions savings were estimated by assuming that for each acre lost to development, 10,000 sq ft (0.23 acre) losses 100% of the soil carbon. The remainder of the acre losses 25% of soil carbon.
- **Key Assumptions:** Above-ground carbon stocks for agricultural lands and rangeland was assumed to be small compared to soil carbon. For each acre of land lost to development, 10,000 square feet is assumed to lose 100% of the soil carbon. This area represents the area in buildings, streets, and other structures that cover the soil. A loss of 25% of the soil carbon is assumed for the remainder of the acre.

Key Uncertainties:

The main areas of uncertainty are the existing soil carbon stocks and the change in soil carbon when land is developed.

Ancillary Benefits and Costs, if applicable:

- Transportation emissions may also be reduced by directing growth to more efficient locations.

Feasibility Issues, if applicable:

None identified.

Level of Group Support:

Unanimous consent.

¹³ Bob Findling, The Nature Conservancy, personal communication with H. Lindquist, CCS, June, 2006.

¹⁴ American Farmland Trust, A National View of Agricultural Easement Programs, <http://www.aftresearch.org/PDRdatabase/NAPidx.htm>.

A-9 Programs to Support Local Farming/Buy Local

Policy Description:

This option seeks to promote consumption of locally produced agricultural commodities, which would offset consumption of commodities transported from other states or countries. It includes the modification, enhancement, and further development of local farm programs employed in Arizona to reduce transport-related GHG emissions.

Policy Design:

- **Goal levels:** The object of expanding local farm programs and coordinating existing community programs is to increase consumption of agricultural products from sources within Arizona. In addition to the benefits of reducing fuel usage, transportation costs and air pollutant emissions, consuming locally grown foods will directly support Arizona producers, consumers, and retailers. This policy looks to increase consumption of Arizona grown commodities by 10%, thereby offsetting commodities transported from other states/countries by the same amount.
- **Timing:** While reducing greenhouse gases in Arizona and achieving a 10% increase in the consumption of local farm commodities, the expansion, coordination, development, and implementation of local farm programs requires financial support and “cause marketing” that will connect consumers to the value of sustaining Arizona’s agricultural industry. To achieve the goal of this policy, implementation milestones are estimated at 5% by 2010 and another 5% by 2020 (total of 10% offset in 2020).
- **Parties:** Agricultural producers, industry, communities, government, and others in Arizona.

Implementation Method(s):

Information and education; technical assistance; codes and standards, including State government preferred purchases for local agricultural commodities; market-based mechanisms; research and development, including research into methods to measure and monitor in-state and local agricultural commodity purchases and imported commodities.

Related Policies/Programs in Place:

Community Supported Agriculture Farmers Markets, North American Farmer’s Direct Marketing Association (NAFDMA), Farmers’ Market Nutrition Program (FMNP), Arizona Grown Program, The 5-A-Day for Better Health Program, U-Pick Programs Greenhouse Production, and Agritainment Business.

Estimated GHG Savings and Costs per tCO₂e (for quantified actions):

- GHG potential in 2010, 2020: 0.01 MMtCO₂e, 0.02 MMtCO₂e
- Net Cost per tCO₂e: \$6.

Data Sources, Methods, and Assumptions (for quantified actions):

- **Data Sources:** Estimates of harvested acres, crop yields, and crop value and production estimates for beef and dairy products were taken from Arizona Agricultural Statistics 2004. Estimates of state exports were obtained from the USDA Economic Research Service (ERS).¹⁵ U.S. per capita consumption rates were obtained from the ERS Food Consumption (Per Capita) Data System.¹⁶ Arizona population data were obtained from the Arizona Department of Economic Security.
- **Quantification Methods:** The amount of each crop produced in Arizona was estimated using harvested acres and estimates of crop yields per acre. The amount of each crop consumed in Arizona was estimated using U.S. per capita consumption rates and the Arizona population. State export values were reported for commodity class. These values were allocated to each crop based on the crop value for each individual crop compared to the total value for all crops in the commodity class. Export values were then converted from dollars to weight using an estimated price calculated from the crop production value and amount produced for each crop. The amount consumed and exported for each crop was then subtracted from the amount produced to determine how much of the crop was imported. For each imported crop, a likely state of origin was chosen (California for carrots, tomatoes, onions, grapes, eggs, and milk; Oklahoma for beef; Idaho for potatoes). The estimated amount of imports for each crop and the estimated round-trip mileage were then used to estimate ton-miles transported and CO₂ emissions. These calculations were repeated for 2010 and 2020 using population projections to estimate future consumption. Reductions were estimated by multiplying the 2010 emissions by 0.05 (representing 5% offset of imported food) and the 2020 emissions by 0.10 (10% offset).

Costs were based on the estimated need for one additional full-time equivalent (FTE) employee employed by the state (e.g., Arizona Department of Agriculture) to implement the elements of this policy. Some of the elements of this policy could be incorporated into existing programs (e.g., Arizona Grown Program; see above). The total cost for this additional FTE is \$75,000/year in 2006 dollars.

- **Key Assumptions:** Transportation emissions were estimated by assuming 23 tons of payload per truck, 6 truck miles per gallon of diesel fuel and 22.4 lb CO₂ per gallon of diesel fuel. To estimate miles traveled, food from California was assumed to travel from Fresno to Phoenix (600 miles), food from Oklahoma was assumed to travel from Oklahoma City to Phoenix (1,000 miles), and food from Idaho was assumed to travel from Boise to Phoenix (1,150 miles). These mileage estimates were then doubled, since it was assumed that each truck would return to its point of origin empty. The amount of food produced and exported is assumed to remain constant, while consumption is assumed to grow with population.

Key Uncertainties:

One uncertainty is the amount of food products leaving the State. State export data from ERS includes only foreign exports. These estimates do not include state-to-state exports. Also, these estimates do not take into account that a large portion of some crops may be shipped out of Arizona when they are in season, and imported into the State when they are

¹⁵ State Export Data, <http://www.ers.usda.gov/Data/StateExports/>.

¹⁶ Food Availability: Spreadsheets, <http://www.ers.usda.gov/Data/FoodConsumption/FoodAvailSpreadsheets.htm>.

not in season. The benefits were quantified at the state level. As such, they do not capture additional GHG benefits where local (e.g., community-level) production and consumption takes place (resulting in additional ton-mile reductions). The quantified benefits could also be conservatively low since the assumptions for out-of-state-produce were based on the nearest likely producer state. Many commodities come from much further away (including foreign countries) and can travel by more energy intensive methods (e.g., air transport). Finally, the assumed transport routes are a single trip from city of origin to Phoenix. Many commodities will make several trips prior to reaching their final point of consumption (e.g., for packaging, storage, processing, etc.). The overall impact of all of the assumptions is that the benefits are underestimated by a large amount.

Ancillary Benefits and Costs, if applicable:

- Reduction in criteria and toxic air pollutants.
- Collaboration of local farm programs with other food programs provides nutritional education and increases the consumption of healthy foods for all Arizonans.
- Educate adults and children, about Arizona agriculture and agriculture's impact on their lives.
- Support for local agricultural jobs.

Feasibility Issues, if applicable:

None identified. Much of this option involves a continuation and/or enhancement of existing programs.

Level of Group Support:

Supermajority.

Barriers to consensus (if less than unanimous consent):

A small minority of the TWG felt that the quantification showed that there was only a small potential for GHG benefits for this option. Some group members also felt that this option needed additional work in the development of implementation details and quantification of benefits and costs. CCAG members should be aware of the uncertainties described above and the conservative approach taken in the quantification of benefits. It should also be noted that the current policy design only calls for offsetting 10% of imported agricultural commodities by 2020. By offsetting 50% of these commodities, a reduction of 0.10 MMtCO_{2e} could be achieved using the same quantification approach.

F-1 Forestland Protection from Developed Uses

Policy Description:

Reduce the rate at which existing forestlands and forest cover are cleared and converted to developed uses or damaged by development that reduces productivity.

Policy Design:

- **Goal levels:** Given the considerable carbon storage potential of forest and woodlands in Arizona, and the trend of loss of these vegetation types in the past two decades, we propose that policy initiatives decrease the conversion of forest and woodlands to urban and other developed uses to 50% or less of the rates of loss to these uses during the 1987–1997 period by 2010 and continuing through 2020.
- **Timing:** see discussion above.
- **Parties:** County governments, Arizona Department of Environmental Quality, and private non-profit land trusts. Forest protection accomplished through acquisition of conservation easements and fee title by public and private conservation organizations.

Implementation Methods:

Information and education; technical assistance; funding mechanisms; voluntary/negotiated agreements.

Related Policies/Programs in Place:

None identified.

Types(s) of GHG Benefit(s):

- **CO₂:** Carbon savings occur when live carbon stocks (trees, shrubs, and some soil organic carbon) are protected from clearing and the associated decay or combustion of cleared biomass. Carbon losses are offset to some extent by the portion of harvested biomass that is converted to durable wood products (carbon storage in product use), and for that portion to be converted to renewable energy and displaces fossil energy use that otherwise would be used. Because conversion of forestland to developed land uses typically is permanent, replacement biomass does not grow back on the site to offset removals of live CH₄ biomass (i.e., to the levels that existed during forest use).
- **CH₄:** New research indicates that about 4% of the carbon storage benefits of live forests are offset by methane release. Methane can be released from land filled biomass under anaerobic conditions.
- **Black Carbon:** Emissions of black carbon (soot) result from combustion of biomass from open burning during land clearing, but the heating effect is likely to be offset by the large amount of organic material that is also emitted during biomass combustion.

Estimated GHG Savings and Costs per tCO₂e (for quantified actions):

- GHG potential in 2010, 2020: 0.31 MMtCO₂e/yr reduced in 2010 and 2020.

- Net Cost per tCO₂e: \$17

Data Sources, Methods, and Assumptions (for quantified actions):

- **Data Sources:** The number of acres that were designated from forested land and rangeland to developed uses between 1982 and 1997 was obtained from the USDA Natural Resource Inventory (NRI). Based on the comparison of rangeland acreage from NRI and pinyon-juniper acreage from USDA Forest Service, it was determined that roughly 38% of rangeland is pinyon-juniper. For the purposes of this analysis, pinyon-juniper is considered forested land. Forest carbon stock per acre data values were calculated from 2003 USDA Forest Service carbon stock and acreage data.¹⁷ Cost data for conservation easements on forested lands was obtained from the New Mexico Forest Legacy Program and The Nature Conservancy.^{18 19}
- **Quantification Methods:** The annual rate of loss from the NRI data was determined to be 7,400 acres/yr (combined forest and rangeland based on loss rates from 1982–1997). The rangeland acreage was adjusted to reflect the amount of pinyon-juniper forest on these lands (38% of rangeland in the NRI was estimated to be pinyon-juniper forest). Reducing the loss rate by 50% yields 3,700 acres/yr protected. Assumptions regarding carbon losses due to development are: for each acre lost to development, 10,000 sq ft (0.23 acre) loses 100% of soil carbon; the remainder of that acre loses 25% of soil carbon; 90% of above ground carbon is lost. The number of acres saved per year was multiplied by the loss of carbon on these acres to estimated carbon savings. Carbon savings were then converted to CO₂e.

Costs were estimated as the midpoint of the high and low costs for identified conservation easements on forested lands in the southwest. The low cost was \$720/acre for an easement; the high cost was \$3,200 (\$4,000/acre appraised land value and assuming 80% of land value for easement).

- **Key Assumptions:** Some rangeland carbon estimates are not currently included in forest carbon estimates due to data limitations; however, “Nonstocked” and “Pinyon-Juniper” forest stands as defined by FIA include many lands classified as “Rangeland” by NRI. Forecasted carbon stock measurements from 2002 to 2020 are based on extrapolations of past trends from 1982 to 1997 and assume a static continuation of all land cover and land use dynamics during that period. Implementation mechanisms are assumed to be “growth neutral” to avoid offsetting development impact, i.e., land protection does not result in land clearing in other areas (also referred to as “leakage”). Cost savings from avoided land clearing costs may be contingent on regulatory acceptance of alternative land development approaches, such as conservation design or cluster development.

Key Uncertainties:

- **Benefits:** The rate at which live biomass stocks would have declined beyond business as usual due to forest health and forest fire risks may be significant. The rate of offsetting development effects from land protection may be sensitive to the design of policy implementation tools.
- **Costs:** Regulatory acceptance of alternative development approaches by local governing bodies may affect potential cost savings of avoided land clearing costs.

¹⁷ Jim Smith, USDA Forest Service, personal communication with S. Roe, CCS.

¹⁸ Bob Sivinski, NM Forest Legacy Program, personal communication with H. Lindquist, CCS, June, 2006.

¹⁹ Bob Findling, The Nature Conservancy, personal communication with H. Lindquist, CCS, June, 2006.

Ancillary Benefits and Costs, if applicable:

- Protection of working lands for sustainable wood products use, recreation, and cultural and natural heritage.
- Environmental asset protection, including watersheds, wildlife, and air quality.
- Reduced costs of infrastructure and services for dispersed or low density development.
- Reduced transportation emissions from increased location efficiency.
- Certain biomass combustion technologies may result in significant air pollution.

Feasibility Issues, if applicable:

None identified.

Level of Group Support:

Unanimous consent.

F-2 Reforestation/Restoration of Forestland

Policy Description:

Expand forest cover (and associated carbon stocks) by regenerating or establishing forests in areas with little or no forest cover at present.

Policy Design:

- **Goal levels:** 430,000 acres of forestland impacted by wildfire restored to stocking rates of 47 tons of above ground biomass per acre (on average depending on forest type). Explore potential for additional benefits in restoring forests impacted by insect damage.
- **Timing:** 430,000 acres of forestland regenerated/established from 2008 to 2020, including approximately 70,000 acres regenerated/established by 2010 and 360,000 acres between 2010 and 2020. Average of 33,000 acres/year.
- **Parties:** USFS, AZ Forestry Division, Universities, City/County Governments, private industry.

Implementation Method(s):

Research and Development – need to identify forest areas that are best suited for restoration efforts; additional research needed to identify the potential for restoring areas impacted by insects/disease.

Funding Mechanisms - Additional work needed to identify funding sources.

Related Policies/Programs in Place:

None identified.

Types(s) of GHG Benefit(s):

- **CO₂:** Carbon savings occur when forest carbon stocks (trees, shrubs, and soil organic carbon) are established and sustained above and beyond existing levels.
- **CH₄:** New research indicates that about 4% of the carbon storage benefits of live forests are offset by methane release.

Estimated GHG Savings and Costs per tCO₂e (for quantified actions):

- GHG reduction potential in 2010, 2020: 0.02 MMtCO₂e/yr in 2010; 0.09 MMtCO₂e/yr in 2020.
- Net Cost per tCO₂e: \$44.

Data Sources, Methods, and Assumptions (for quantified actions):

- **Data Sources:** See footnotes to Option F1 for common references used to estimate carbon densities on Arizona forestlands [carbon stocks and above ground carbon densities are derived from the Forest Inventory Analysis (FIA) volumetric measurements conducted on a 5-year cycle by the USFS]. Acres burned in Arizona between 2000 and

2005 were obtained from USFS²⁰. The total acres burned were used as the basis for the acreage to be reforested. A map of these areas is provided below.

- **Quantification Methods:** Reforestation of 5% of the burned areas was assumed for the 2008–2010 period. Another 25% of the burned areas was assumed to be reforested within the 2010–2020 timeframe. The amount of carbon to be sequestered on these lands was determined using the average above-ground carbon stocking for Arizona forestlands based on the Arizona Inventory & Forecast. The length of time for each restored stand to reach maturity was assumed to be 50 years. It was further assumed that without restoration, it would take 100 years for each stand to reach maturity. Cost data for reforestation projects were taken from a survey conducted by the Interstate Compact Mining Commission (relative to restoring coal mining lands).²¹ These data suggest reforestation costs could range from \$50 to \$250 per acre. Due to the relative lack of Arizona-specific data and the years represented by the cost data, the high end of this range was used to provide a conservative estimate of program costs.
- **Key Assumptions:** Rates of forest regeneration (i.e., 2% annual biomass replacement in restored areas; 1% annual replacement without restoration).

Key Uncertainties:

- **Benefits:** The rate at which live biomass is regenerated on restored lands versus lands that do not receive any restoration treatment.
- **Costs:** The representativeness of the cost/acre data in the survey by Conrad⁵. The high end of the cost range was used in this analysis.

Ancillary Benefits and Costs, if applicable:

Restoration of forest ecosystems; watershed protection.

Feasibility Issues, if applicable:

CCS also received data on forested acres impacted by insect damage and disease. Additional GHG benefits could potentially be achieved through restoration efforts on these lands. Over 500,000 acres were impacted by insects and disease by 2002.²² The TWG did not have sufficient time to explore the potential for restoring these insect-damaged areas.

Level of Group Support:

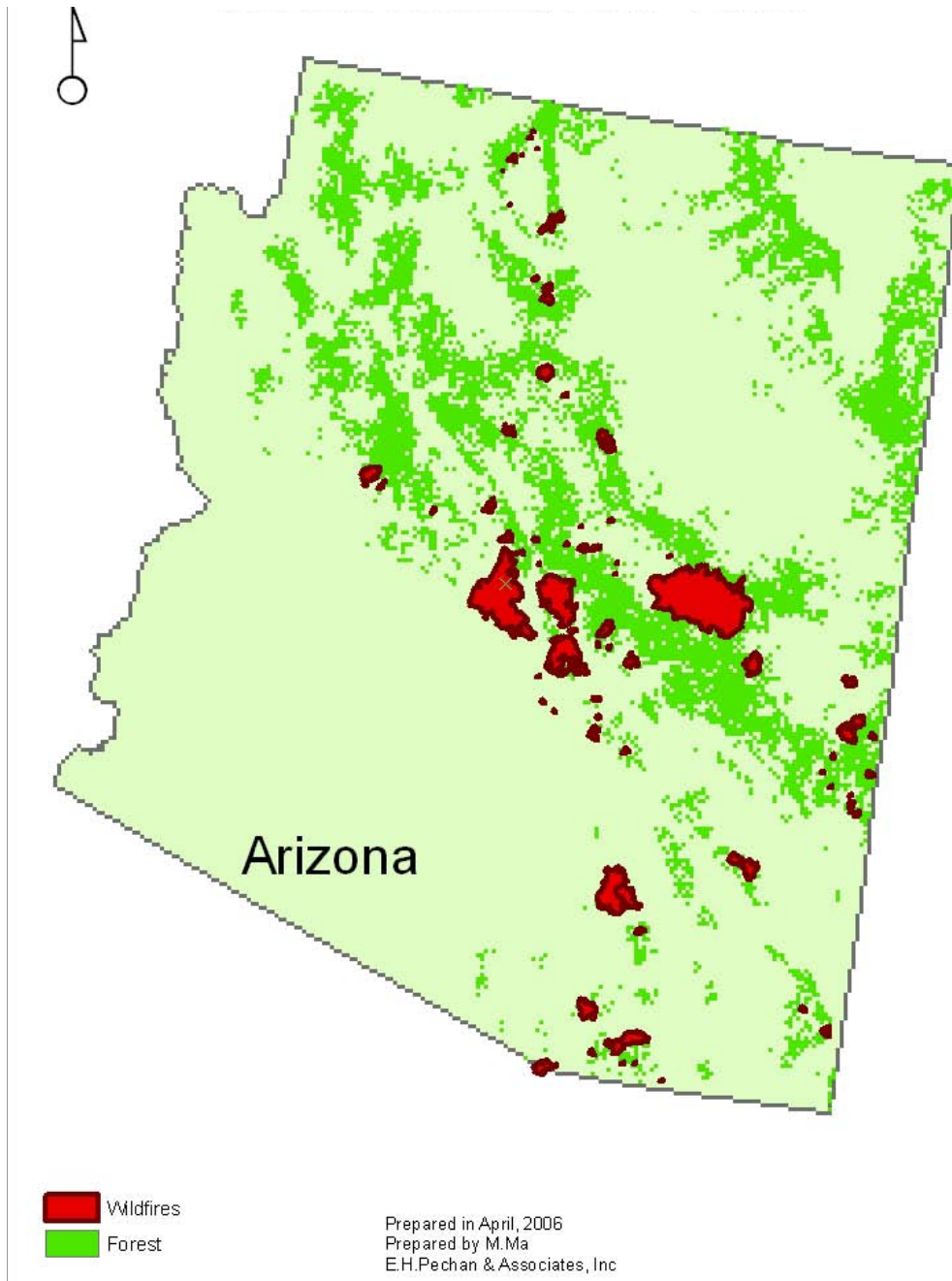
Unanimous consent.

²⁰ Fire Perimeter data from D. Ryerson USFS; http://www.fs.fed.us/r3/gis/az_data.shtml.

²¹ Conrad, G. Summary Report On State Reforestation and Tree Planting Statistics, Interstate Compact Mining Commission, <http://www.mcrcc.osmre.gov/PDF/Forums/Reforestation/Session%201/1-4.pdf>, date unknown.

²² <http://www.fs.fed.us/projects/hfi/docs/fact-sheet-arizona.pdf>.

Figure 1. Arizona Wildfires, 2000-2005



F-3a Forest Ecosystem Management – Residential Lands

Policy Description:

Manage sustainable thinning or biomass reduction from residential forestlands (intended to address fire and forest health issues) so that harvested biomass is directed to wood products and renewable energy instead of open burning or decay. This option is directed at forestlands bordering residential areas (the wildland-urban interface or WUI). Option F-3b is directed at forests in non-WUI areas.

Policy Design:

- **Goal levels:** Wildfire and other threats to forest health and sustainability, and community safety have led to a number of initiatives within the state of Arizona to reduce biomass in residential forests and woodlands. Most of these efforts include some emphasis on utilizing the extracted woody biomass for wood products and/or energy production, rather than eliminating these materials through open burning, or storage or decay off site. Although this is an existing or potential objective for many restoration and biomass treatments on these lands, a greater emphasis and focus on wood products and/or energy production, through appropriate mechanisms, incentives, etc., is recommended. In particular, a reasonable goal of utilizing 50% or more of biomass extracted from residential lands for wood products and/or energy production is recommended to be achieved by 2010 and continuing through 2020. We also recommend that current and planned fuels treatments in Arizona be accelerated, so that all high priority areas (e.g., in wildland-urban interface) are treated by 2015. We further recommend that forest management practices and policies aimed at GHG reduction and carbon sequestration be reviewed by and coordinated with the Governor’s Forest Health Oversight Council and Forest Health Advisory Council. It is quite likely that some policies already recommended by these councils, or may be recommended by the councils, are complementary and supportive of GHG reduction and carbon sequestration goals, while also promoting forest and ecosystem health and public safety. One of the key initiatives of the Forest Health Councils is a plan called “Sustainable Forests, Economies and Communities: A Statewide Strategy for Arizona Forests”. This plan calls for, among other things, spatial database development and hazard assessment, and prioritized treatments.
- **Timing:** See text above.
- **Parties:** USFS, AZ Forestry Division, City/County Governments, and private industry.
- **Other:** For the purposes of estimating GHG benefits and costs, biomass is assumed to be utilized for the production of commercial steam/space heat or residential space heat. As stated above, other end uses (electricity generation, liquid fuels, durable wood products) should also be targeted by this policy.

Implementation Method(s):

Funding Mechanisms – Provide tax incentives to reduce the capital costs of biomass energy production, including electricity generation and heating of residences and public buildings; establish utility “Buyback Rates” for biomass derived energy where utilities offer a standard

rate for which they purchase biomass generated energy (electricity and/or heat); and expand/develop renewable energy tax credits to develop new incentives for smaller distributed biomass generation.

Codes and Standards – Increase efficiency standards for wood burning equipment and appliances (e.g., wood burning furnaces and stoves). Develop or expand existing net-metering regulations to enable smaller projects to net-meter at retail energy rates.

Related Policies/Programs in Place:

None identified.

Types(s) of GHG Benefit(s):

- **CO₂:** Carbon savings occur when live and dead carbon stocks (trees, shrubs) that otherwise would decay or burn in the forest, or be left for decay and or open burning following harvest, are harvested and converted to: 1) durable wood products that store carbon; 2) to low embedded energy wood building materials that substitute for high embedded energy conventional building materials (steel and concrete); or 3) to renewable energy that displaces fossil energy use. Sustainable management ensures that replacement biomass grows back to the maximum extent on thinned sites to offset removals of live biomass. Only the benefits associated 3) above have been quantified.
- **CH₄:** New research indicates that about 4% of the carbon storage benefits of live forests are offset by methane release. Methane can be released from land filled biomass under anaerobic conditions.
- **Black Carbon:** Emissions of black carbon (soot) result from combustion of biomass from open burning of land clearing, but the heating effect may be offset by the large emissions of organic material associated with biomass combustion.

Estimated GHG Savings and Costs per tCO₂e (for quantified actions):

- GHG potential in 2010, 2020: Approximately 0.46 MMtCO₂e/yr in both 2010 and 2020. Assumes that all biomass from mechanical treatments is diverted to energy use (displacing natural gas) and that 50% of all biomass treated by fire is diverted to energy use.
- Net Cost per tCO₂e: -\$21 (based solely on displacement of natural gas; does not account for capital and annual costs associated with new biomass fired equipment.)

Data Sources, Methods, and Assumptions (for quantified actions):

- **Data Sources:** CCS obtained data on both mechanical and fire treatments conducted in Arizona from 2001 to 2006.²³ These data contained information on treatments that had occurred on both wildland-urban interface (WUI) lands and non-WUI lands. The WUI lands are those considered to be residential areas applicable to this option. The average acres treated during these years was used as the starting point for analysis. A map is provided below, which has county-level information (highest level of geographic resolution that the USFS would provide) on the total number of areas treated from 2001 to 2006, population centers, interstates, rail, transmission lines, and the small number of biomass plants currently operating in Arizona. The average carbon stocking on Arizona forestlands was taken from the USFS data that underlie the AZ Inventory &

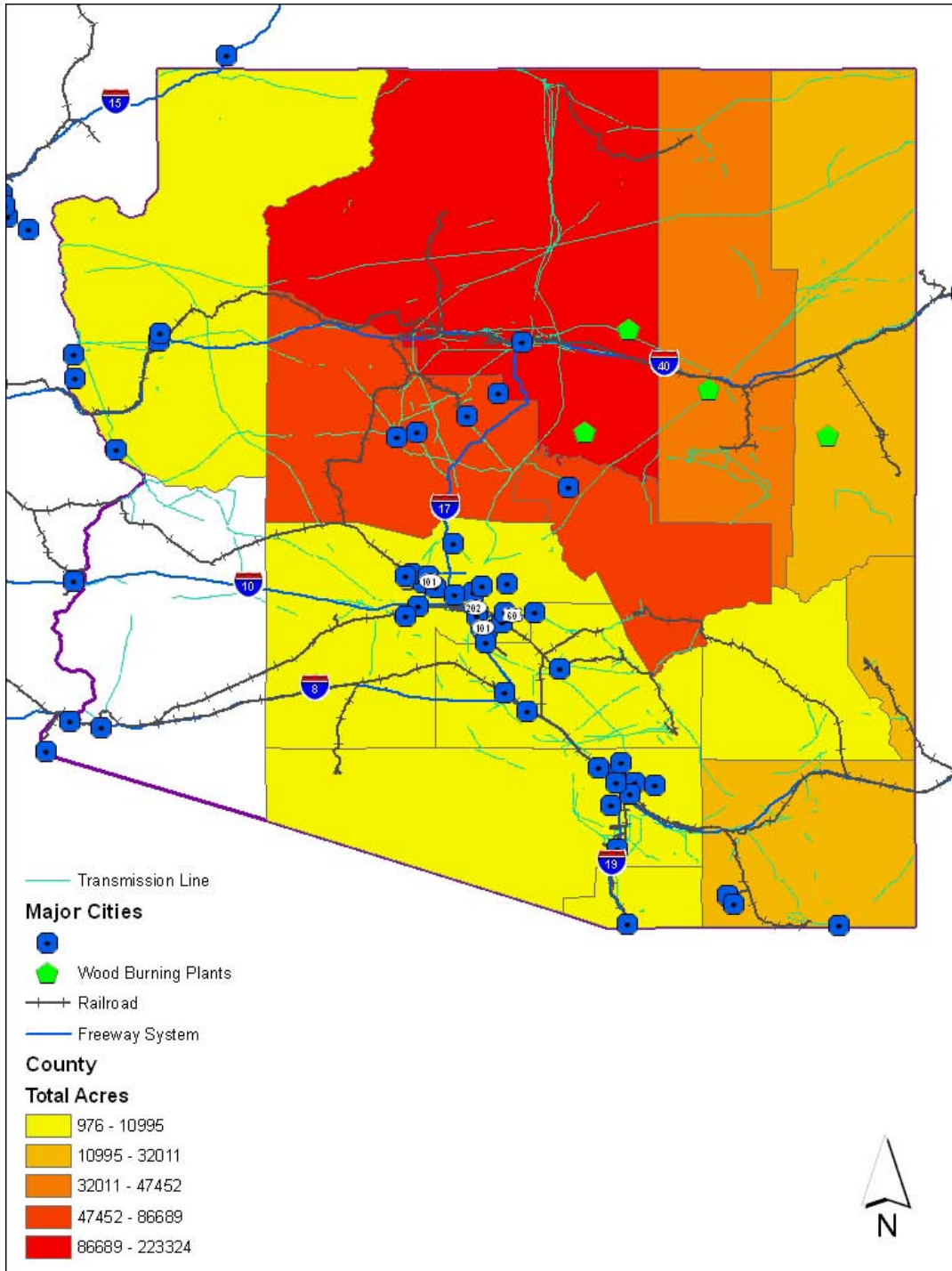
²³ J. Roland, USFS, email communication with S. Roe, CCS, 4/26/06. Data from the National Fire Plan Operations and Reporting System (NFPORS) database.

Forecast (i.e., USFS FIA). Estimates of the fraction of biomass to be removed in WUI and non-WUI areas was taken from an assessment by a researcher at Colorado State University.²⁴ A reduction in basal area of 42% associated with an "Intermediate Restoration Level" was selected for WUI lands. The reduction in basal area was assumed to be representative of a reduction in biomass density.

- **Quantification Methods:** The amount of biomass removed was then calculated by multiplying the annual acres treated by the above ground carbon density and the treatment fraction (0.42). CCS assumed that all of the biomass from mechanically treated areas would be diverted to energy use (space heat), while biomass from 50% of the fire treated acreage would be diverted. The heat content associated with the diverted biomass was then used to estimate the equivalent amount of natural gas offset (with no adjustment for potential differences in energy efficiency). Emissions from this offset natural gas were quantified as the benefit of this option. No effort was made to quantify the embedded energy (and CO₂e) associated with biomass diversion (neither were the life-cycle emissions associated with natural gas production and delivery investigated).
- **Key Assumptions:** Historical treatment areas are representative of future treatment programs. The average Arizona forest carbon density is representative of areas requiring treatment (areas requiring treatment could be stocked at levels higher than the State average). Historical treatment levels selected for analysis are representative of those to be achieved in future practice.

²⁴ Brett Dickson, CO State Univ.; Data on forest restoration levels provided to George Koch of the AZ AF TWG on 4/05/06; "Intermediate Restoration" level of treatment selected for WUI areas; reduction in basal area assumed to be representative in reduction of above-ground biomass.

Figure 2. County-level 2001-2006 AZ Fire Treatment Acreage



Key Uncertainties:

- **Benefits:** These initial estimates only account for utilization of the biomass as an energy source. Some fraction of this biomass could also find its way into merchantable timber. The benefits of this route of sequestration were not quantified. The market demand for new supplies of wood products and renewable energy is dynamic and not likely to fully absorb all new supply sources without offsetting decreases in other sources, unless there is support from policies that expand the market and, potentially, establish

preferential treatment of these products in comparison to conventional supplies. The rate of biomass replacement growth in thinned stands could be less than full due to ecological barriers and forest health issues. Finally, the benefits associated with the lower risk of wildfire (i.e., associated carbon losses) are not quantified here, since these benefits are tied to forest treatments and this policy option is focused solely on the beneficial use of biomass energy from these treatments.

- **Costs:** As noted above, costs are based solely on displacement of natural gas. Capital and annual costs associated with new biomass fired equipment (e.g., municipal boilers or residential pellet stoves) are not captured in this assessment. Future cost reductions for wood product development and biomass energy recapture technologies are likely to fall with market expansion and “learning by doing” but are difficult to estimate at this time.

Ancillary Benefits and Costs, if applicable:

- Protection of residential and or municipal lands from fire risk.
- Expansion of markets for industrial producers of sustainable wood products and renewable energy use. Creation of Arizona jobs in the associated forestry management industries.
- Environmental asset protection, including watersheds, wildlife, and air quality.

Feasibility Issues, if applicable:

None identified.

Level of Group Support:

Unanimous consent.

F-3b Forest Ecosystem Management – Other Lands

Policy Description:

Increase sustainable thinning of biomass from forests and direct the harvested wood and wood waste to wood products and renewable energy. This option is directed at forests in non-WUI areas.

Policy Design:

- **Goal levels:**

Scenario 1:

Wildfire and other threats to forest health and sustainability have led to a number of initiatives within the state of Arizona to reduce biomass in forests and woodlands. Many of these efforts include some emphasis on utilizing the extracted woody biomass for wood products and/or energy production, rather than eliminating these materials through open burning, or storage or decay off site. Although this is an existing objective or potential objective for many restoration and biomass treatments on these lands, a greater emphasis and focus on wood products and/or energy production, through appropriate mechanisms, incentives, etc., is recommended. In particular, a reasonable goal of utilizing 50% or more of biomass extracted for wood products and/or energy production is recommended. We also recommend that current and planned fuels treatments in Arizona be accelerated, so that all high priority areas (e.g., in valuable watersheds and habitats) are treated by 2015 and continue through 2020.

We further recommend that forest management practices and policies aimed at GHG reduction and carbon sequestration be reviewed by, and coordinated with, the Governor's Forest Health Oversight Council and Forest Health Advisory Council. It is likely that some policies already recommended by these councils, or may be recommended by the councils, are complementary and supportive of GHG reduction and carbon sequestration goals, while also promoting forest and ecosystem health and public safety. One of the key initiatives of the Forest Health Councils is a plan called "Sustainable Forests, Economies and Communities: A Statewide Strategy for Arizona Forests." This plan calls for spatial database development and hazard assessment, and prioritized treatments, among other things. This strategic plan is still in draft form as of writing this report. It would be useful to coordinate objectives and strategies of various forest and woodland policy options from the CCAG with this plan.

Scenario 2:

Accelerated restoration levels are anticipated as economic utilization activity increases demand for small diameter timber and woody biomass and decreases amounts paid for restoration/fuel reduction treatments through "service contracts" and actually results in land managers being paid for material removed through, for example, "timber sales" under current conditions approximately 52,800 acres of U.S. Forest Service land was projected to be treated by forest thinning in 2005, with 195,700 CCF of timber 5" dbh or greater removed and 229,200 tons of residue generated;

Timing of implementation: An average of 53,700 acres of U.S. Forest Service land on 6 national forests are proposed to be treated per year by thinning from 2005 through 2015, with an annual average of 192,500 CCF of timber over 5" dbh removed and 248,800 tons of residue generated, under current conditions. The acreage used to estimate benefits were taken from historical USFS treatment data (see data sources for F-3a above). For non-WUI areas, the acreage used was slightly lower than the initial policy design noted above. Annual acres treated from 2008 through 2020 are approximately 45,000.

Other: Current emphasis is on the wildland/urban interface zones throughout the State where communities and infrastructure are threatened by destructive wildfire, most have developed "Community Wildfire Protection Plans"; AZ Forest Health Oversight/Advisory Councils are developing a proposal – "Sustainable Forests, Economies and Communities: A Statewide Strategy for Arizona Forests" that will prioritize treatments statewide; focus mostly on ponderosa pine forests, but pinyon-juniper woodland treatments also needed.

- **Timing of implementation:** See discussion above.
- **Parties:** US Forest Service; AZ State Land Department.; DOI; Tribal lands; fire department & fire district fuel management crews; private landowners; local community-based groups – AZ Sustainable Forest Partnership, Greater Flagstaff Forests Partnership, Prescott Area Wildland/Urban Interface Commission, etc.
- **Other:** For the purposes of estimating GHG benefits and costs, biomass is assumed to be utilized for the production of commercial steam/space heat or residential space heat. As stated above, other end uses (electricity generation, liquid fuels, durable wood products) should also be targeted by this policy.

Implementation Method(s):

See Option F-3a.

Related Policies/Programs in Place:

None identified.

Types(s) of GHG Benefit(s):

- **CO₂:** Carbon savings occur when live and dead carbon stocks (trees, shrubs) that otherwise would decay or burn in the forest are harvested and converted to: 1) durable wood products that store carbon; 2) low embedded energy wood building materials that substitute for high embedded energy conventional building materials (steel and concrete); or 3) renewable energy that displaces fossil energy use. Sustainable management ensures that replacement biomass grows back to the maximum extent on thinned sites to offset removals of live biomass. Only the benefits associated with number 3 above have been quantified.
- **CH₄:** New research indicates that about 4% of the carbon storage benefit of live forests is offset by methane release. Methane can be released from land filled biomass under anaerobic conditions.
- **Black Carbon:** Emissions of black carbon (soot) result from combustion of woody biomass from open burning of land clearing, but the heating effect is likely to be offset by the cooling from the large amount of organic material emitted from biomass combustion.

Estimated GHG Savings and Costs per tCO₂e (for quantified actions):

- GHG potential in 2010, 2020: 0.21 MMtCO₂e/yr in both years (assumed constant treatment acreage)
- Net Cost per tCO₂e in 2010, 2020: -\$21 (accounts for the costs associated with offsetting natural gas; does not include costs associated with the purchase of new biomass-fired equipment)

Data Sources, Methods, and Assumptions (for quantified actions):

- **Data Sources:** See discussion under F-3a above for a description of the data sources used. For non-WUI areas, the treatment level was assumed to be the “Fuels Reduction” level of restoration from the same source cited under F-3a. This led to a 21% reduction in biomass (and carbon) density on the treated acres.
- **Quantification Methods:** See the discussion under F-3a. The same approach was applied for non-WUI lands using a different level of treatment (21% reduction) as mentioned above.
- **Key Assumptions:** See Option F-3a.

Key Uncertainties:

- **Benefits:** The market demand for new supplies of wood products and renewable energy is dynamic and not likely to fully absorb all new supply sources, unless there is support from policies that expand the market and, potentially, establish preferential treatment of these products in comparison to conventional supplies. The rate of biomass replacement growth in thinned stands could be less than full due to ecological barriers and forest health issues. The benefits associated with the lower risk of wildfire (i.e., associated carbon losses) are not quantified here, since these benefits are tied to forest treatments and this policy option is focused solely on the beneficial use of biomass energy from these treatments.
- **Costs:** Future production cost reductions for wood product development and biomass energy recapture technologies are likely to fall with market expansion and “learning by doing” but are difficult to estimate at this time.

Ancillary Benefits and Costs, if applicable:

- Protection of working lands and associated industries for sustainable wood products use, recreation, and cultural and natural heritage.
- Expansion of markets for industrial producers of sustainable wood products and renewable energy use. Creation of Arizona jobs in the associated forestry management industries.
- Environmental asset protection, including watersheds, wildlife, and air quality.

Feasibility Issues, if applicable:

None identified.

Status of Group Approval:

Completed.

Level of Group Support:

Unanimous consent.

F-4 Improved Commercialization of Biomass Combustion, Gasification and Combined Cycle

Policy Description:

Accelerate the rate of technology development and market deployment of biomass combustion, gasification and combined cycle (BGCC) technologies.

Policy Design:

- **Goal levels:** 10 megawatts of biomass energy between 2006 and 2010, and an additional 25 megawatts between 2010 and 2020 (or equivalent amount of new biomass thermal energy).
- **Timing:** See above.
- **Parties:** Western Energy Resources (Eager); Renergy Systems (Snowflake); Northern Arizona University (Flagstaff); Camp Navajo/Volunteer Mountain Industrial Park (Bellemont); Forest Energy (Snowflake & Bellemont); Arizona Public Service, APS Energy Services; Salt River Project; Tucson Electric Power; and Rural Electric Cooperatives.
- **Other:** Technology improvements required to reduce emissions and improve efficiency of direct combustion; development of full scale commercial gasification systems needed; improved efficiencies for alcohol production from cellulose needed; and appropriate technologies to efficiently remove and transport biomass from forests need to be in place

Implementation Method(s):

Funding mechanisms and or incentives [USDA/DOE Biomass Initiative RFP; private investment; surcharges on Renewable Energy Standard & Tariff (RES, formerly EPS)], voluntary and or negotiated agreements [power purchase agreement; stewardship contracts to assure supply of biomass], codes and standards [Environmental Portfolio Standard revisions, proposed as RES], market-based mechanisms [green tags & RES credits], pilots and demonstrations [gasification systems; 3 MW ChipTek Unit of APS; Western Energy Resources; Renergy], research and development [NAU systems].

Related Policies/Programs in place:

USDA/DOE Biomass Initiative; RES proposals approved.

Types(s) of GHG Benefit(s):

- **CO₂:** Carbon savings occur when biomass energy combustion processes are converted from conventional technology to new technologies with greater thermal efficiency and reduced emissions with lower pollution outputs. New conversion technologies also may expand the use of available biomass supplies that substitute biomass energy for conventional fossil fuels. Increased efficiency and reduced emissions from burning/gasifying biomass in plants rather than “slash burning” in the forest as currently done. There will be significant reductions in CO₂ released from wildfire combustion of

forest biomass when thinning treatments restore forest health and reduce the occurrence, areal? extent and intensity of wildfires; needs to be offset with contributions from increased prescribed burning necessary to maintain forest health.

- **CH₄:** New research indicates that about 4% of the carbon storage benefits of live forests are offset by methane release. Methane can be released from land-filled biomass under anaerobic conditions.
- **Black Carbon:** Emissions of black carbon (soot) result from combustion of woody biomass from open burning of land clearing, but the heating effect is likely to be offset by the cooling effects of the large amount of organic material emitted during biomass combustion.

Estimated GHG Savings and Costs Per tCO₂e (for quantified actions):

- GHG potential in 2010, 2020: Not quantified (forest biomass energy currently quantified under Options F-3a and F-3b).
- Net Cost per tCO₂e in 2010, 2020: Not quantified.

Data Sources, Methods, and Assumptions (for quantified actions):

- **Data Sources:** Steve Gatewood, AF TWG, provided the following data on the estimated costs and criteria pollutant production at biomass gasification facilities planned or proposed for application in Arizona.

The existing 3MW Eager WER/APS plant consumes 110 tons/day of 40% moisture biomass, with approx. 46 tpy PM₁₀, 52 tpy PM, 95 tpy CO, 4 tpy SOX, 35 tpy NOX & 6 tpy VOC; cost unknown;

The ChipTek 3MW plant (not online yet – may go to NAU) consumes ~100 tons/day of 20% moisture chips, with approximately 45 tpy PM₁₀, 52 tpy PM, 94 tpy CO, 4 tpy SOX & 35 tpy NOX; cost is about \$7.8M;

The proposed/permitted 24MW Renergy Snowflake plant would consume 480 tons/day of 50% moisture biomass, with approx. 23 tpy PM₁₀, 252 tpy CO, 156 tpy SOX, 205 tpy NOX & 22 tpy VOC; cost is unknown;

A 10MW plant proposed for Snowflake that might be replaced by the above 24 MW would use 295 tons/day of 38% moisture biomass, with 44 tpy PM₁₀, 58 tpy CO, 11 tpy SOX, 57 tpy NOX & 8 tpy VOC; cost unknown;

A 10MW gasification system proposed for NAU would use 248 tons/day of 40% moisture biomass, with unknown emissions; cost would be ~ \$15M.

- **Quantification Methods:** The costs and benefits of this option were not quantified due to the overlap in biomass energy resource consumption with F-3a and F-3b. The TWG feels that this option supporting advancement of biomass gasification/combined cycle technology could produce even better GHG benefits than those shown for F-3a and F-3b.
- **Key Assumptions:** None.

Key Uncertainties:

- **Benefits:** The market demand for new supplies of renewable energy is dynamic and not likely to fully absorb all new supply sources without offsetting decreases in other sources, unless there is support from policies that expand the market and, potentially,

establish preferential treatment of these products in comparison to conventional supplies.

- **Costs:** Future production cost reductions for biomass energy recapture technologies is likely to fall with market expansion and “learning by doing” but are difficult to estimate at this time.

Ancillary Benefits and Costs, if applicable:

- Criteria air pollution levels are lower with advanced technology. Gasification reduces emissions below the levels emitted via direct combustion.
- Alcohol production can reduce emissions of GHGs by offsetting gasoline use.
- Expanded biomass energy use also expands rural biomass industries.
- Eliminates open burning of slash—reduced smoke impacts and emissions and scarification of soils with resulting exotic species invasion.
- Significant reductions in emissions and pollutants through controlled combustion or gasification compared to open burning of slash or large wildfire releases.
- Criteria air pollution levels are lower with advanced technology than conventional biomass technology. Emission levels might not be as low as some conventional fossil fuel technologies (e.g., natural gas combustion technologies).
- Expanded biomass energy use also expands rural biomass industries.

Feasibility Issues, if applicable:

None identified.

Status of Group Approval:

Completed.

Level of Group Support:

Unanimous consent.

establish preferential treatment of these products in comparison to conventional supplies.

- **Costs:** Future production cost reductions for biomass energy recapture technologies is likely to fall with market expansion and “learning by doing” but are difficult to estimate at this time.

Ancillary Benefits and Costs, if applicable:

- Criteria air pollution levels are lower with advanced technology. Gasification reduces emissions below the levels emitted via direct combustion.
- Alcohol production can reduce emissions of GHGs by offsetting gasoline use.
- Expanded biomass energy use also expands rural biomass industries.
- Eliminates open burning of slash–reduced smoke impacts and emissions and scarification of soils with resulting exotic species invasion.
- Significant reductions in emissions and pollutants through controlled combustion or gasification compared to open burning of slash or large wildfire releases.
- Criteria air pollution levels are lower with advanced technology than conventional biomass technology. Emission levels might not be as low as some conventional fossil fuel technologies (e.g., natural gas combustion technologies).
- Expanded biomass energy use also expands rural biomass industries.

Feasibility Issues, if applicable:

None identified.

Status of Group Approval:

Completed.

Level of Group Support:

Unanimous consent.