Sustainable Infrastructure and South Mountain Village: Building Energy Use

COURSE PROJECT PRESENTATION

23 April 2018

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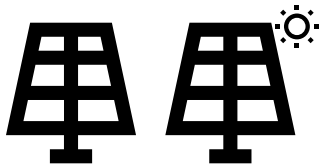
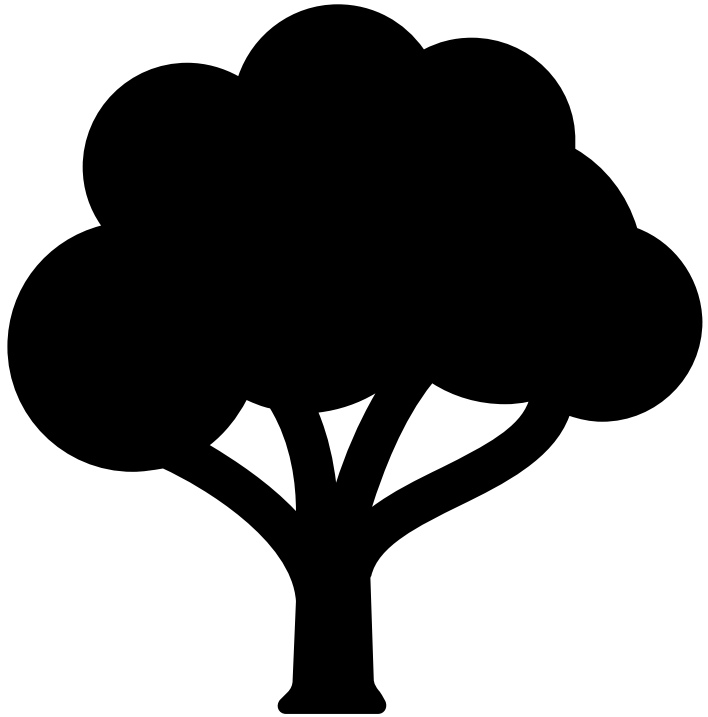
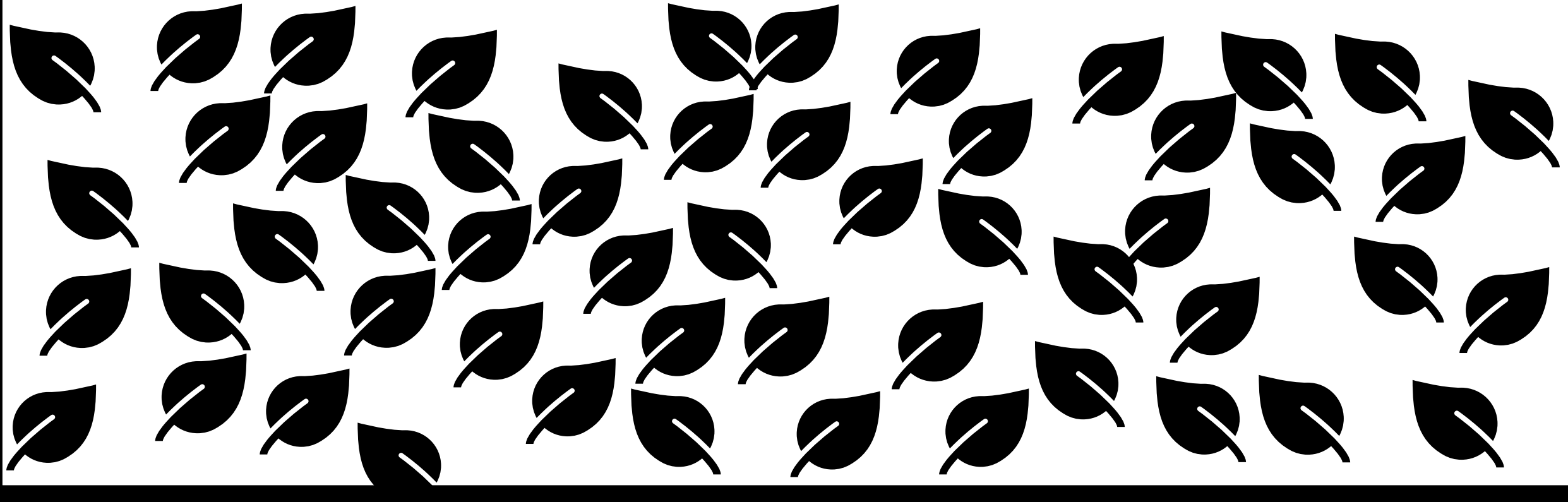
SPRING 2018 COURSE

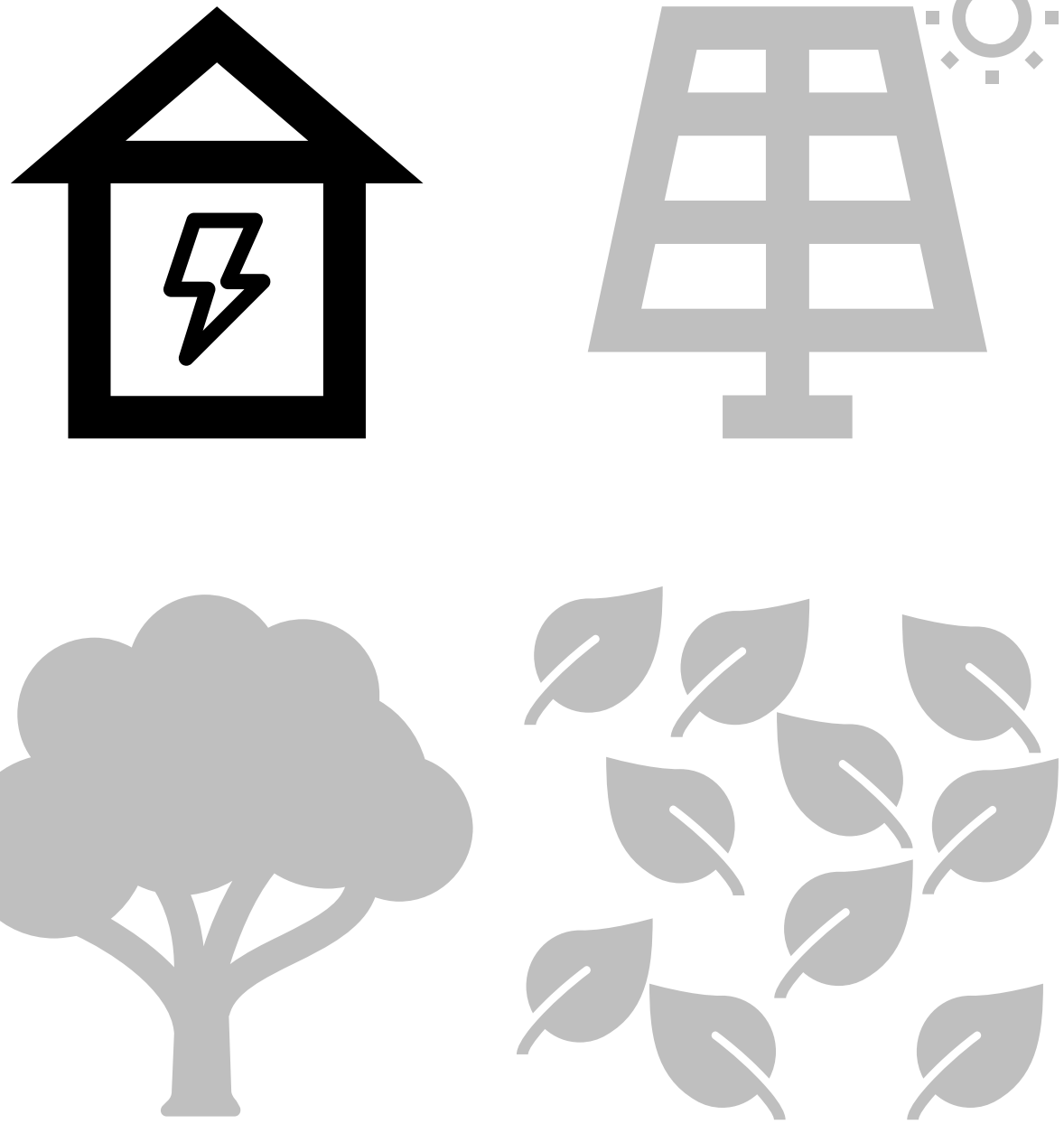
Urban Infrastructure Anatomy and Sustainable Development

CEE 507 ▫ SOS 547 ▫ PUP 553









Energy Consumption

- 3 Building Types
  - Single Family Detached
  - Single Family Attached
  - Low Rise Apartments
- 5 Energy Profiles Created (Hour data for whole year)
  - Low Residential (Single Family detached)
  - Base Residential (Single Family detached)
  - High Residential (Single Family detached)
  - Single Family Attached
  - Low Rise Apartment
  - TMY3 zone is Phoenix International Airport

South Mountain Village

Agriculture

Business / Industrial Park

Commercial

Parking

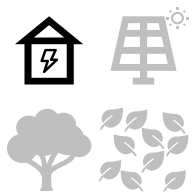
Planned Development

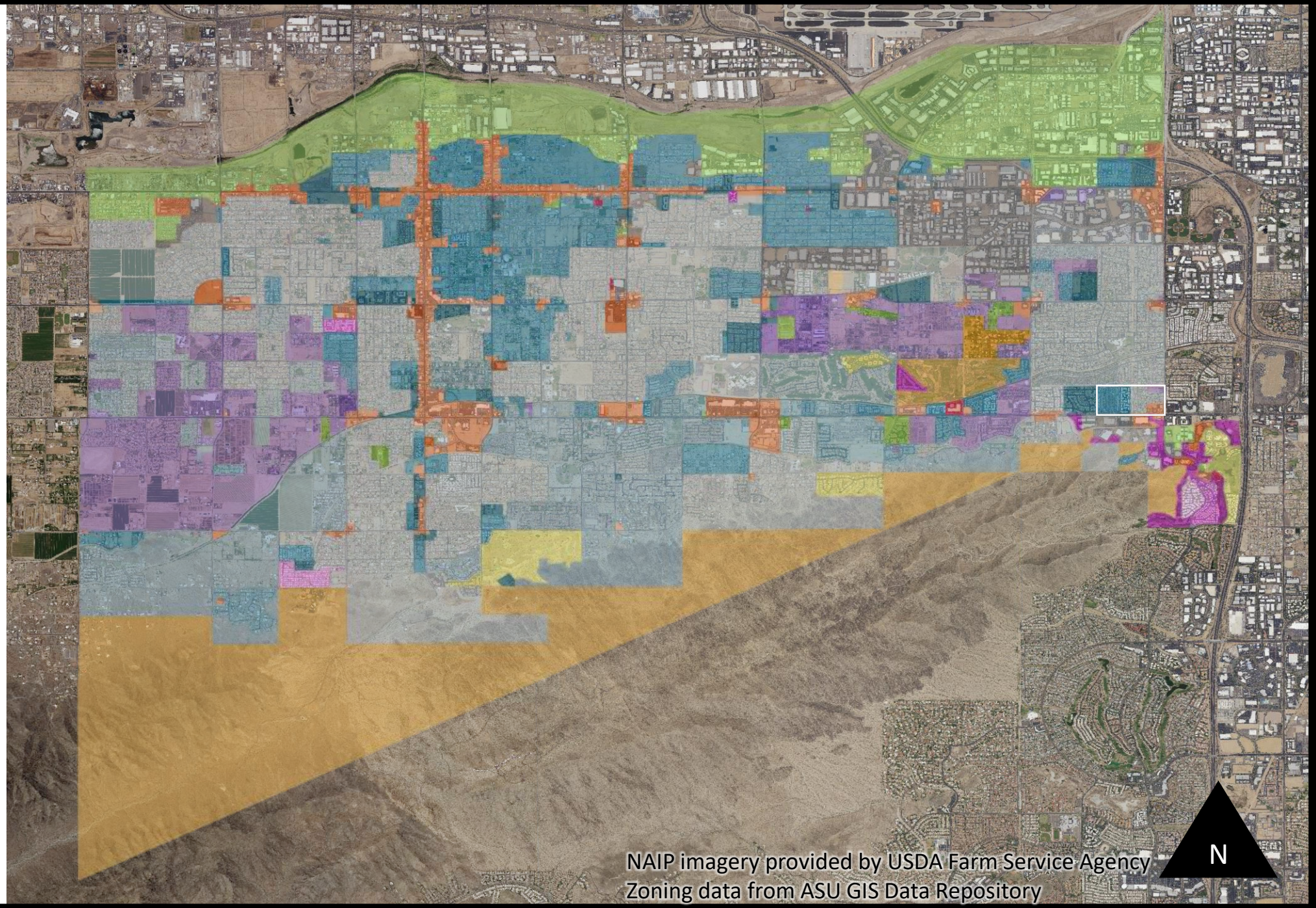
Ranch

Residential

Residential Estate

Resort





NAIP imagery provided by USDA Farm Service Agency
Zoning data from ASU GIS Data Repository

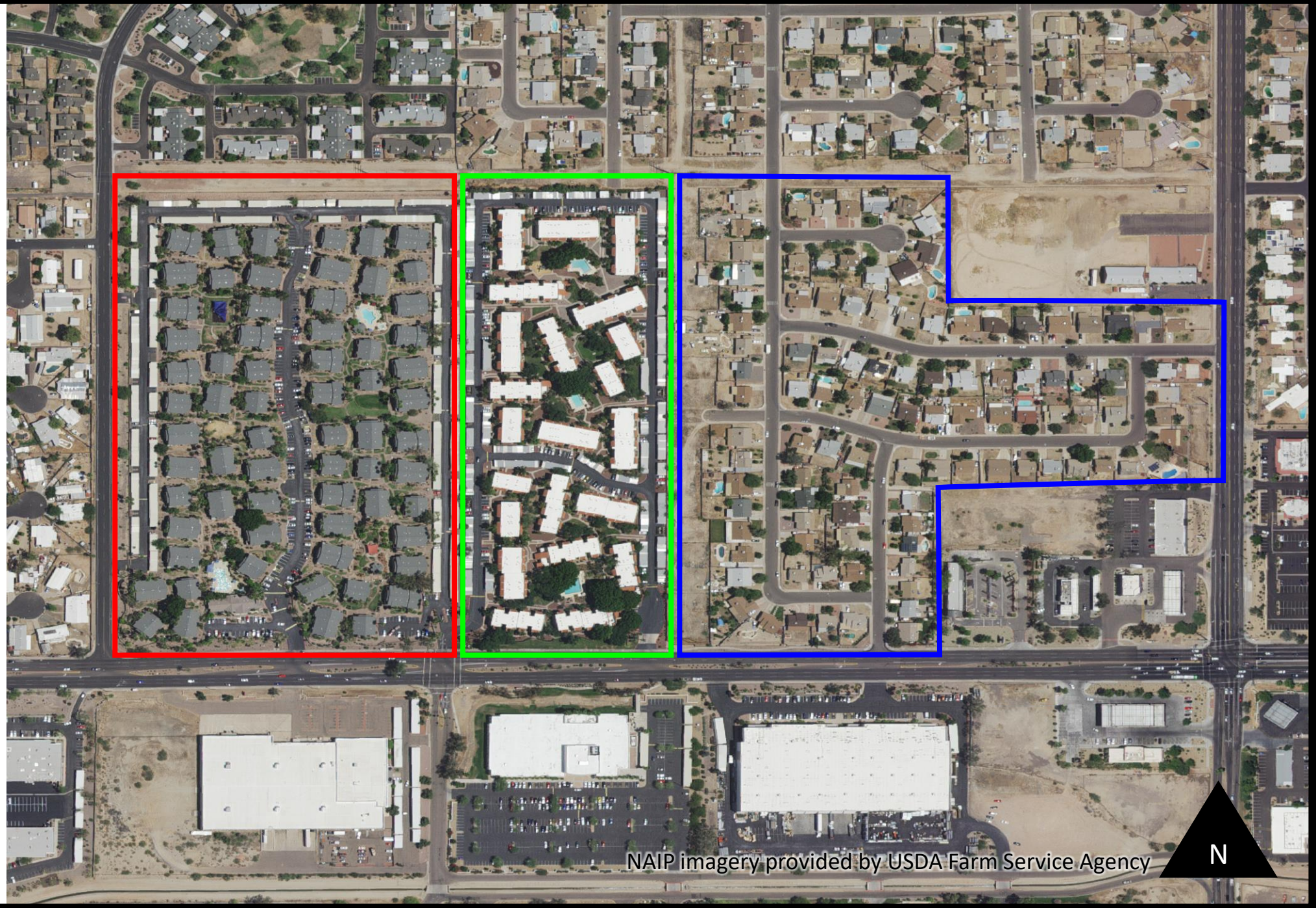
N

Study Area

Single Family – Attached

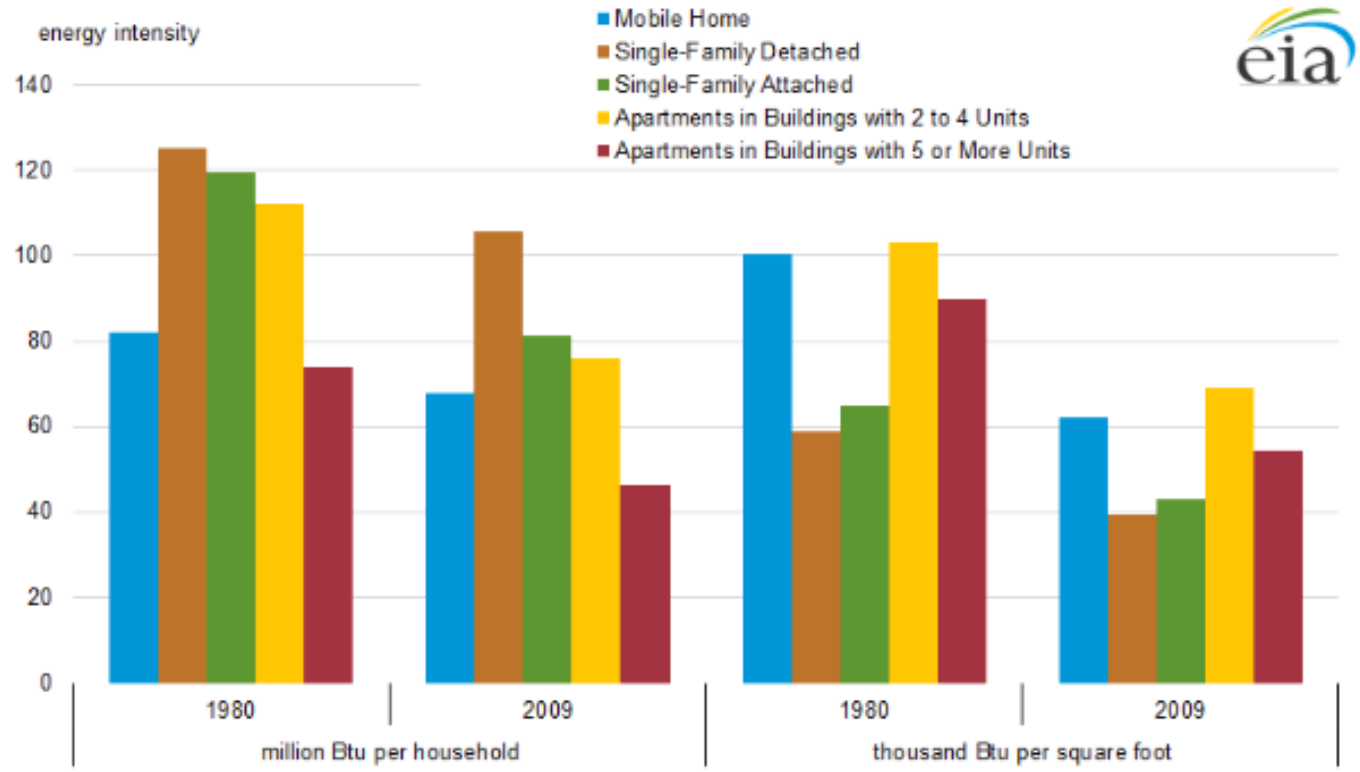
Low-Rise Apartments

Single Family – Detached



Residential Energy Consumption (2009 Survey)

- Hourly consumption profiles developed by Office of Energy Efficiency & Renewable Energy
  - Residential building parameters from Residential Energy Consumption Survey

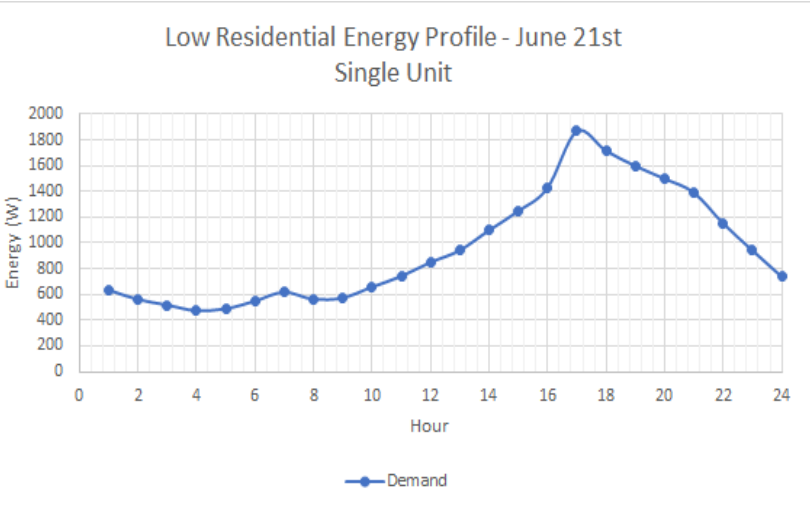


https://www.eia.gov/analysis/studies/buildings/households/pdf/drivers_hhec.pdf

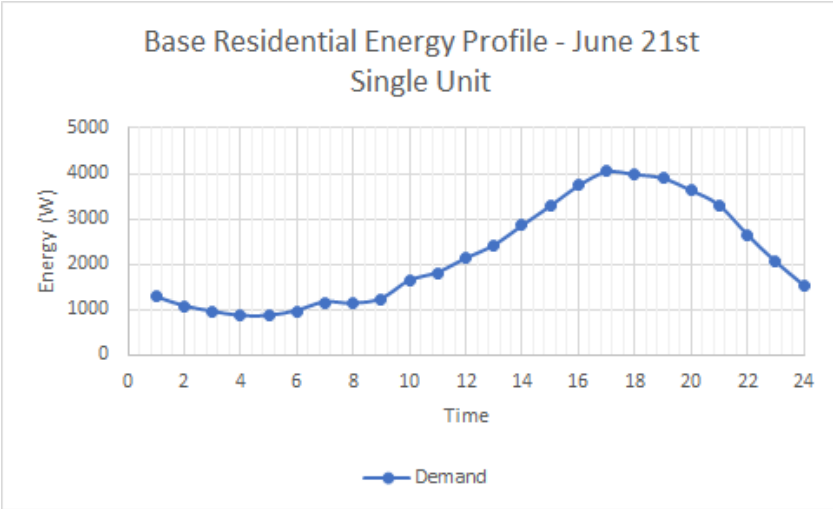
Single Family Detached

Building Demand (June 21st)

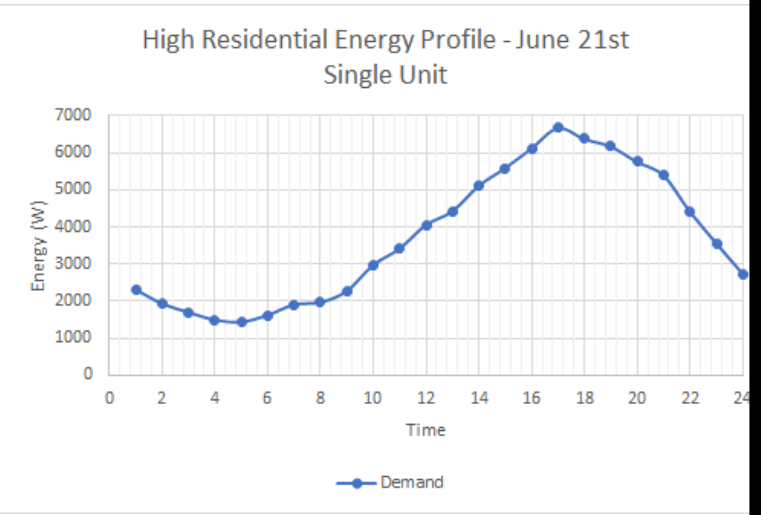
Single Family Detached (Low)



Single Family Detached (Base)



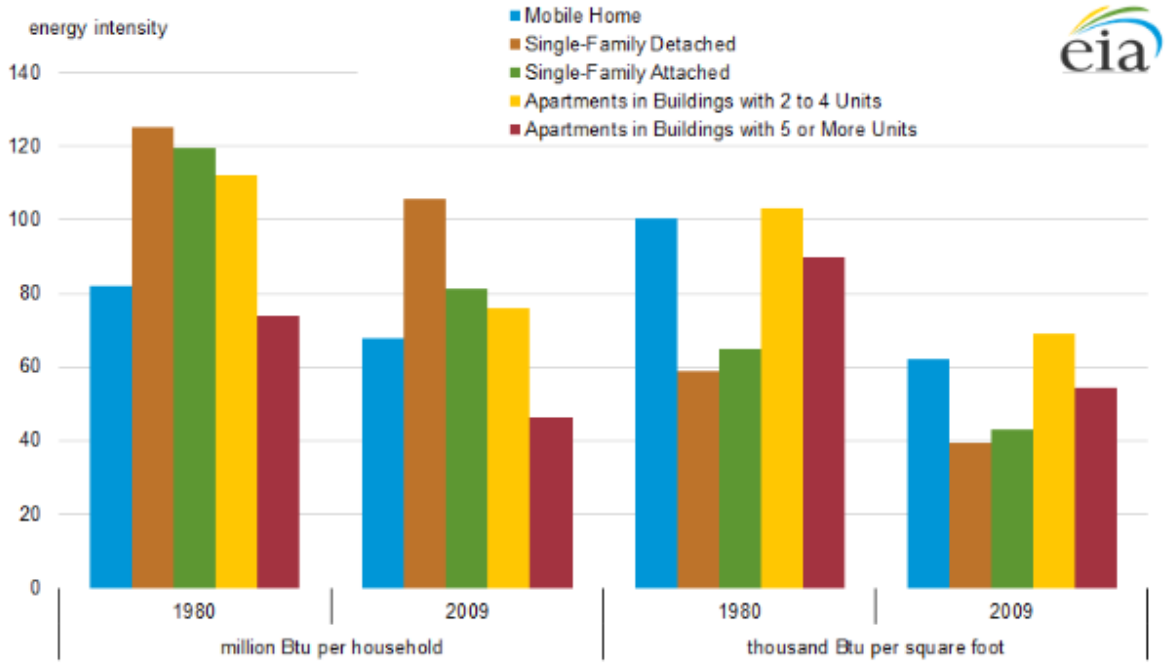
Single Family Detached (High)

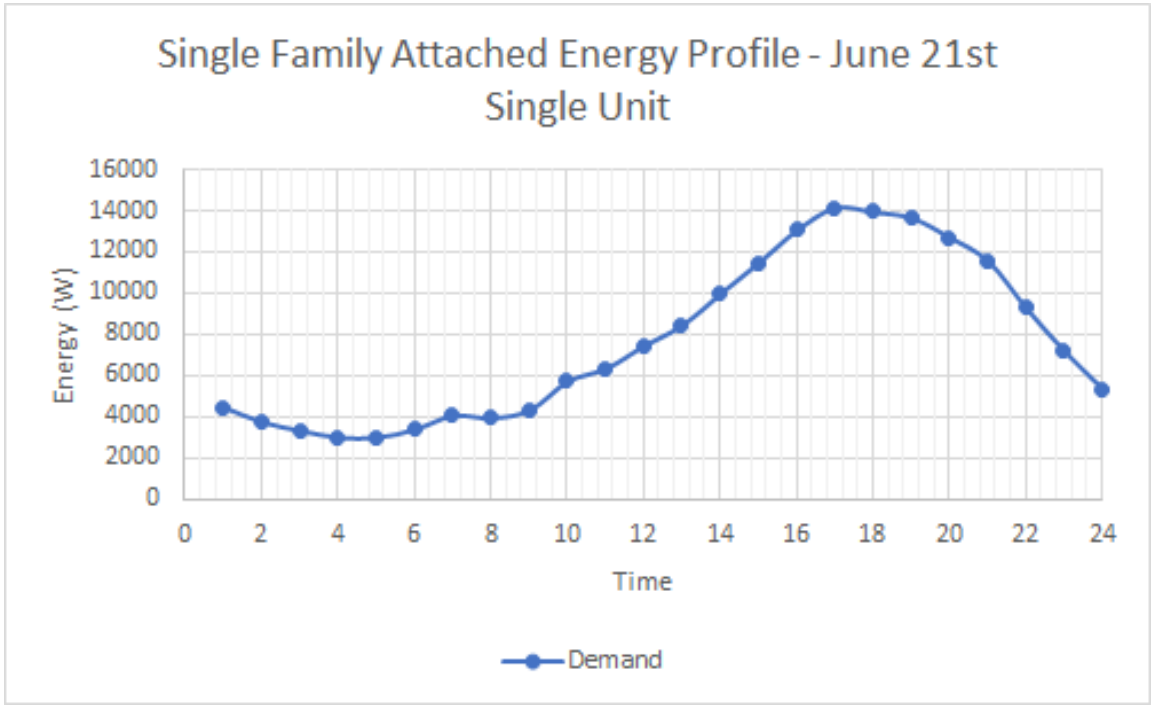


Single Family Attached Energy Consumption

- Uses: average of:
  - (Single Family Attached) x (# of units) [Over Estimate]
  - (Single Family Attached) x (Ratio of Floor Area) [Underestimate]

Single Family Attached

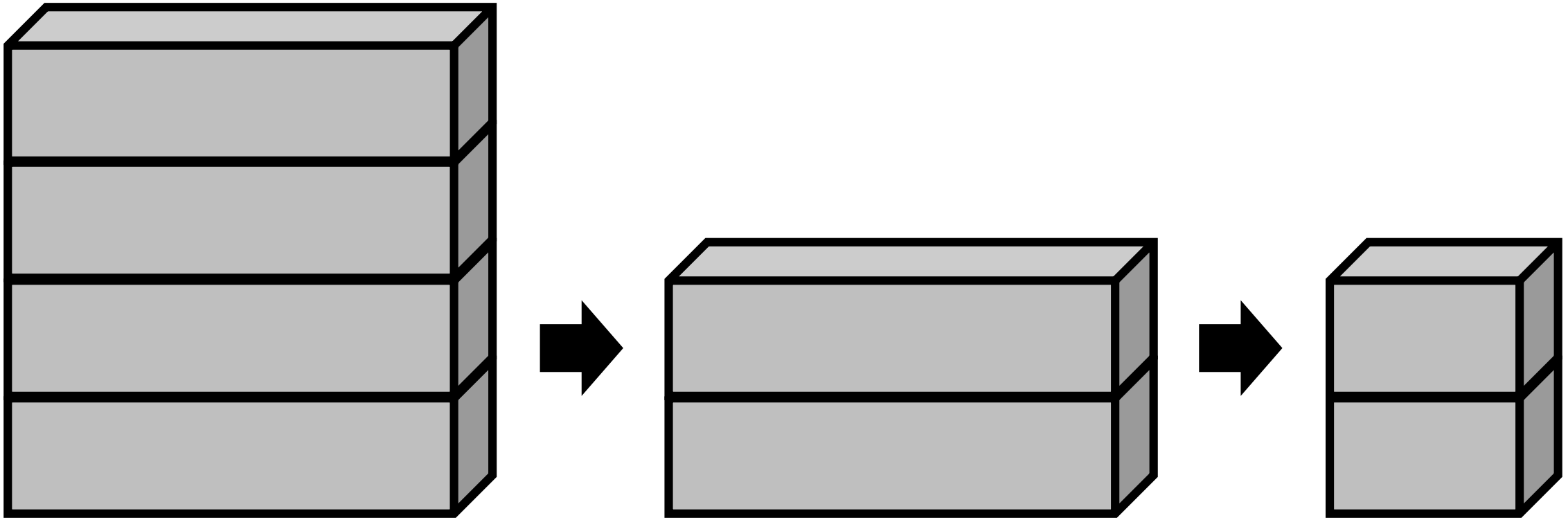




https://www.eia.gov/analysis/studies/buildings/households/pdf/drivers_hhec.pdf

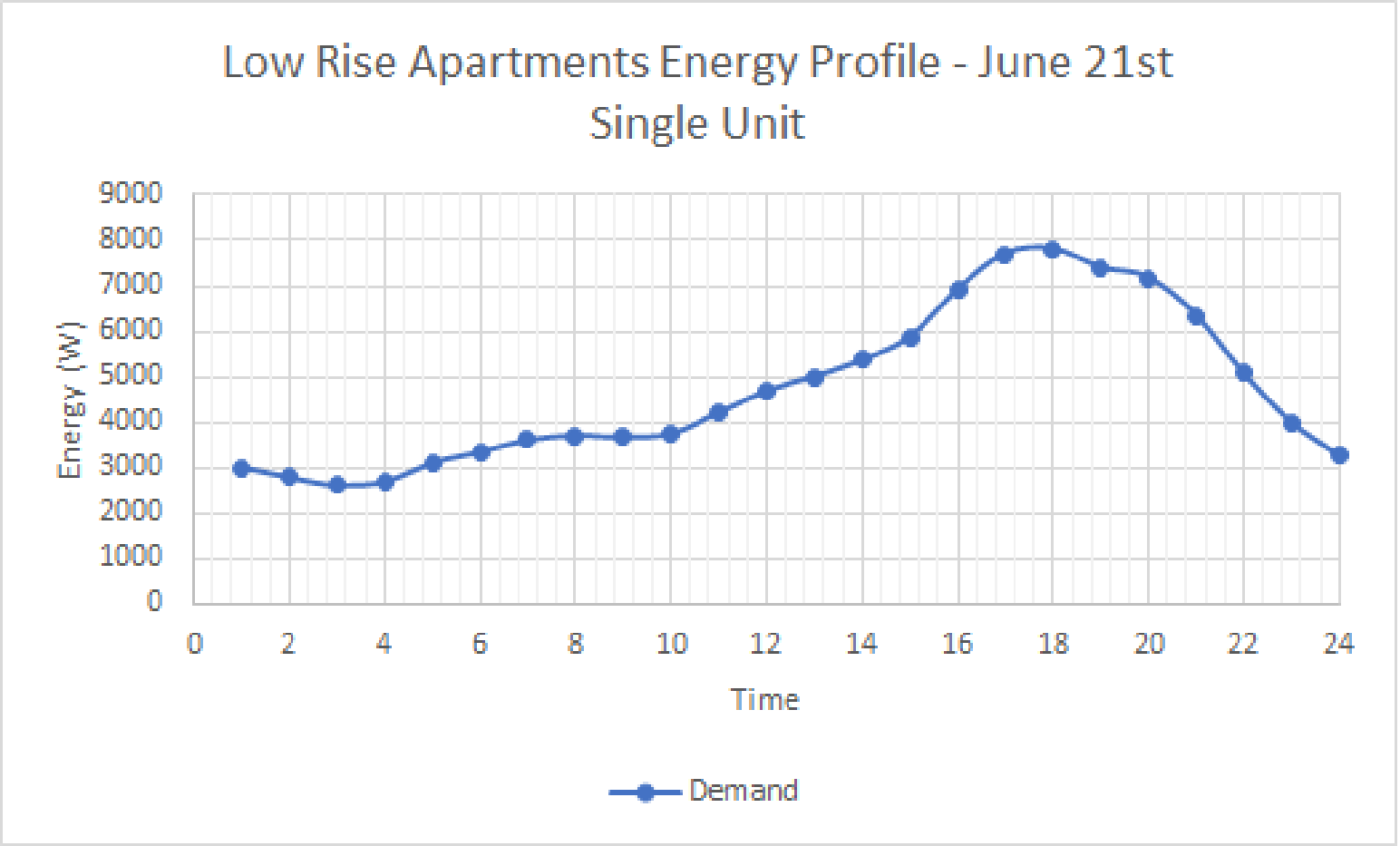
Low Rise Apartments Energy Consumption

- Mid Rise Apartment parameters based on US DOE Commercial Reference Building Models

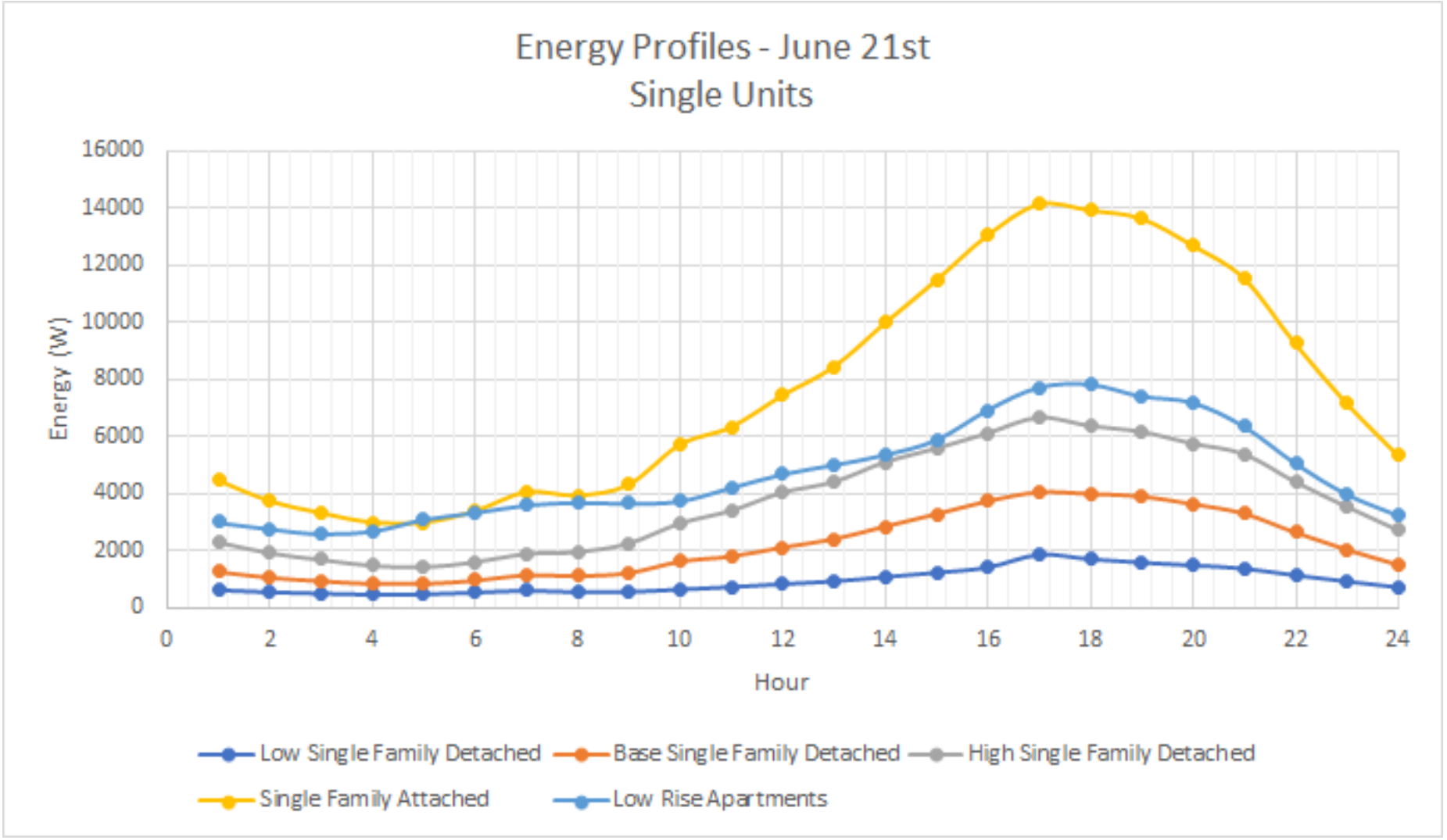


Low Rise Energy Consumption

Low Rise Apartments



Demand Profiles



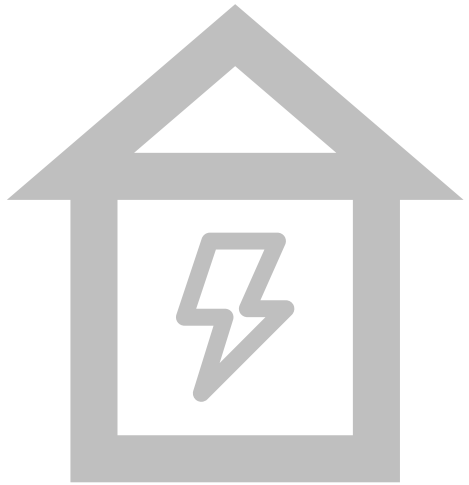
SRP Rate Schedules

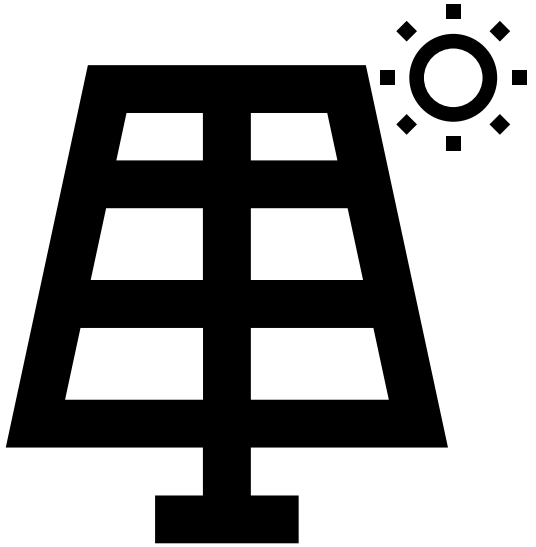
Pre Solar Rates

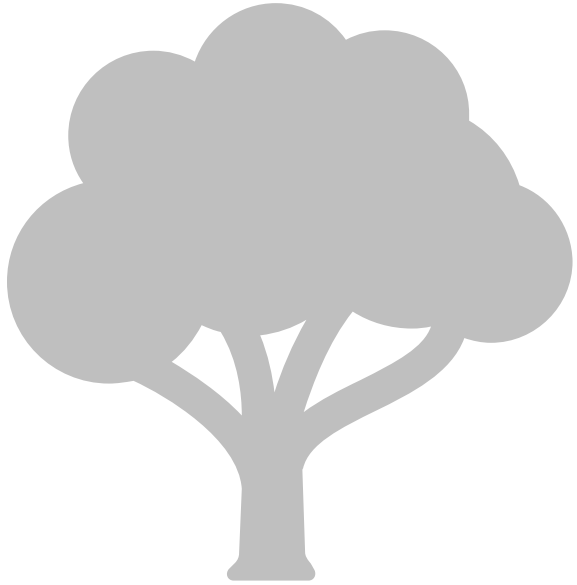
- E-21 Residential Super Peak TOU
  - No Net Metering
  - No Demand
- E-36 Business General Service
  - Demand
  - $0.02/kWh Solar Export Purchase

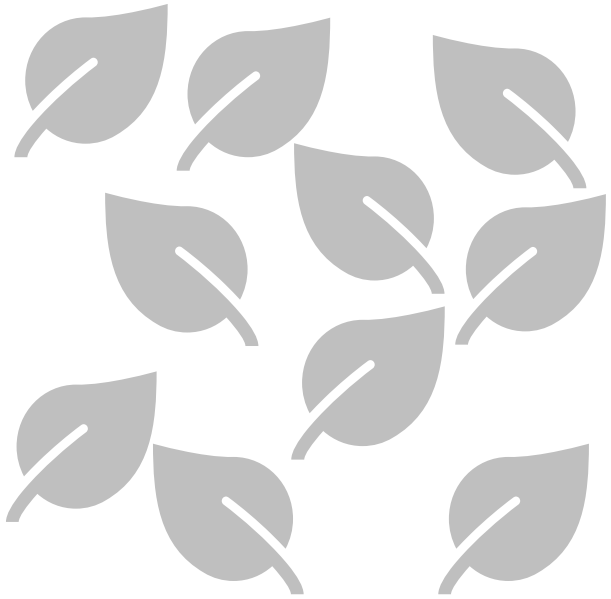
Post Solar Rates

- E-27 Residential Customer Generation
  - Net Metering
  - Demand
- E-36 Business General Service
  - Demand
  - $0.02/kWh Solar Export Purchase









Solar Modeling

Solar

Helioscope

Battery, Offset, & Bills

EnergyToolbase

Solar Systems

Single Family Detached (Low)

Single Family Detached (Base)

Single Family Detached (High)

Aerial Imagery Source: Google Earth

Solar Systems

Single Family Attached

Low Rise Apartments

Aerial Imagery Source: Google Earth

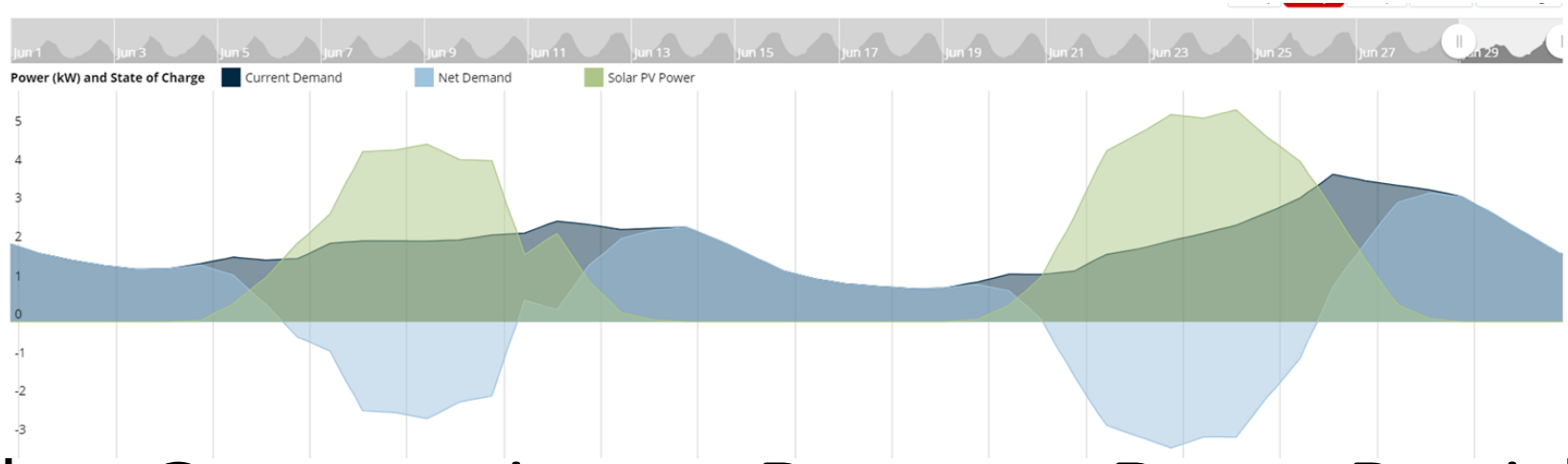
Solar Generation

Solar PV										
Building Type	Usage (kWh)	System Size (kW DC)	System Size (kW AC)	Energy Production (kWh)	Energy Offset (%)	Export (%)	Pre - Solar Rate Schedule	Pre - Solar Bill ($)	Post- Solar Rate Schedule	Post - Solar Bill ($)
Residential (Low)	6,020	3.6	3.1	6211	103%	60%	E-21	$ 863.00	E-27	$ 488.00
Residential (Base)	12,918	7.9	6.9	13,605	105%	58%	E-21	$ 1,604.00	E-27	$ 620.00
Residential (High)	21,520	13.3	11.6	23,189	108%	57%	E-21	$ 2,527.00	E-27	$ 877.00
Single Family Attached (Base)	45,210	25.4	22.1	45,676	101%	60%	E-21	$ 4,932.00	E-27	$ 2,156.00
Low Rise Apartments	31,607	58.8	51.2	107,655	341%	85%	E-36	$ 3,445.00	E-36	$ (2,966.00)

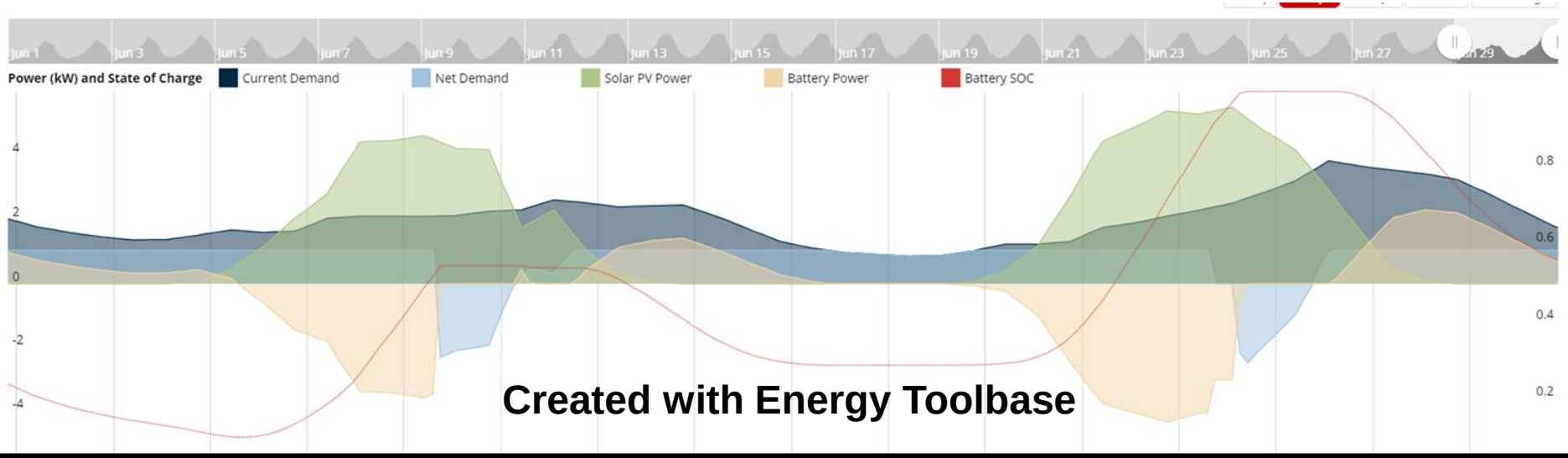
Solar Generation + Battery

Solar PV + Battery											
Building Type	Usage (kWh)	System Size (kW DC)	System Size (kW AC)	Battery Packs	Energy Production (kWh)	Energy Offset (%)	Export (%)	Pre - Solar Rate Schedule	Pre - Solar Bill ($)	Post- Solar Rate Schedule	Post - Solar Bill ($)
Residential (Low)	6,020	3.6	3.1	1	6,211	95%	25%	E-21	$ 863.00	E-27	$ 450.00
Residential (Base)	12,918	7.9	6.9	2	13,605	95%	14%	E-21	$ 1,604.00	E-27	$ 463.00
Residential (High)	21,520	13.3	11.6	3	23,189	98%	16%	E-21	$ 2,527.00	E-27	$ 496.00
Single Family Attached (Base)	45,210	25.4	22.1	8	45,676	92%	14%	E-21	$ 4,932.00	E-27	$ 1,194.00
Low Rise Apartments	31,607	58.8	51.2	7	107,655	329%	67%	E-36	$ 3,445.00	E-36	$(3,622.00)

Solar Generation Base Residential

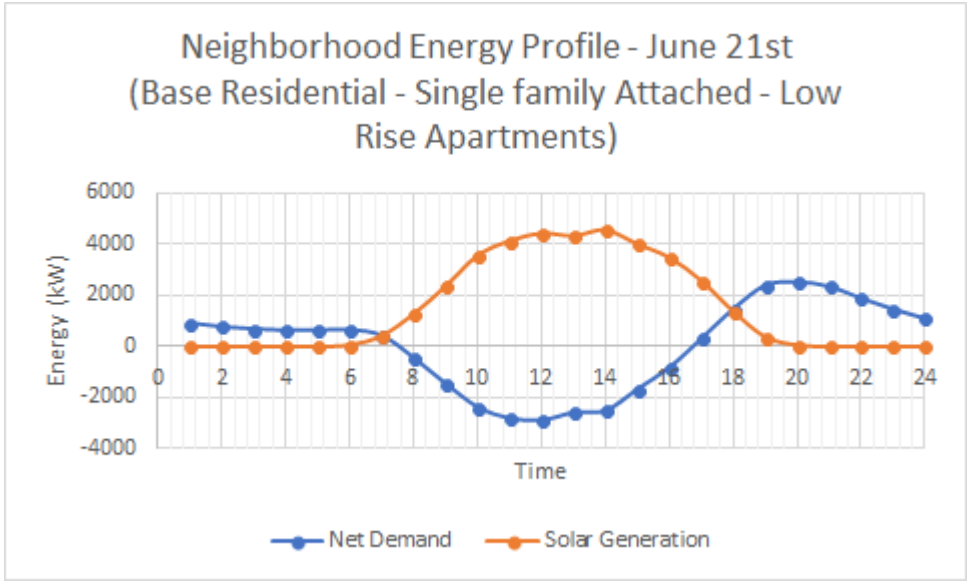


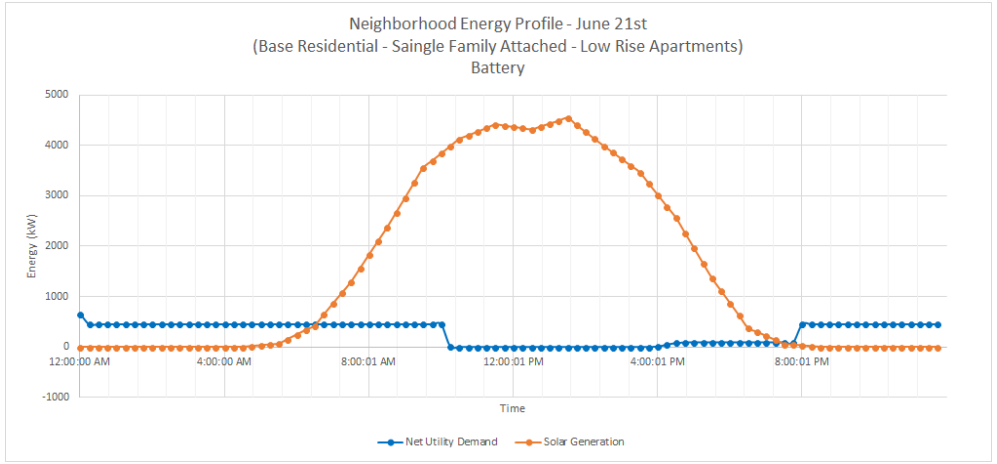
Solar Generation + Battery Base Residential

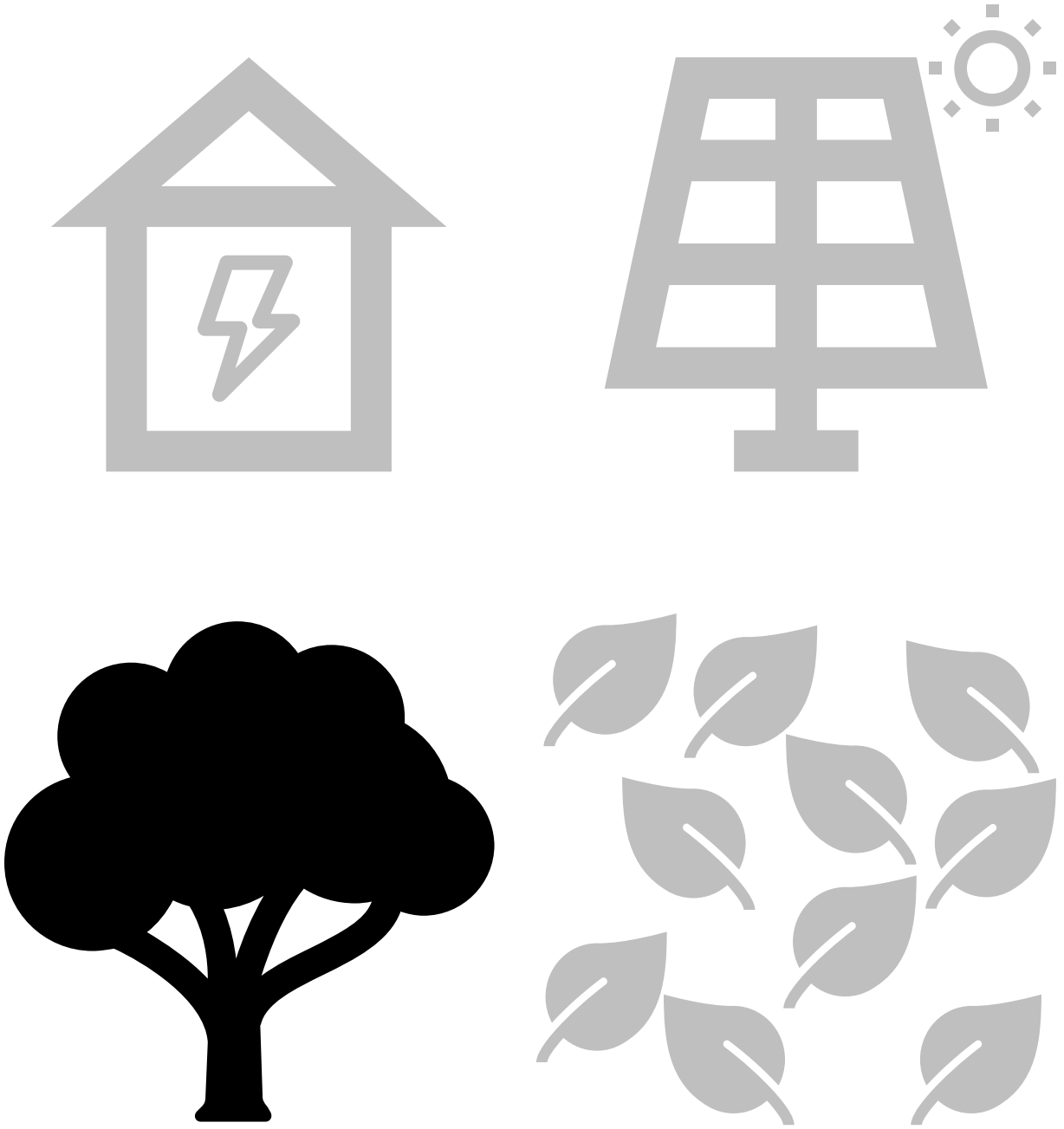


Created with Energy Toolbase

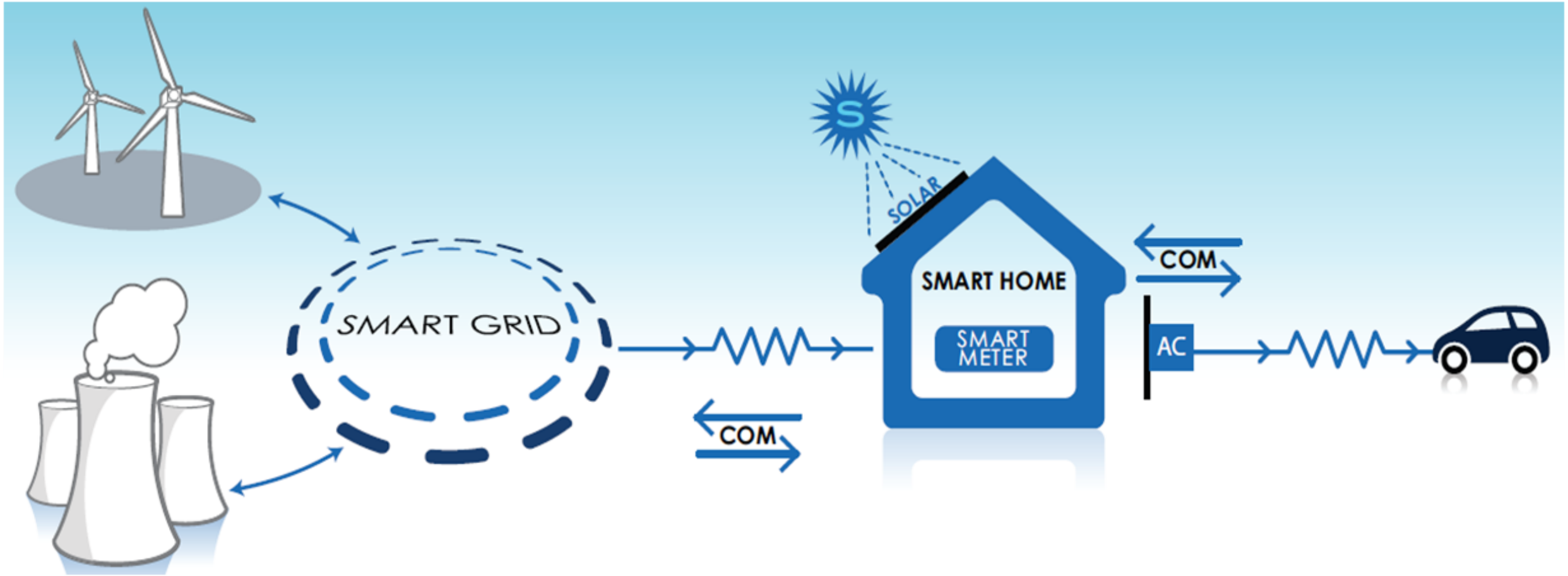
Neighborhood Solar Generation





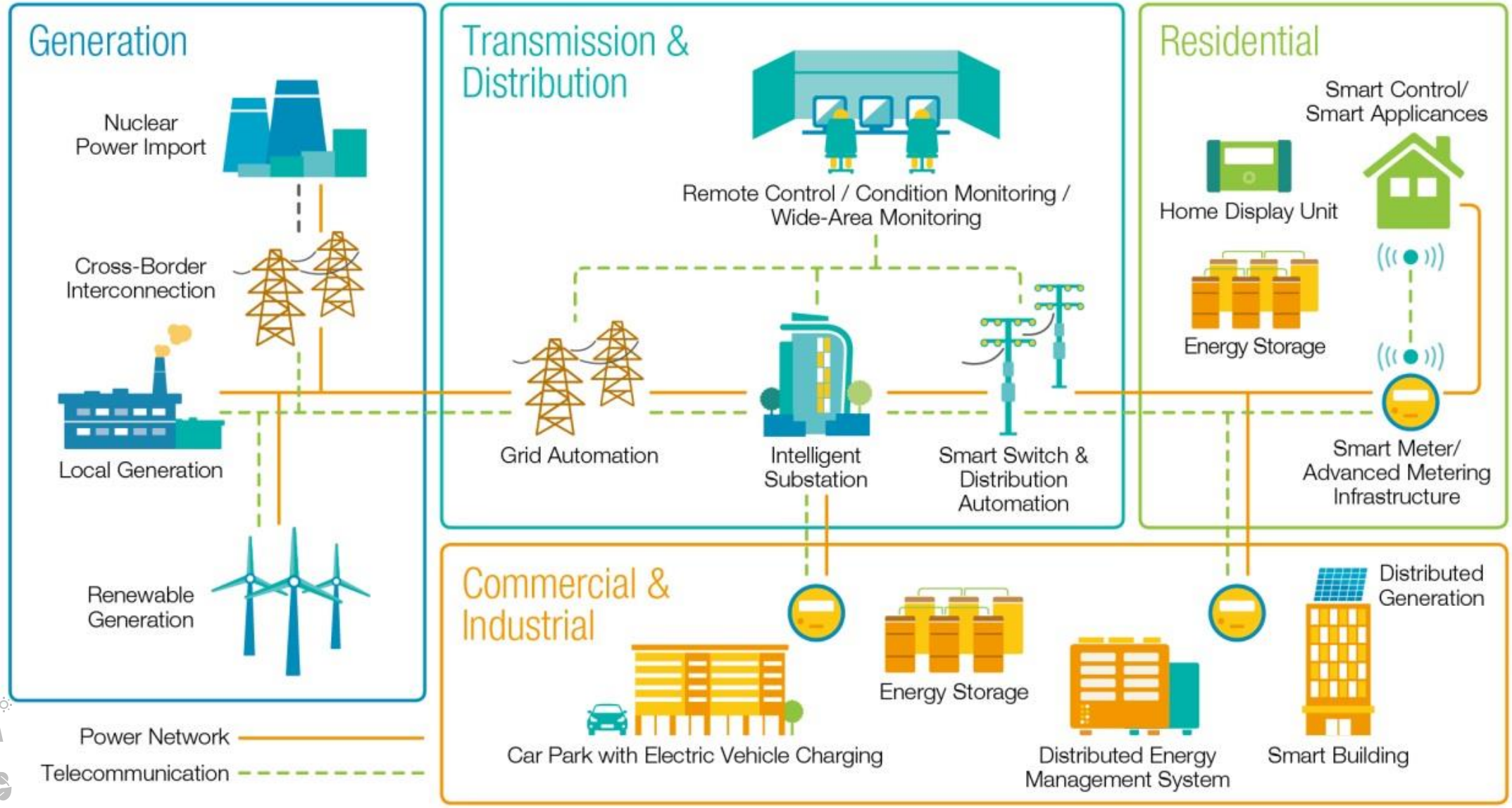


Smart Grid

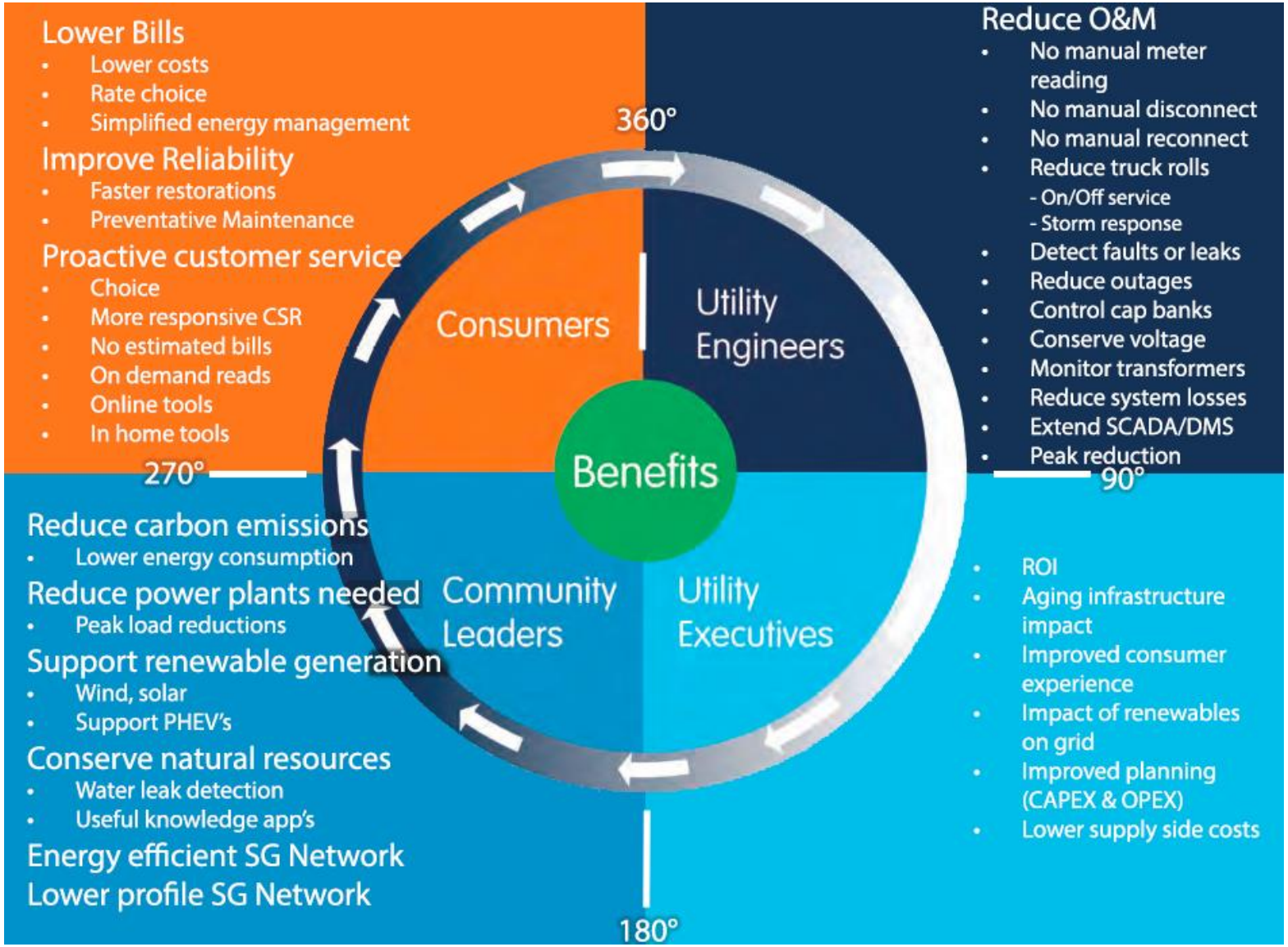


https://www.voltimum.co.uk/articles/building-automation-key-successful

Smart Grid: Assets & Functions



Smart Grid: Benefits



http://www.tdworld.com/other-resources/3d-interoperability-multi-dimensional-benefits

CBA of Smart Grid Implementation

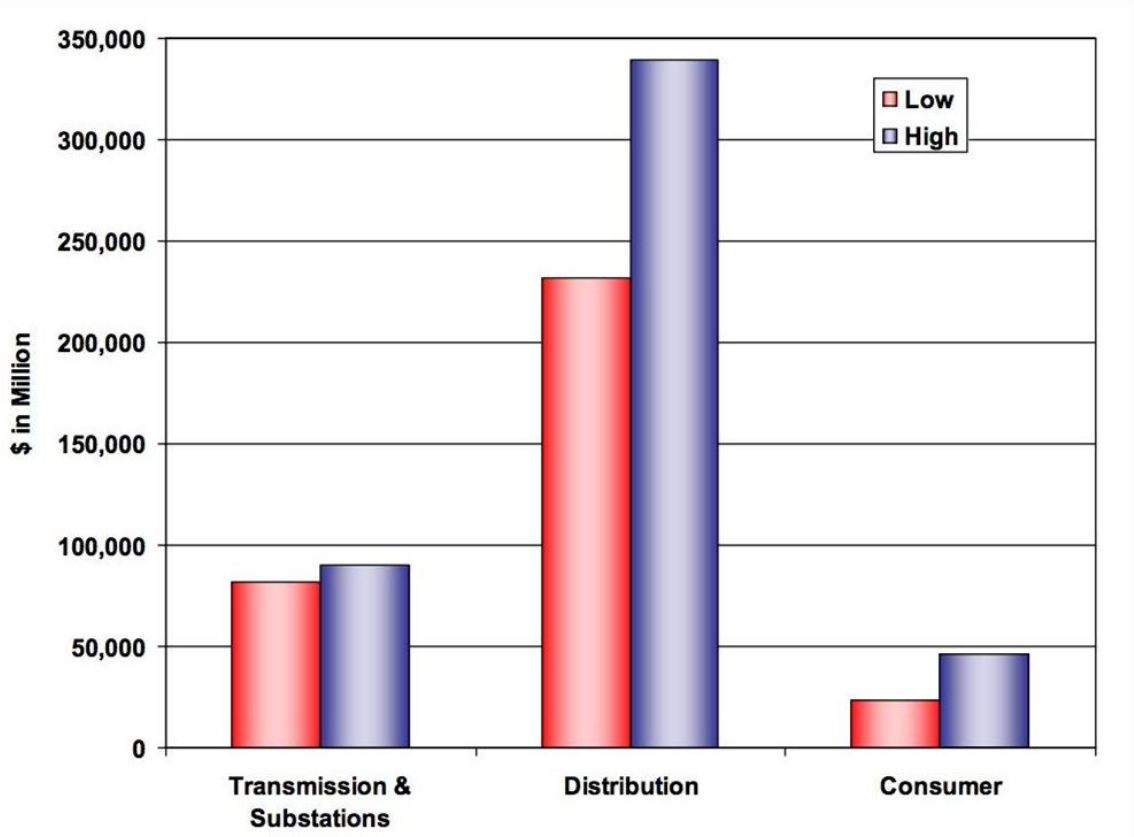


Figure 1-3
Total Smart Grid Costs

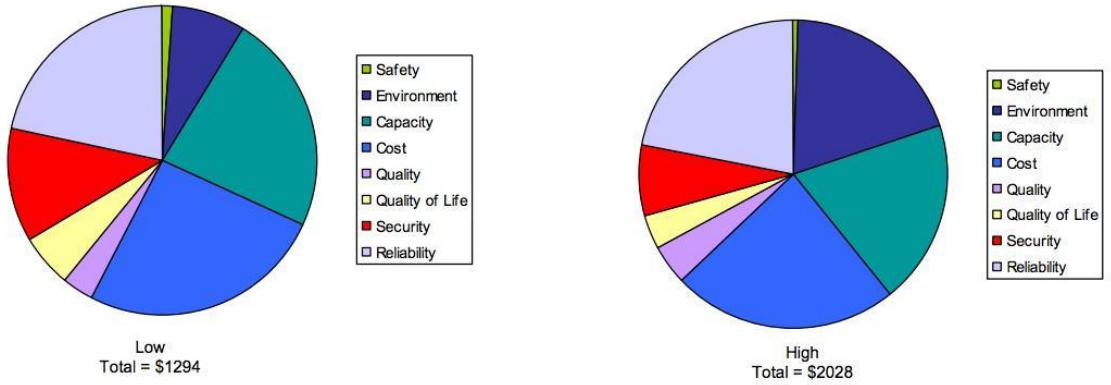


Figure 1-4
Estimated Benefits of the Smart Grid ($ in billions)

Table 1-1
Summary of Estimated Cost and Benefits of the Smart Grid

	20-Year Total ($billion)
Net Investment Required	338 – 476
Net Benefit	1,294 – 2,028
Benefit-to-Cost Ratio	2.8 – 6.0

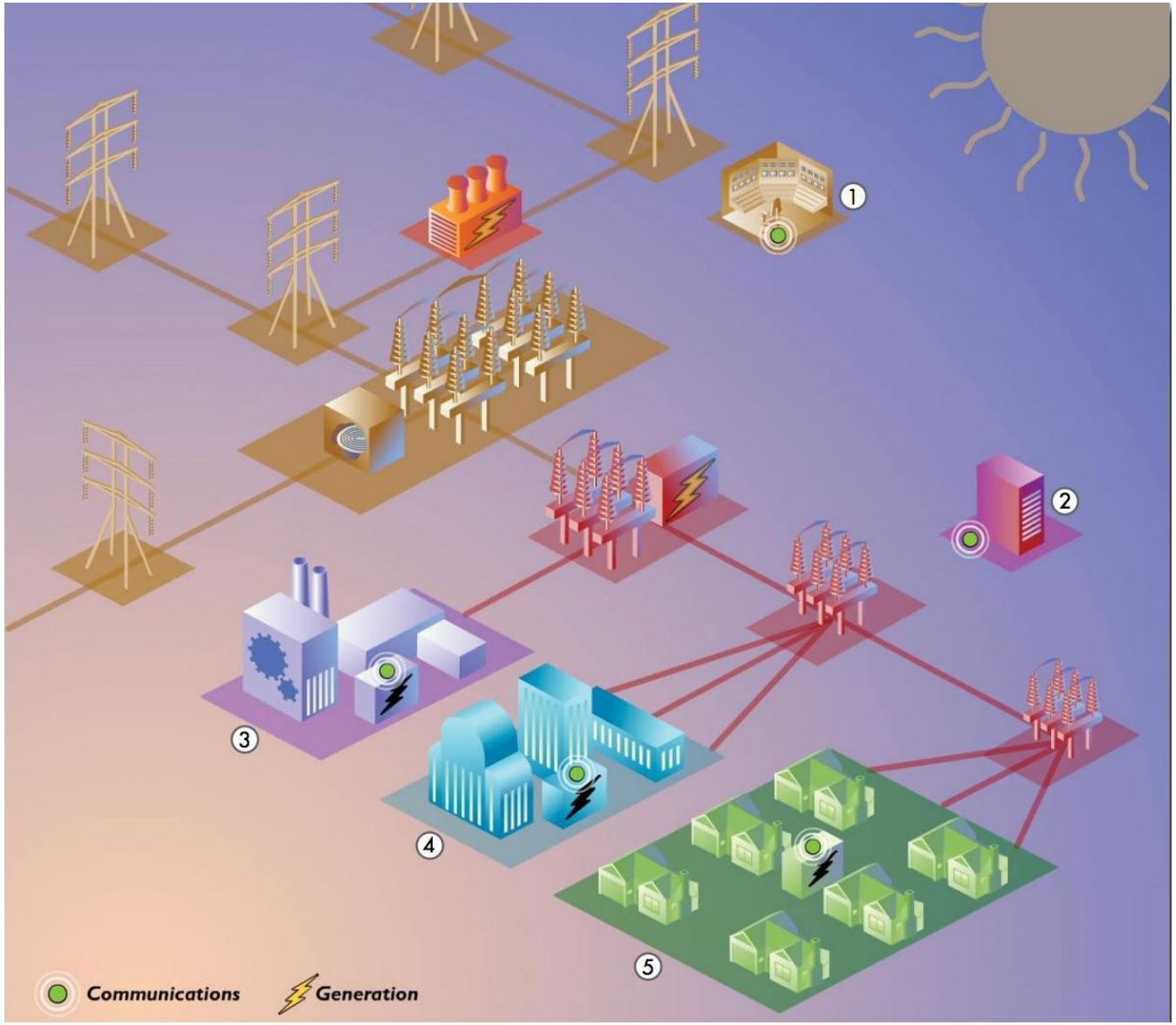
http://smartenergycc.org/wp-content/uploads/2012/08/000000000001022519.pdf

SRP Modernizing the Grid (7 Initiatives)

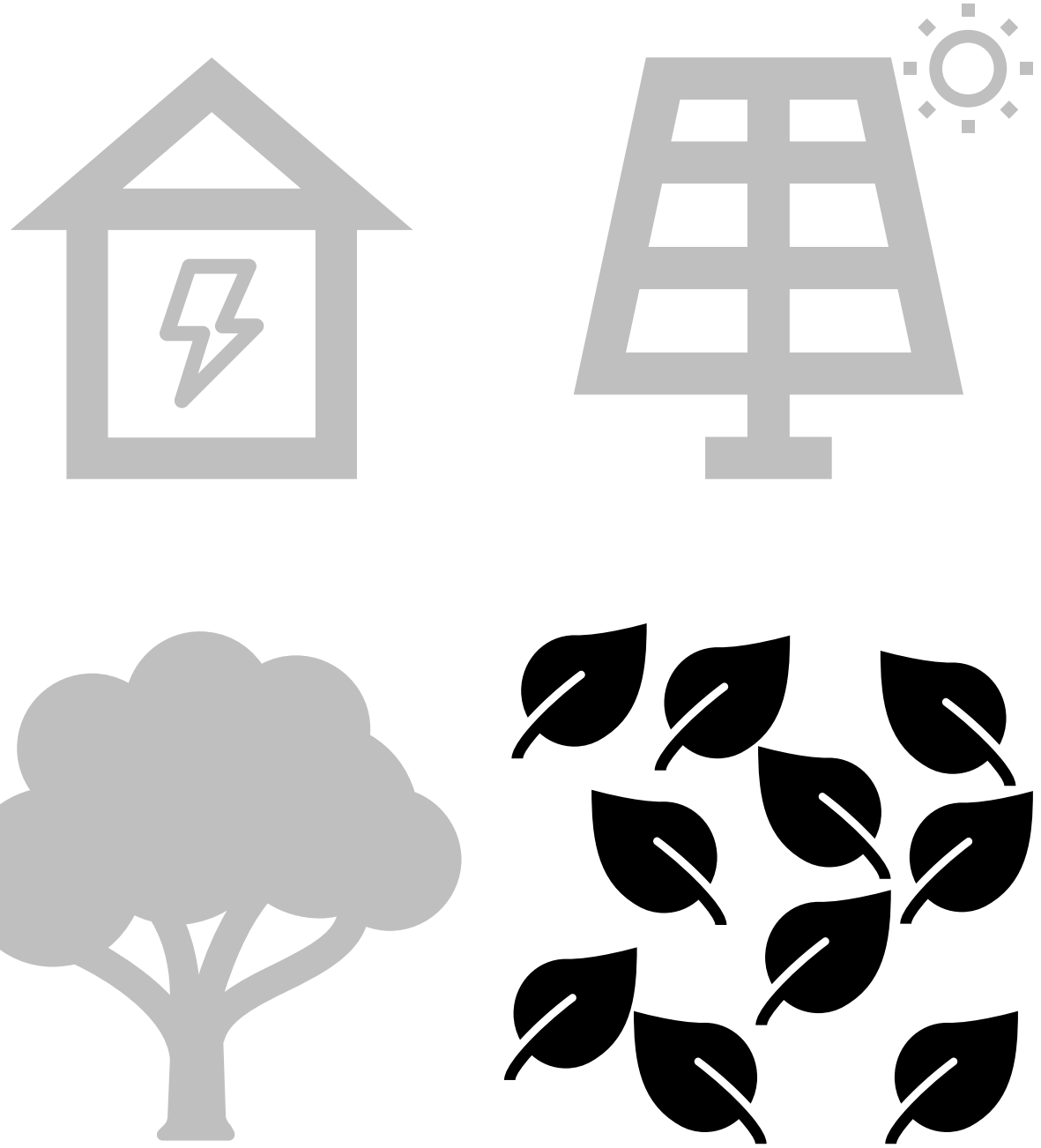
- Improve existing **Cyber Security** strategies
- Implement automated tools for **WAN Monitoring**
- Create and deploy an **Integrated Substation LAN** strategy
- Utilize a single **Unified Communications** infrastructure for field devices
- Expand the deployment of **Distribution Feeder Automation**
- Deploy an **Electrical System Data Acquisition and Management** for automation and analysis
- Implement an integration bus for secure **Enterprise Application Integration** between applications and databases

https://www.vermontlaw.edu/sites/default/files/Assets/iee/SRP-Report-Final-120618.pdf

Projected Outcomes of Smart Grid Implementation

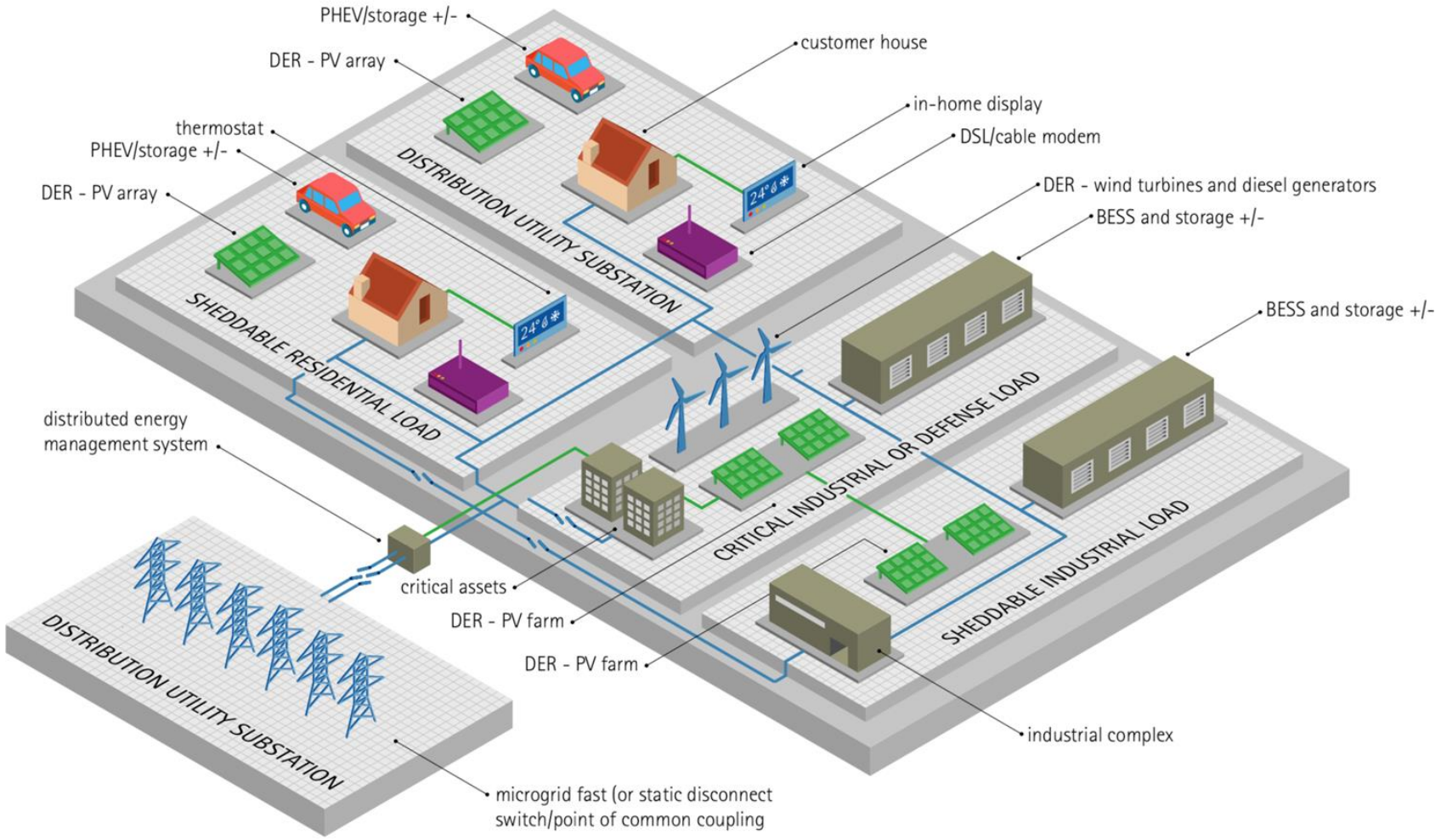


http://mydocs.epri.com/docs/CorporateDocuments/EPRI_Journal/2005-Fall/1012885_IntelliGrid.pdf



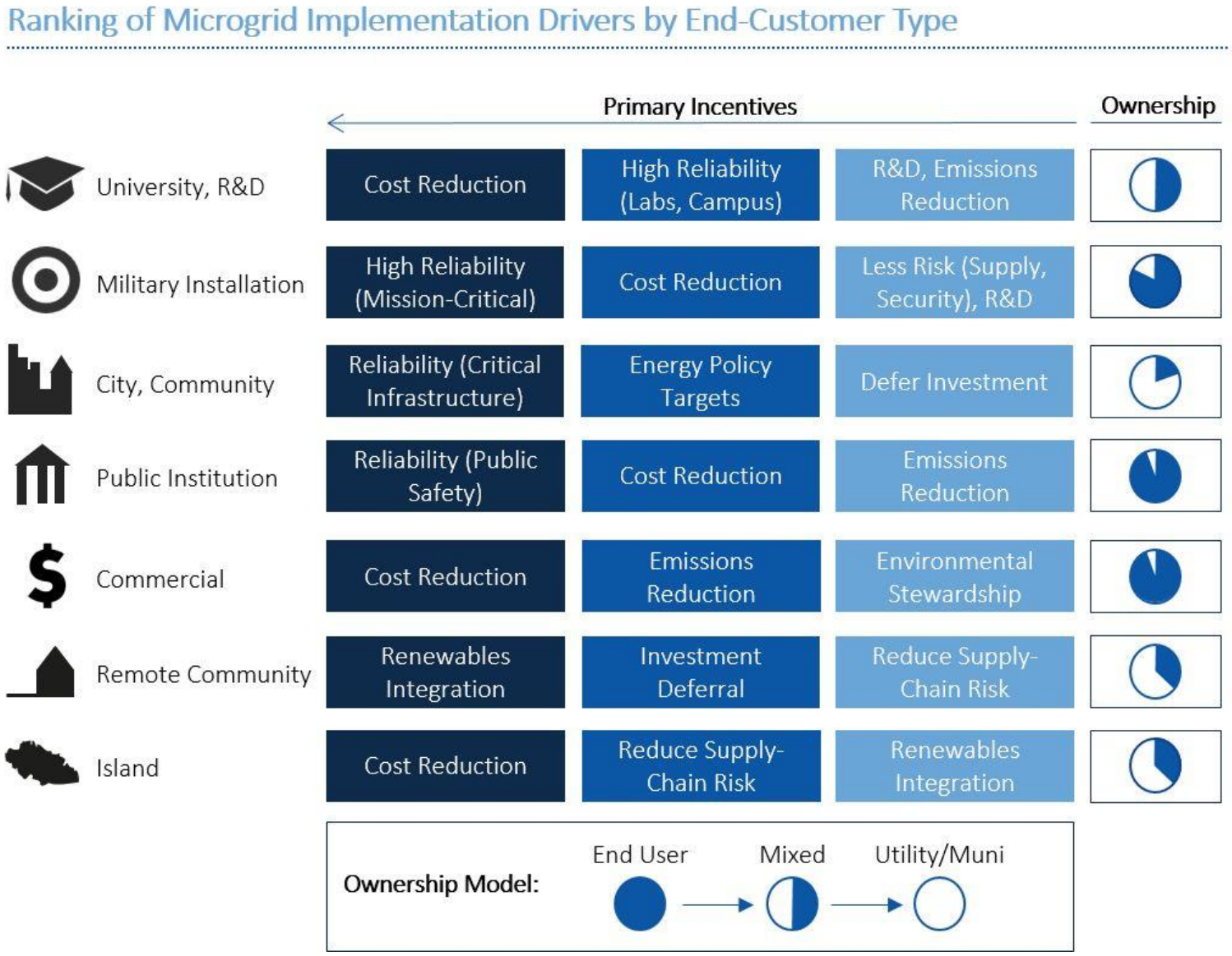
Microgrid: Assets & Functions

Figure 1. High-level framework illustrating the microgrid partitions



Source: Accenture

Microgrid: Benefits



https://www.greentechmedia.com/articles/read/3-trends-that-suggest-microgrids-are-for-more-than-just-resiliency

CBA of Microgrid Implementation

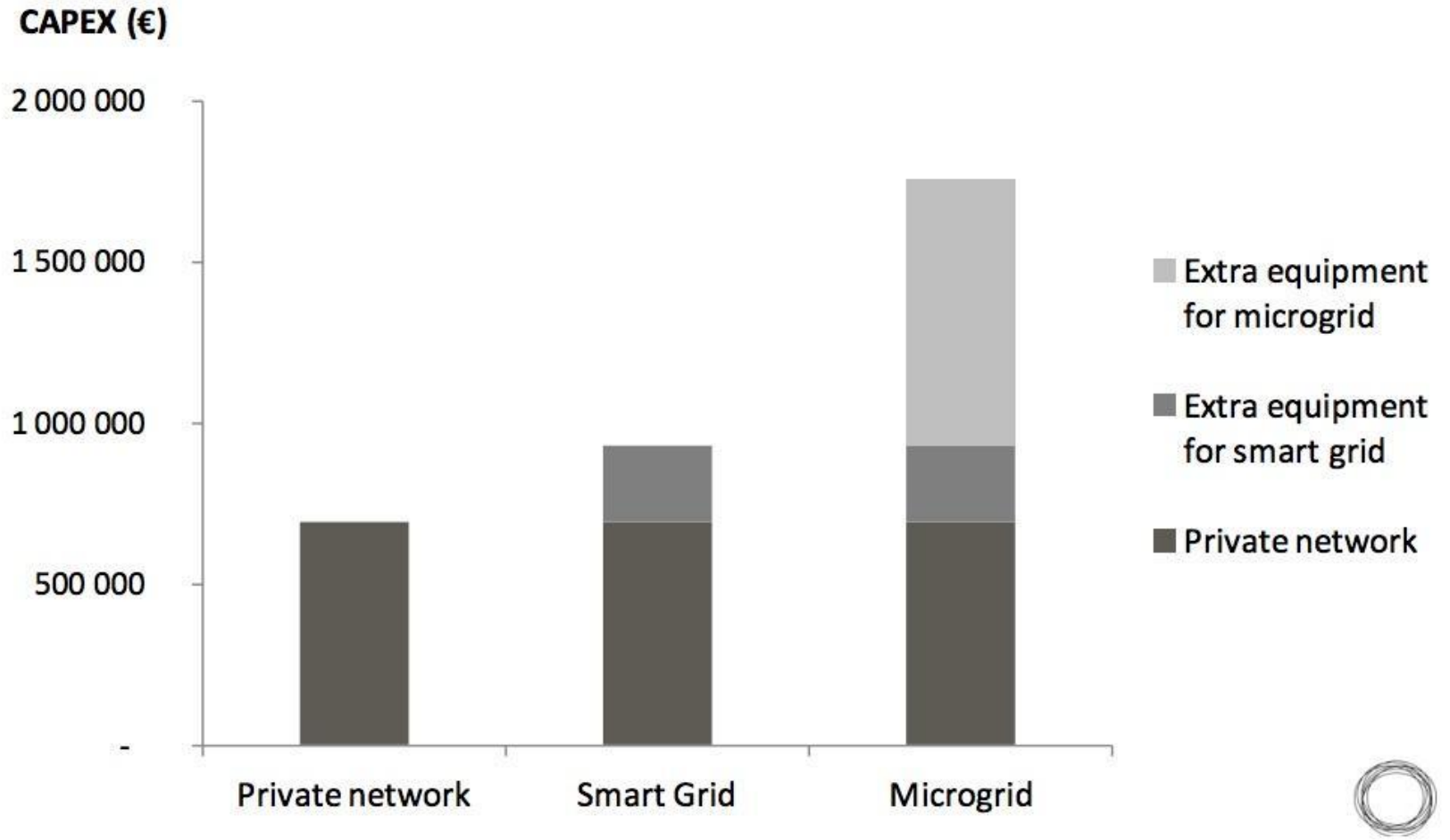
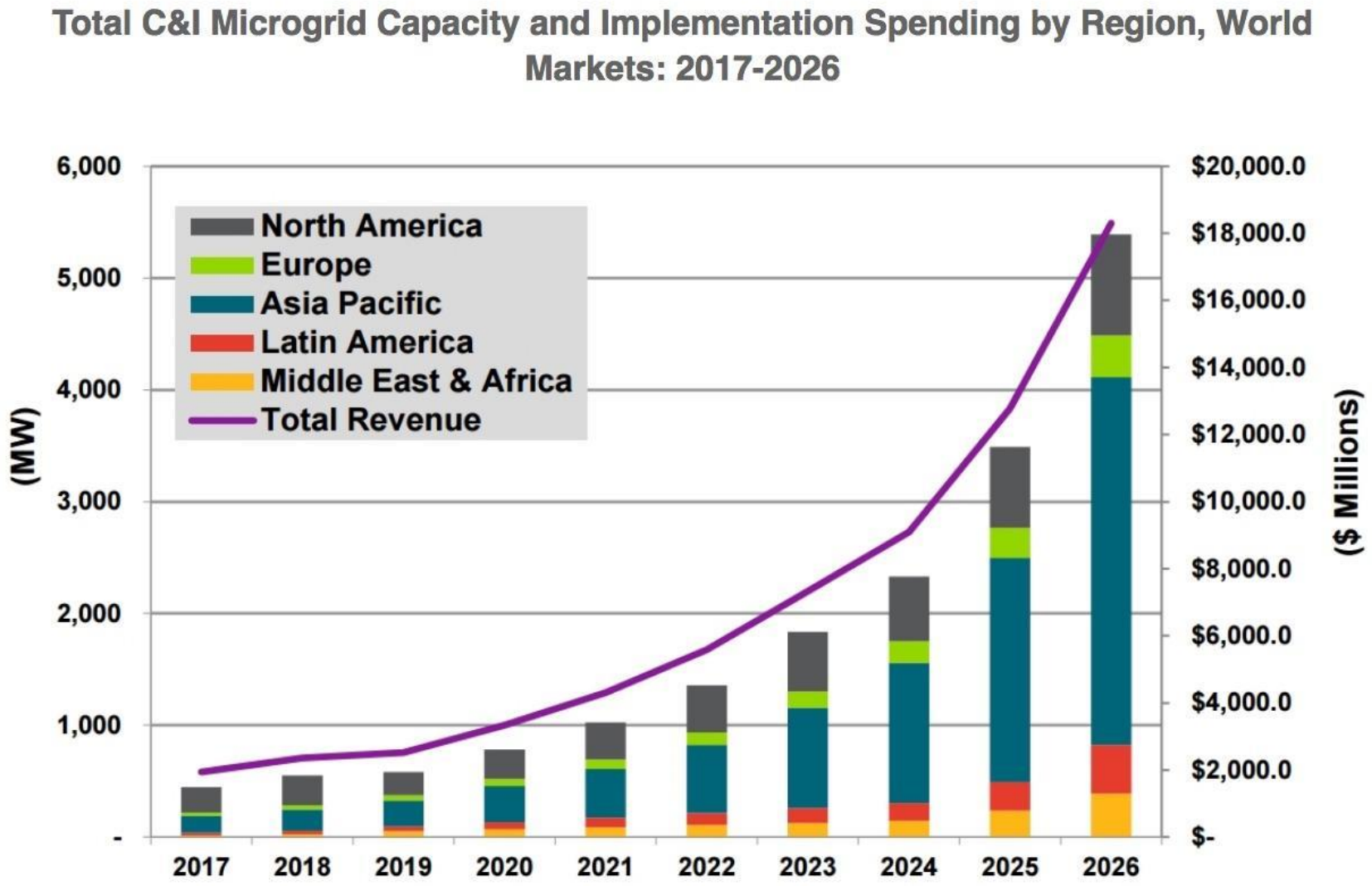


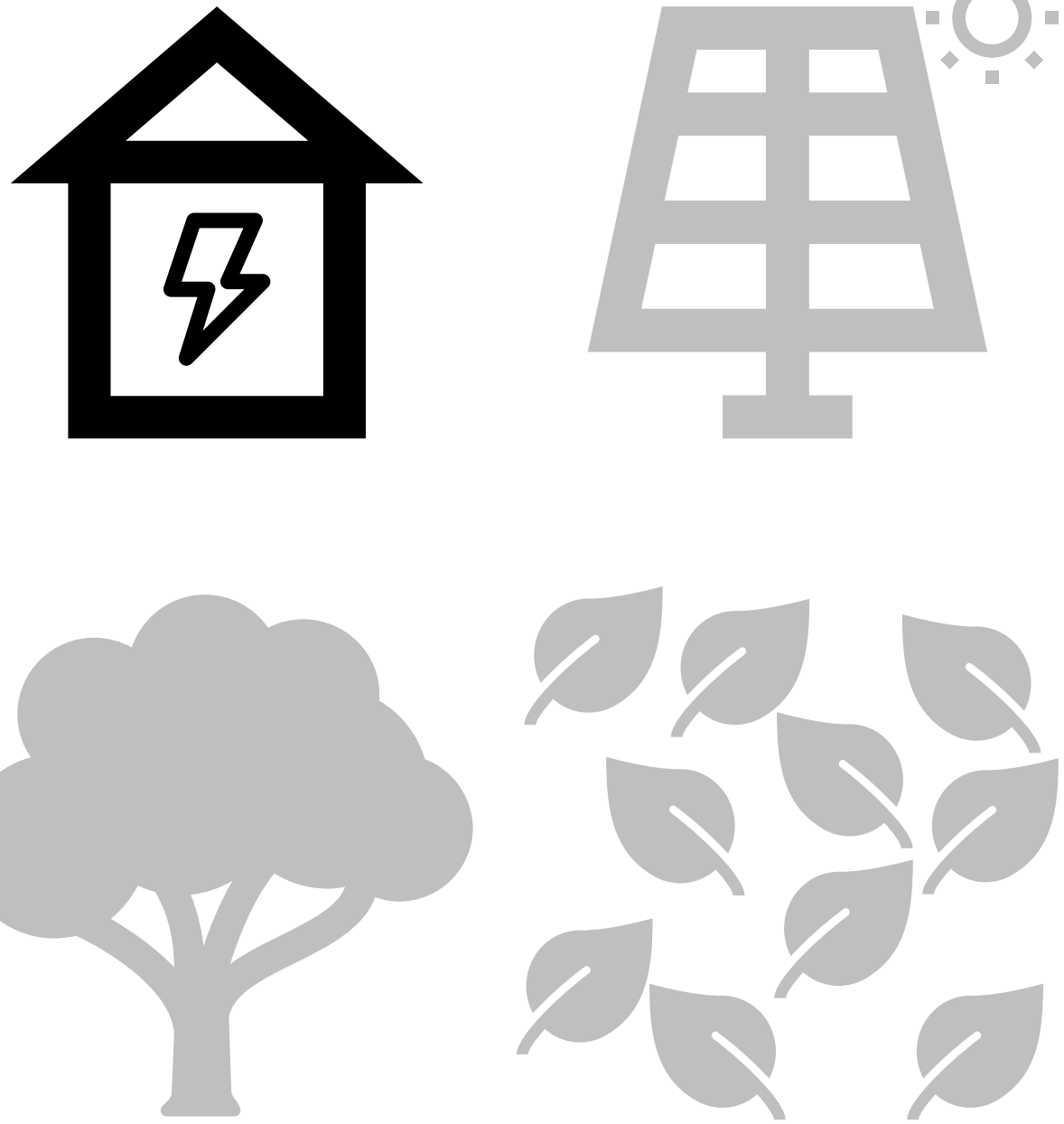
Figure 20 – CAPEX breakdown of equipment needed in three different private network configurations, apart from generation and storage assets (Enea Consulting analysis based on [32, 33, 19, 34, 35, 36, 37])

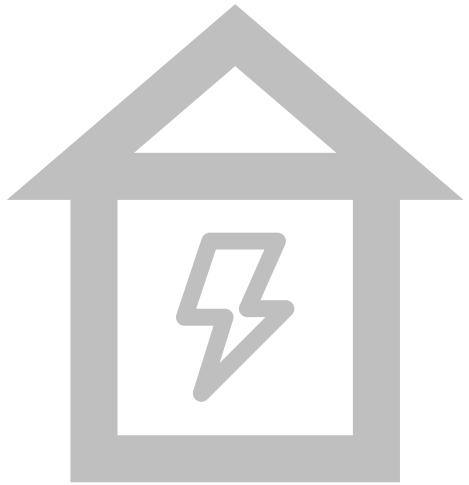
http://www.enea-consulting.com/wp-content/uploads/2017/02/Urban-Microgrids-Public-report_VF3.pdf

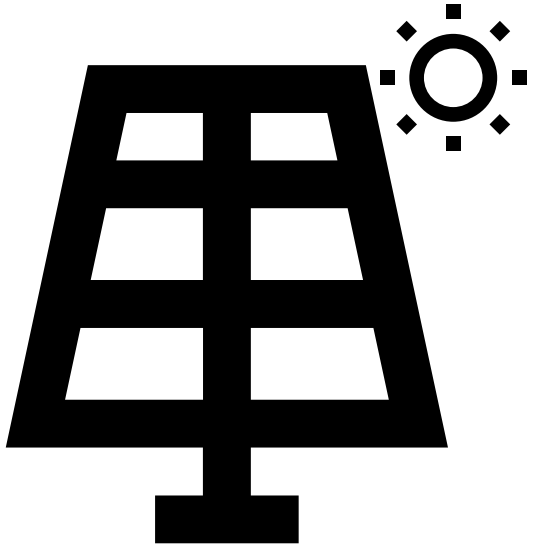
Microgrid Future

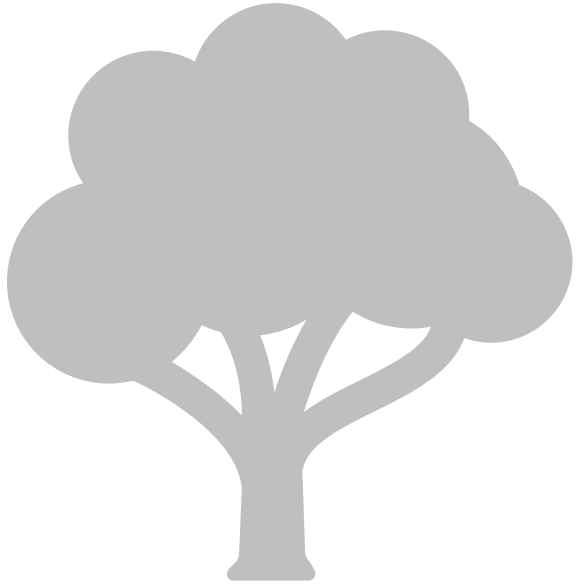


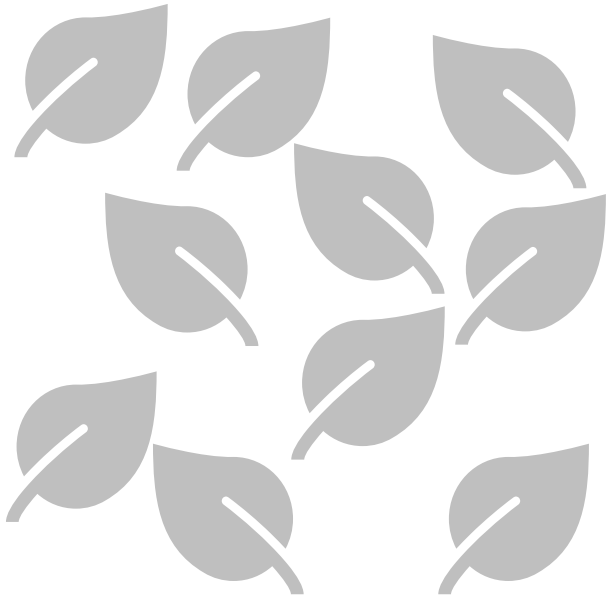
Source: https://cleantechnica.com/2017/05/25/commercial-industrial-microgrids-market-set-hit-5-4-gw-2026-navigant/

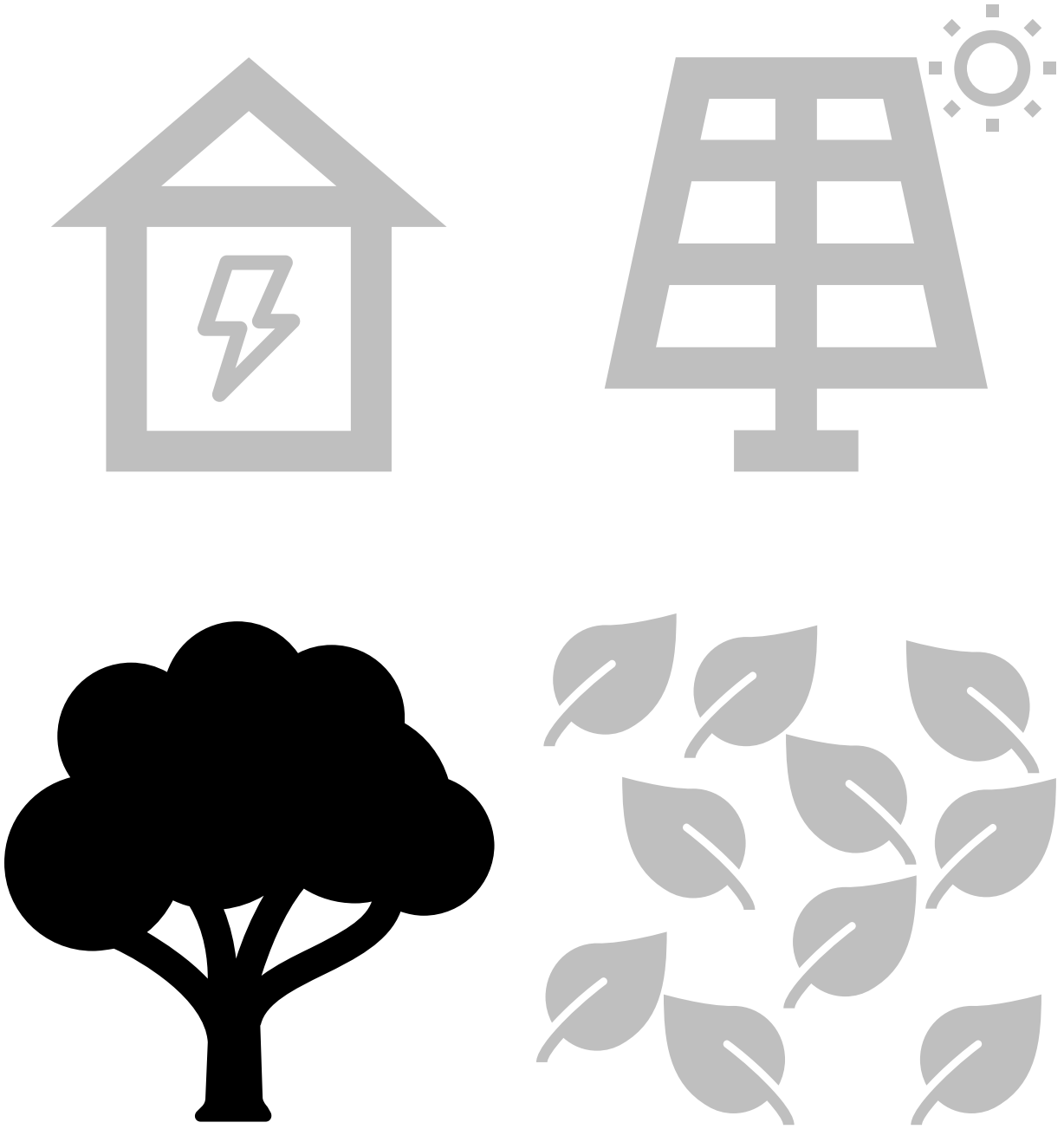


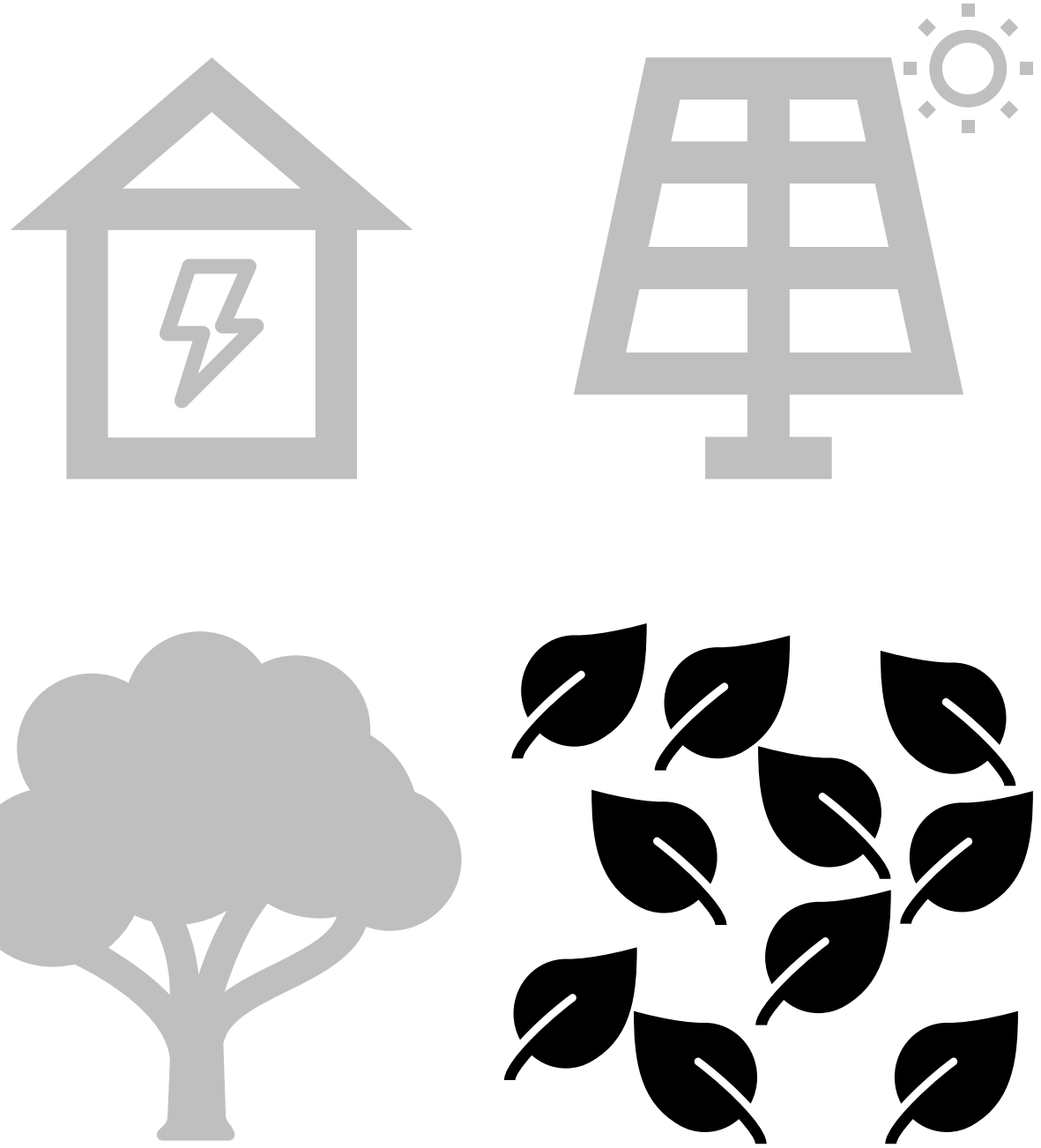












Extra Slides

POWERWALL

Tesla Powerwall is a fully-integrated AC battery system for residential or light commercial use. Its rechargeable lithium-ion battery pack provides energy storage for solar self-consumption, time-based control, and backup.

Powerwall's electrical interface provides a simple connection to any home or building. Its revolutionary compact design achieves market-leading energy density and is easy to install, enabling owners to quickly realize the benefits of reliable, clean power.

PERFORMANCE SPECIFICATIONS

AC Voltage (Nominal)	120/240 V
Feed-In Type	Split Phase
Grid Frequency	60 Hz
Total Energy[1]	14 kWh
Usable Energy[1]	13.5 kWh
Real Power, max continuous	5 kW (charge and discharge)
Real Power, peak (10 s, off-grid/backup)	7 kW (charge and discharge)
Apparent Power, max continuous	5.8 kVA (charge and discharge)
Apparent Power, peak (10 s, off-grid/backup)	7.2 kVA (charge and discharge)
Maximum Supply Fault Current	10 kA
Maximum Output Fault Current	32 A
Overcurrent Protection Device	30 A
Imbalance for Split-Phase Loads	100%
Power Factor Output Range	+/– 1.0 adjustable
Power Factor Range (full-rated power)	+/– 0.85
Internal Battery DC Voltage	50 V
Round Trip Efficiency[1,2]	90%
Warranty	10 years

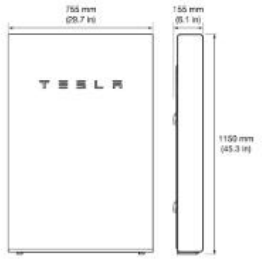
[1]Values provided for 25°C (77°F), 3.3 kW charge/discharge power.
[2]AC to battery to AC, at beginning of life.

COMPLIANCE INFORMATION

Certifications	UL 1642, UL 1741, UL 1973, UL 9540, IEEE 1547, UN 38.3
Grid Connection	Worldwide Compatibility
Emissions	FCC Part 15 Class B, ICES 003
Environmental	RoHS Directive 2011/65/EU
Seismic	AC156, IEEE 693-2005 (high)

MECHANICAL SPECIFICATIONS

Dimensions	1150 mm x 755 mm x 155 mm (45.3 in x 29.7 in x 6.1 in)
Weight	125 kg (276 lbs)
Mounting options	Floor or wall mount



ENVIRONMENTAL SPECIFICATIONS

Operating Temperature	-20°C to 50°C (-4°F to 122°F)
Optimum Temperature	0°C to 30°C (32°F to 86°F)
Operating Humidity (RH)	Up to 100%, condensing
Storage Conditions	-20°C to 30°C (-4°F to 86°F) Up to 95% RH, non-condensing State of Energy (SoE): 25% initial
Maximum Elevation	3000 m (9843 ft)
Environment	Indoor and outdoor rated
Enclosure Type	NEMA 3R
Ingress Rating	IP67 (Battery & Power Electronics) IP56 (Wiring Compartment)
Wet Location Rating	Yes
Noise Level @ 1m	< 40 dBA at 30°C (86°F)

TESLA

TESLA.COM/ENERGY

Rate Schedule

E-21

Bill Date Ranges			Energy Use (kWh)		Charges ($)		
Start Date	End Date	Season	On Peak	Off Peak	Other	Energy	Total
1/1/2017	2/1/2017	W	74	649	$20	$57	$77
2/1/2017	3/1/2017	W	62	569	$20	$50	$70
3/1/2017	4/1/2017	W	71	595	$20	$53	$73
4/1/2017	5/1/2017	W	108	686	$20	$64	$84
5/1/2017	6/1/2017	S1	165	875	$20	$121	$141
6/1/2017	7/1/2017	S1	242	1,348	$20	$183	$203
7/1/2017	8/1/2017	SP1	246	1,680	$20	$230	$250
8/1/2017	9/1/2017	SP1	250	1,480	$20	$214	$234
9/1/2017	10/1/2017	S2	204	1,179	$20	$158	$178
10/1/2017	11/1/2017	S2	164	919	$20	$125	$145
11/1/2017	12/1/2017	W	71	564	$20	$51	$71
12/1/2017	1/1/2018	W	74	642	$20	$57	$77
			1,731	**11,186**	**$240**	**$1,364**	**$1,604**

Rate Schedule

E-27

Bill Date Ranges			Energy Use (kWh)		Max Demand (kW)	Charges ($)			
Start Date	End Date	Season	On Peak	Off Peak	On Peak	Other	Energy	Demand	Total
1/1/2017	2/1/2017	W	216	507	2	$32	$29	$7	$69
2/1/2017	3/1/2017	W	187	444	2	$32	$25	$7	$65
3/1/2017	4/1/2017	W	202	464	2	$32	$27	$7	$66
4/1/2017	5/1/2017	W	218	576	3	$32	$32	$11	$75
5/1/2017	6/1/2017	S1	355	686	4	$32	$43	$39	$114
6/1/2017	7/1/2017	S1	529	1,061	4	$32	$65	$39	$136
7/1/2017	8/1/2017	SP1	547	1,379	4	$32	$93	$47	$172
8/1/2017	9/1/2017	SP1	553	1,177	4	$32	$85	$47	$164
9/1/2017	10/1/2017	S2	444	938	4	$32	$56	$39	$128
10/1/2017	11/1/2017	S2	358	725	4	$32	$44	$39	$115
11/1/2017	12/1/2017	W	195	440	2	$32	$26	$7	$65
12/1/2017	1/1/2018	W	206	510	2	$32	$29	$7	$68
			4,010	**8,907**		**$389**	**$554**	**$294**	**$1,237**

Rate Schedule

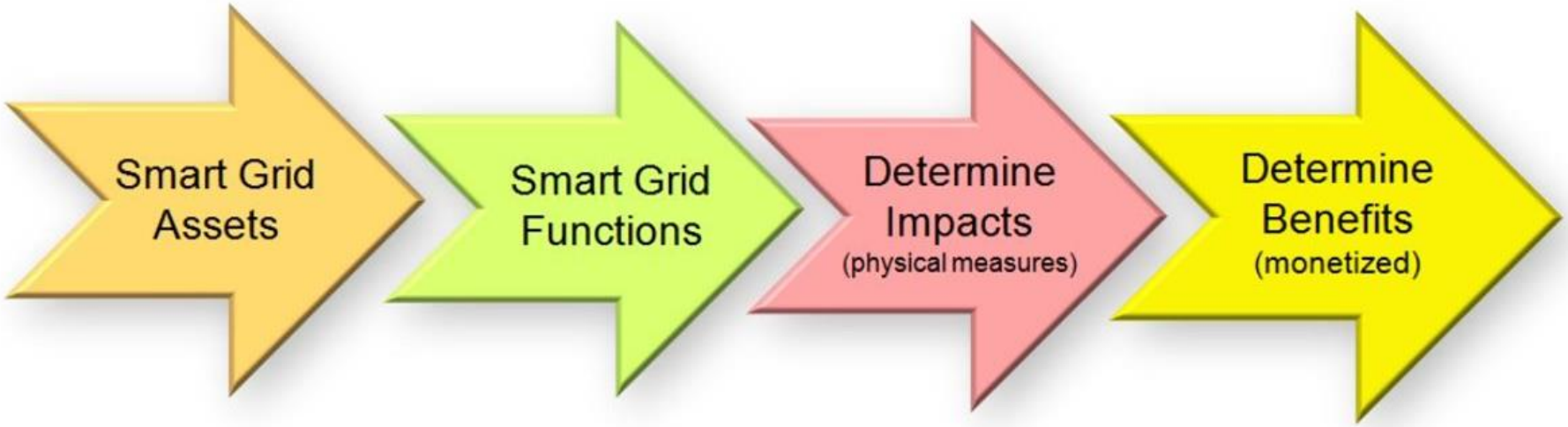
E-36

Bill Date Ranges			Energy Use (kWh)	Max Demand (kW)	Charges ($)			
Start Date	End Date	Season	Total	NC / Max	Other	Energy	Demand	Total
1/1/2017	2/1/2017	W1	1,842	5	$57	$131	$0	$188
2/1/2017	3/1/2017	W1	1,777	6	$57	$131	$4	$192
3/1/2017	4/1/2017	W1	2,019	5	$57	$140	$0	$197
4/1/2017	5/1/2017	W1	2,350	7	$57	$172	$9	$237
5/1/2017	6/1/2017	S1	2,760	8	$64	$246	$14	$325
6/1/2017	7/1/2017	S1	3,492	8	$64	$290	$14	$368
7/1/2017	8/1/2017	SP1	4,040	8	$72	$369	$21	$463
8/1/2017	9/1/2017	SP1	3,796	8	$72	$352	$21	$446
9/1/2017	10/1/2017	S2	3,112	8	$64	$267	$14	$346
10/1/2017	11/1/2017	S2	2,617	7	$64	$227	$10	$301
11/1/2017	12/1/2017	W1	1,969	5	$57	$138	$0	$195
12/1/2017	1/1/2018	W1	1,833	5	$57	$131	$0	$187
			31,607		**$741**	**$2,594**	**$109**	**$3,445**

Example: IntelliGrid Deals With a Heat Wave

IntelliGrid's real-time assessment and control capabilities will help utilities avoid a variety of problems. One example involves an especially hot summer day, when increased customer air-conditioner use threatens to boost electricity demand sharply. The transmission system operator (1), integrating weather data with real-time information from sensors embedded in the grid, forecasts that it may not be able to meet the coming peak load for a part of its service territory. To prevent a shortfall, the operator calls for reduced customer usage and asks distributed generators to sell any surplus generation. The energy service provider (2) facilitates the curtailment request by sending a signal to its customers' communication portals, offering special incentives for customers who shed load during the peak period. In response, one industrial customer (3) decides to shut down one of its three assembly lines for several hours. A commercial customer (4) shifts over to an on-site backup generator and is able to sell some excess power back to the utility. Several residential customers (5) have preprogrammed their portals to automatically dim their lights and reset their thermostats higher in response to such an offer; another residence, which has rooftop solar panels, feeds electricity back onto the grid. Because the smart grid's power and communications systems are integrated, the utility can take advantage of all available supply- and demand-side options and avoid an almost certain power shortfall.

Components of a Smart Grid: Functions



Technologies, Devices, & Systems

Examples:

- AMI/Smart meters
- Distribution Automation
- 2-way communication
- Smart Appliances
- Intelligent Electronic Devices (IEDs)

Systems' Intended Functions

Examples:

- Volt/VAR control
- Dynamic Capability Rating
- Flow control
- Intelligent line switching
- Real-time load management

Project performance relative to baseline scenario

Example measures:

- kWh reduction
- Peak kW reduction
- Loss reductions
- Outage reductions
- Improved asset utilization

Monetization of Impacts

Example metrics:

- Fuel savings
- Capacity savings
- Reduced outage costs
- Reductions in CO_2, Hg, etc.

https://www.energy.gov/sites/prod/files/2017/01/f34/Guidebook-Cost-Benefit-Analysis-Smart-Grid-Demonstration-Projects.pdf