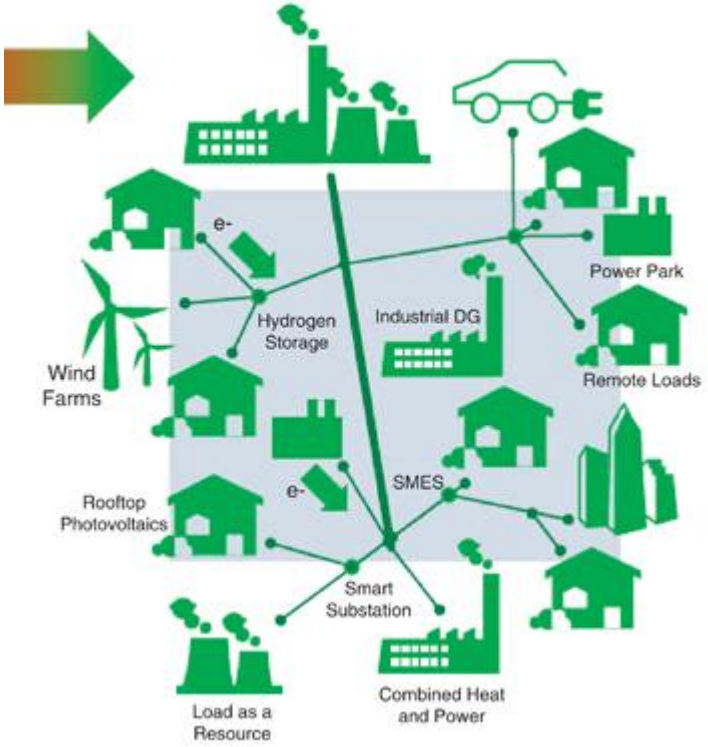
ELG4126
Distributed Generation
in Electric Power Systems



What is Distributed Generation?

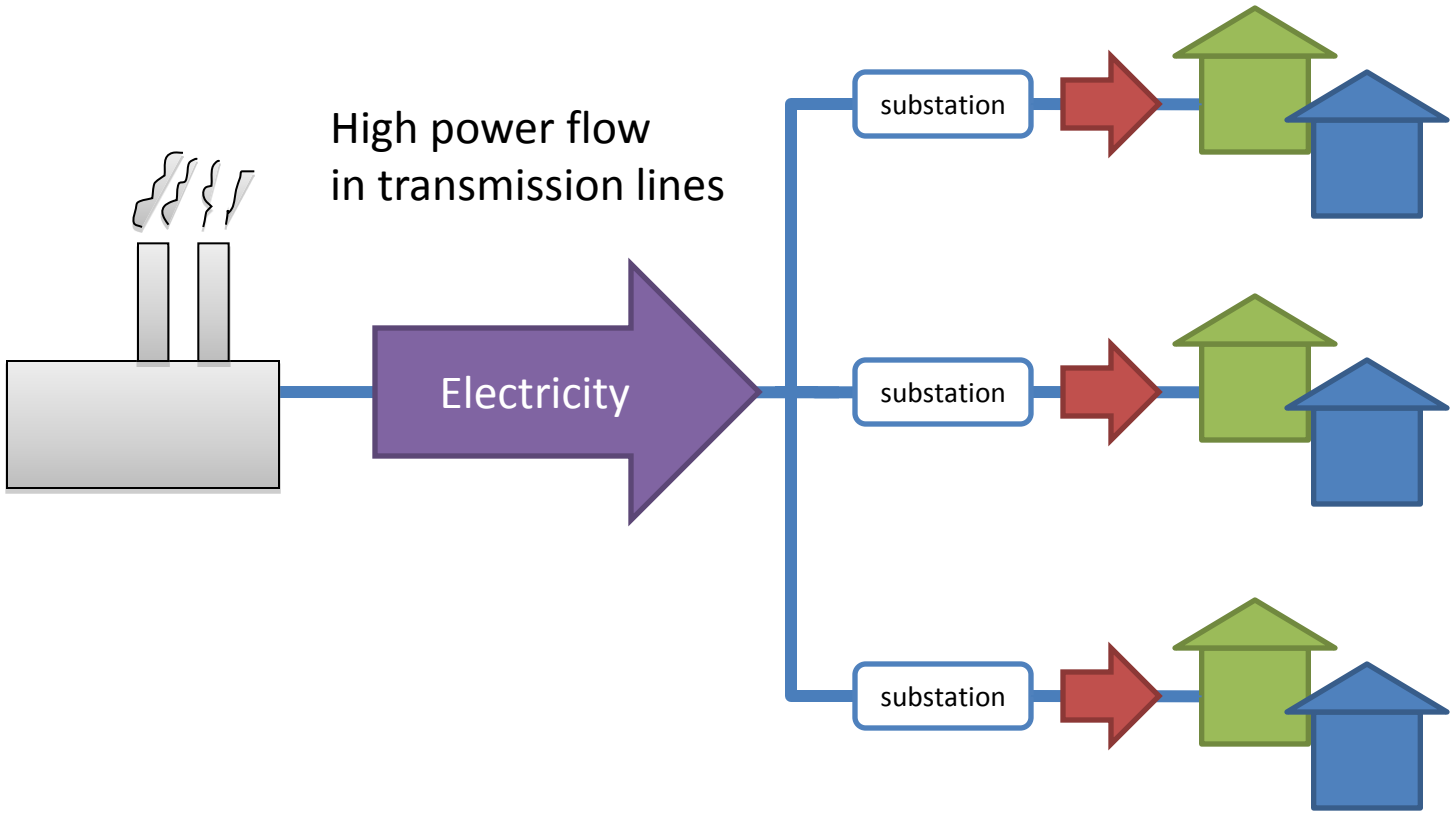
- Small-scale power generation technologies located close to the load being served.
- Renewables or non-renewables!
- Typically, 10 MW or less.
- Also called generational distributed resources (DR); distributed energy resources (DER); or dispersed power (DP).

- **EPA definition:**

  "Small, modular, decentralized, grid-connected or off-grid energy systems located in or near the place where energy is used."

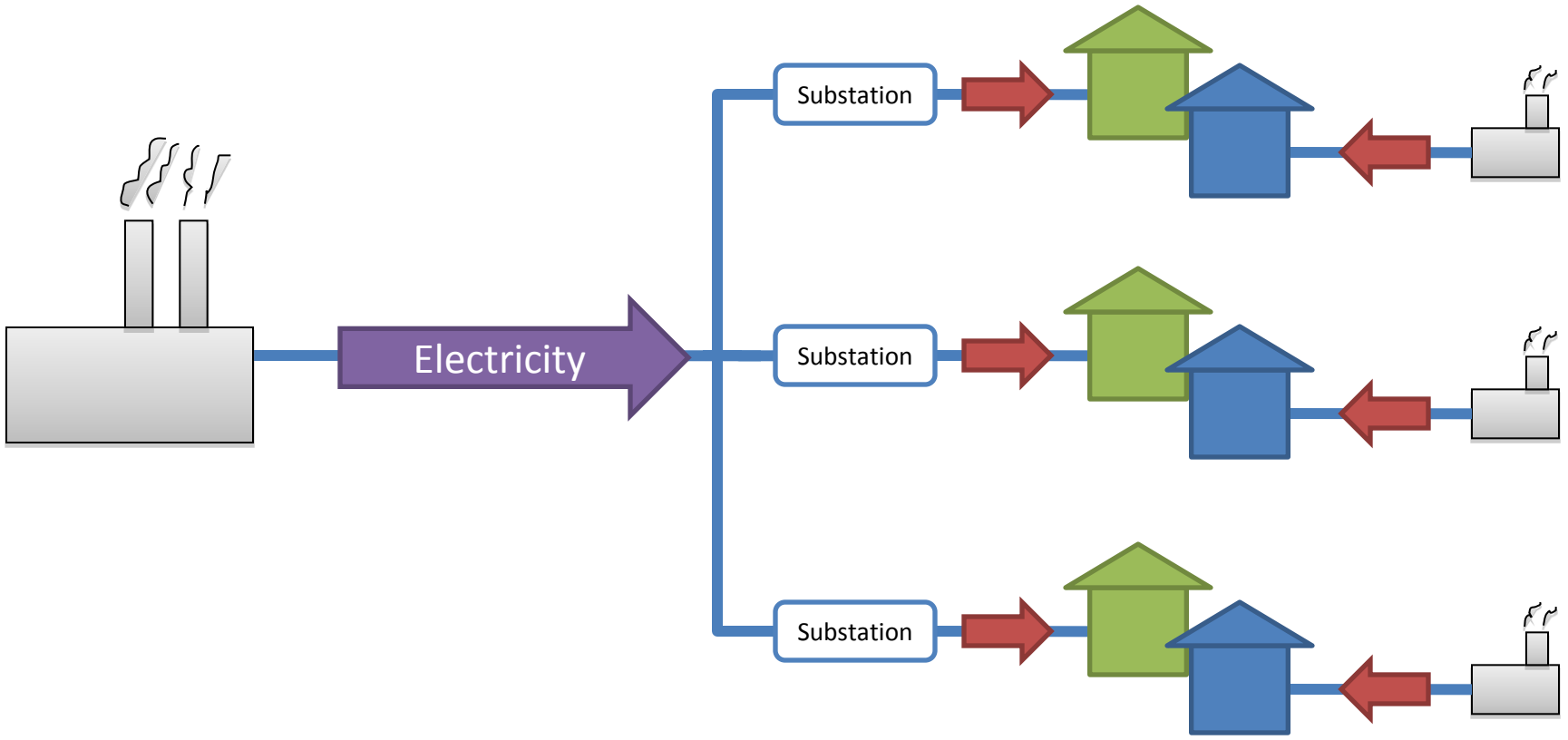
The Power Grid

The classic model

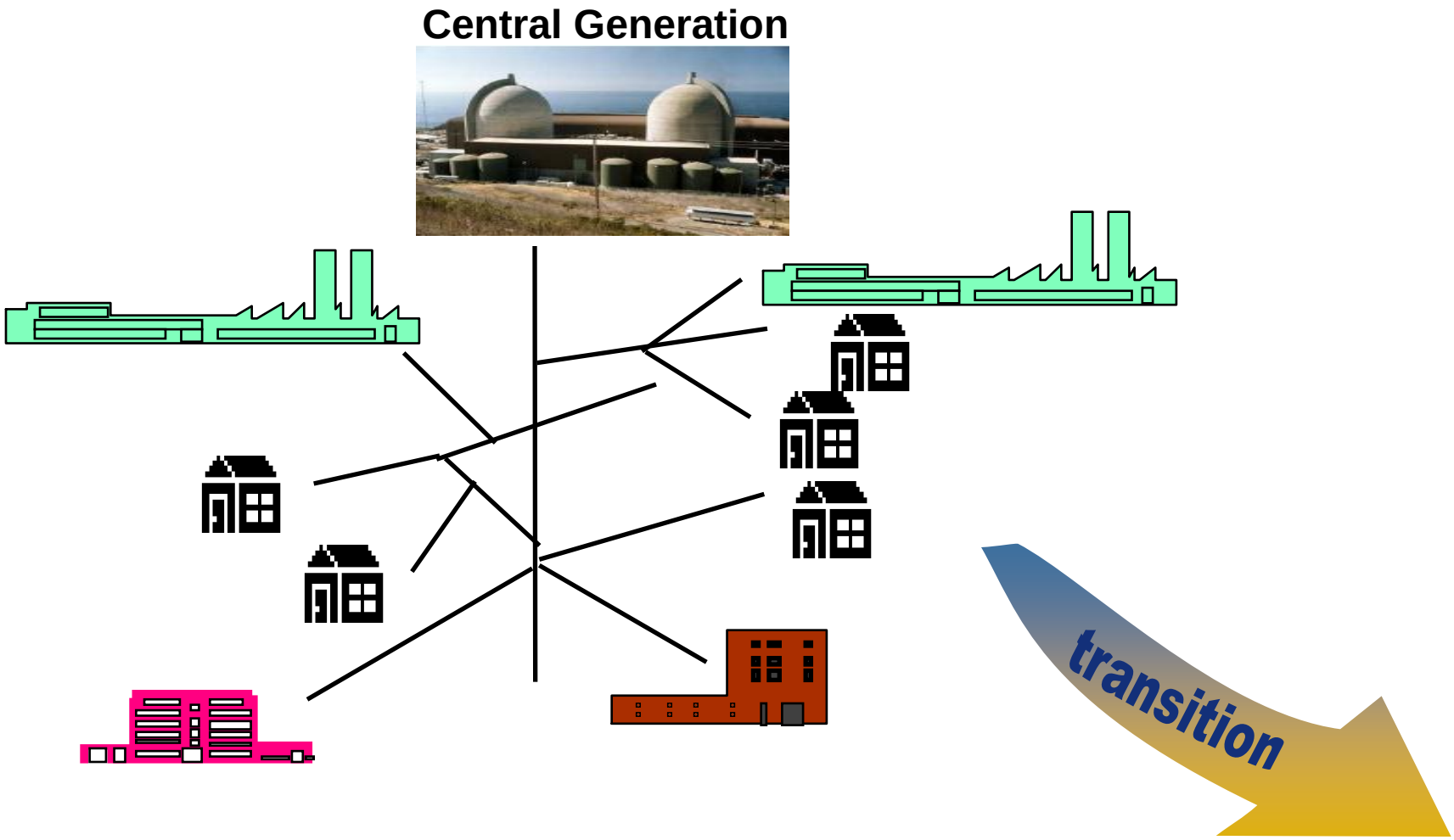


The Power Grid

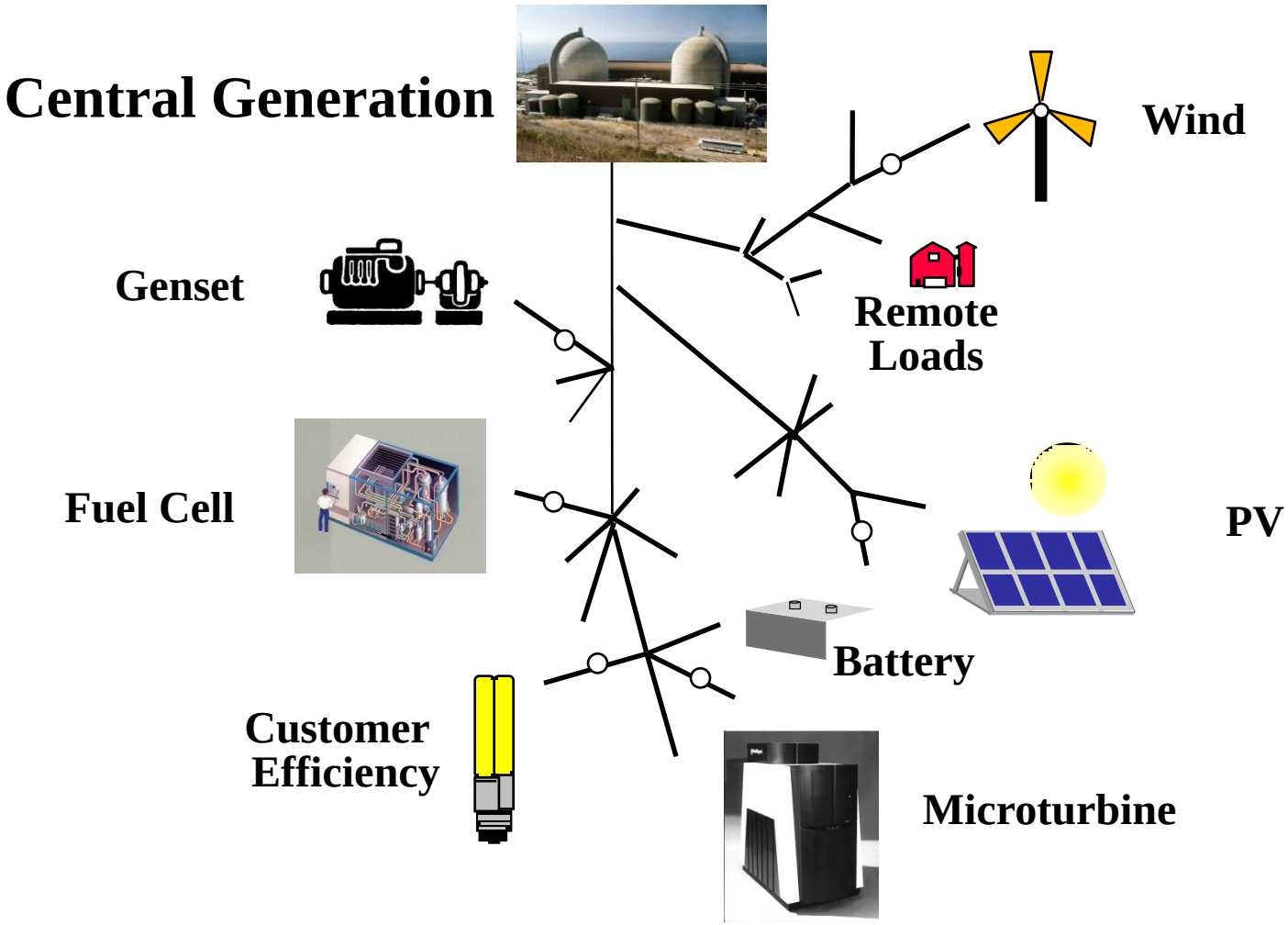
What can distributed generation do?



Today's Nature of Utility



Distributed Utility



Types of DGs

- **Combustion Engines:**
  - Diesel or gas; low installation cost; high efficiency; low start up and shut down time; suitable for heat and power; available from few kW to 30 MW; high Nitrogen Oxides (Nox) and CO_2 emissions.
  - The main users of the ICE DG units gas, electric and water utilities. Other users include manufacturing facilities, hospitals, educational facilities and office buildings.

Combustion Turbines

- They are usually used in the 500 kW to 30 MW.
- Typical start up time to full output power is between 2-10 minutes, which makes gas turbines a good choice for reserve support.
- Although the CO_2 emissions of gas turbines are nearly like engines (580-680 kg/MWh), they have significantly lower NO*x* emissions.
- The typical efficiency is around 35% in the 5 MW range.

Microturbines

- These units can use a wide range of fuels such as natural gas, hydrogen, propane and diesel to produce
- electricity.
- Microturbines can be used for base load power, stand-by power, peak shaving and cogeneration applications and well-suited for small commercial buildings.
- Microturbine DG units have a good NO*x* emissions performance (0.1 kg/MWh); however, their CO2 emissions are sometimes more than ICE DG units (720 kg/MWh).

Fuel Cells

- Fuel cells can convert chemical energy to electricity without combustion.
- Fuel cell technologies were initially developed for space applications, and then the transportation sector found it to be a promising technology.
- Since this technology has good efficiency, compact size, very low noise, negligible NO*x*, SO, CO and reliable operation, it has found its market in the power industry as well.
- The electrical efficiency of fuel cells ranges from 30 to 55 percent.

Photovoltaic (PV)

- Since PV systems convert sunlight to electricity directly without combustion or any other fuel consumption, this technology is emission free and has very little operation costs and maintenance.
- PV can be considered to be the best DG technology for household and small commercial applications.
- PV systems are now commercially available in rooftop small sizes (less than 10 kW), medium size (10-100 kW) and large systems above 100 kW connected to distribution system feeders.

SUMMARY OF THE REVIEWED DG TECHNOLOGIES.

Technology	Capital costs US$/kW	O&M costs US$/MWh	NO_x kg/MWh	CO_2 kg/MWh	Efficiency	Available size	Start up time	Main features	Applications
ICE Diesel	350-500	5-10	10	650	36-43%	A few kW to 30 MW	10 s to 15 min	*Mature industry *Fast start and stop *Low costs *High efficiency *CHP capability *High emissions	*Emergency power *Peak shaving *Load following *Reserve support *Grid On & Off
ICE Gas-fired	600-1000	7-15	0.2-1	500-620	28-42 %				
Combustion Turbine	650-900 (Size dependent)	4-5	0.3-0.5	580-680	20-45% (up to 55% in combined cycle)	500 kW to 265 MW	2-10 min	*Well established market and service *Readily available *Low costs *Good efficiency	*CHP *Base load *Portable units *Reserve support *Grid On & Off
Microurbine	700-1100	5-16	0.1	720	20-30% Up to 85% In CHP	25-500 kW	Up to 120 s	*Low Noise *Small Size *Long Maintenance Intervals *Flexibility in Fuel	*CHP *Peak Shaving *Stand-by power *Grid On & Off
Fuel Cell (PAFC)	4000 - 5500	5-10	0.005 to 0.01	430-490	36-42%	5-250 kW	1-4 h	*Very Low Noise *Good efficiency *Compact size *Negligible NO_x emissions *Reliable operation	*CHP *DC applications *Base load *Grid On & Off *Back up systems
Photovoltaics	6000 - 10000	1% of first investment annually	0	0	NA[a]	A few kW to more than 100 kW	Quick[b]	*Clean energy *Negligible noise *High costs *Environmental Dependant *No emissions	*Communication systems *Remote buildings *Household powering *Grid On & Off

Power Disruptions

- Classification
  - Power Shortages:
    - **Blackout:** complete loss of power
    - **Rolling blackout:** intentional, temporary shutoff
    - **Brownout:** voltage reduction, may be intentional
  - Power Quality:
    - Voltage and frequency fluctuations

Power Disruptions

- Commercial and Industrial Impact
  - Data storage, retrieval, processing.
  - Research and development operations.
  - Telecommunications.
  - Financial operations.
  - Precision and general manufacturing.
  - Transportation.
  - Utilities (e.g. water, natural gas).

Power Disruptions

- Residential consumer impact
  - Power-sensitive high-tech devices
    - Possible equipment damage
    - Expensive to replace or repair
    - Possible irreversible data loss
  - Essential devices
    - Refrigeration
    - Heating and cooling
    - Medical

Infrastructure Issues

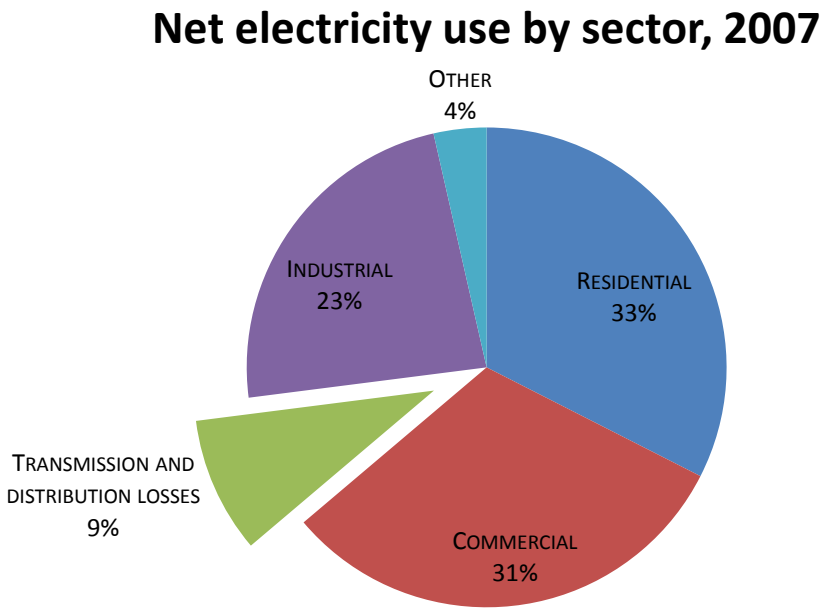
- Why is not the system reliable now?
  - High peak demand
  - Delivery bottlenecks
  - Grid fragility
  - Power Loss.

Infrastructure Issues

- The demand pattern
  - Higher during the day, lower at night
  - Higher in the summer, lower in the winter
  - Result: highest during the day in the summer
- Why does this matter?
  - We don’t know how much higher it will be

Infrastructure Issues

- Power loss
  - Transmission loss 6-8% during peak demand
  - Heat released into atmosphere



Power Quality Issues

- Sustained Interruptions
- Voltage Regulation
- Voltage Ride Through
- Harmonics
- Voltage Sags
- Load Following
- Power Variation
- Misfiring of Reciprocating Engines