2022 Tribal Energy Webinar Series: Empowering Native Communities and Sustaining Future Generations

August 3: Technologies of the Energy Transition

Renewable Energy

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Energy Systems Integration Directorate

Renewable Energy Technologies

Solar Photovoltaics

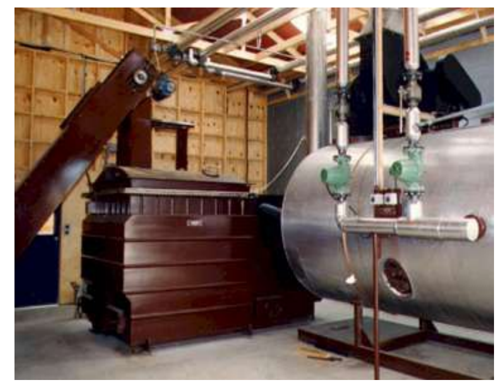
Wind Power, Marine Energy

Solar Water Heating

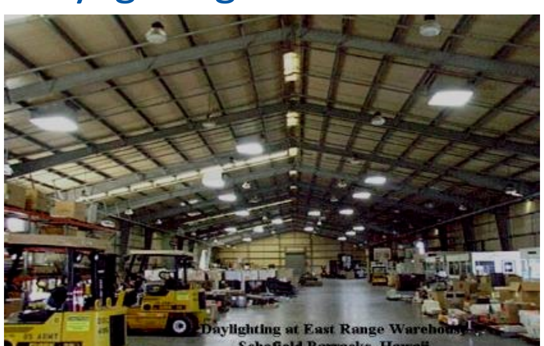
Solar Vent Air Preheat

Concentrating Solar Heat/Power

Biomass Heat/Power



Daylighting



Geothermal

Landfill Gas

Monthly Energy Review
May 2022

https://www.eia.gov/totalenergy/data/monthly/pdf/mer.pdf

Figure 1.2 Primary Energy Production
(Quadrillion Btu)

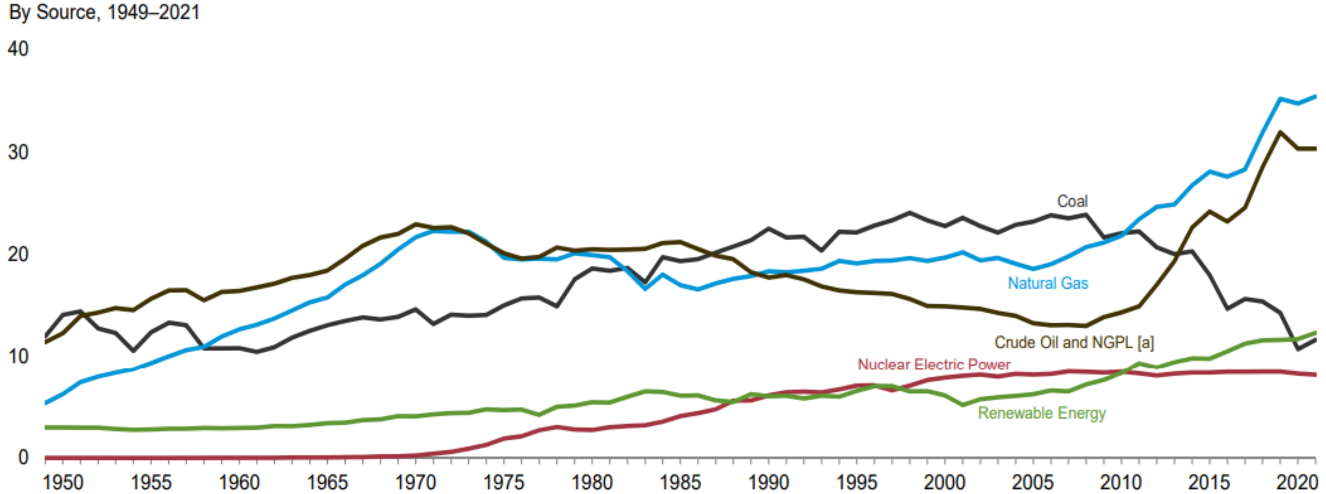
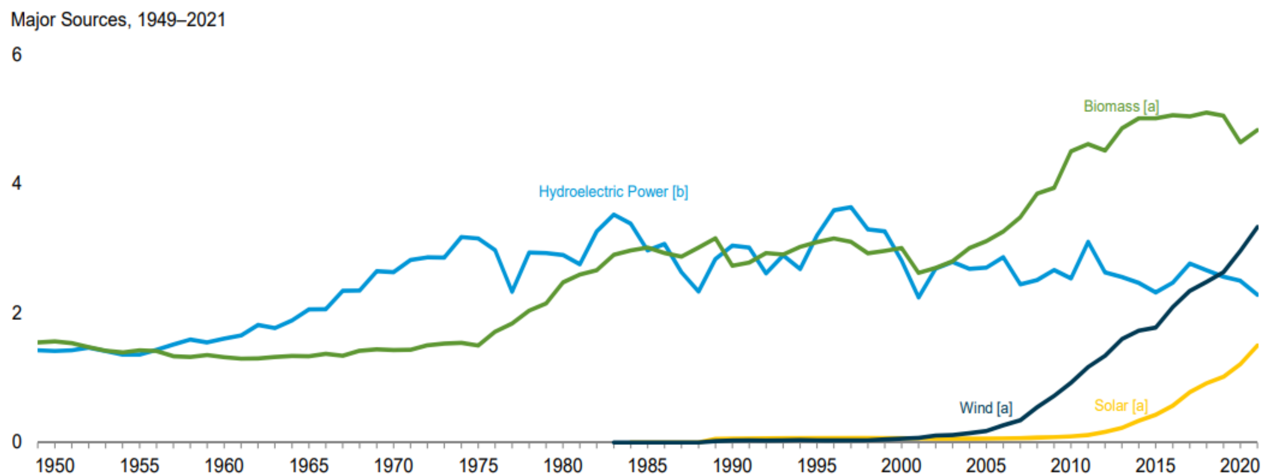
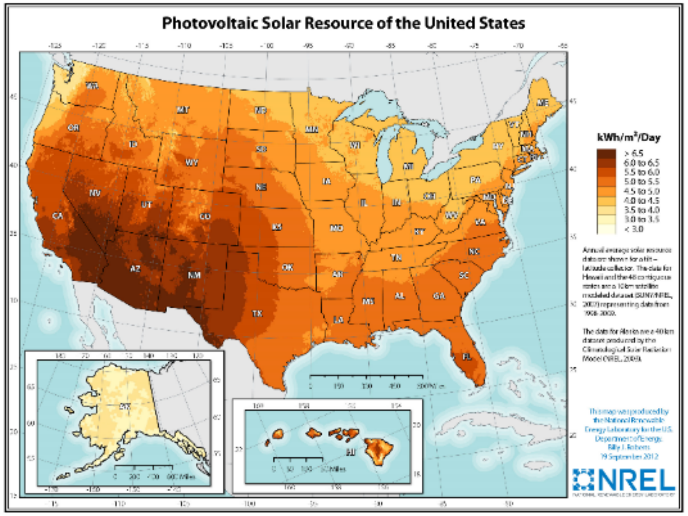


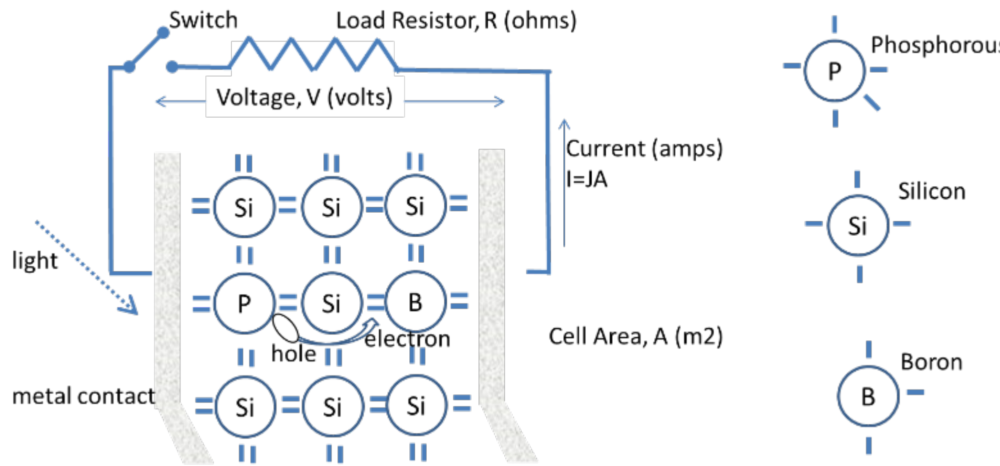
Figure 10.1 Renewable Energy Consumption
(Quadrillion Btu)

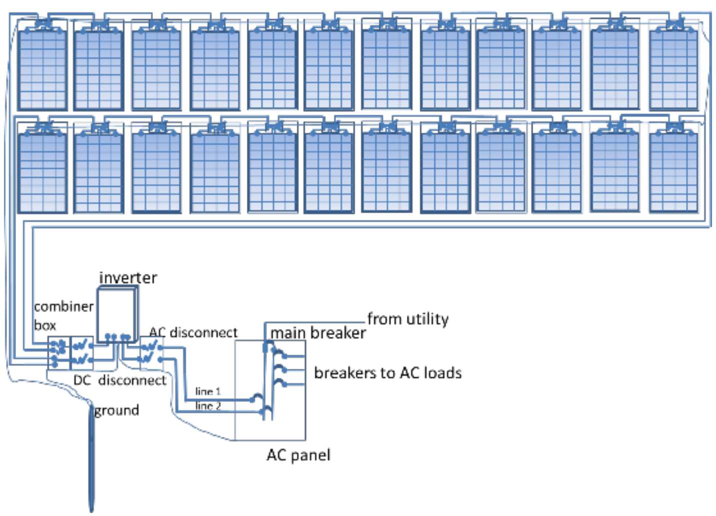


https://www.eia.gov/totalenergy/data/monthly/pdf/mer.pdf

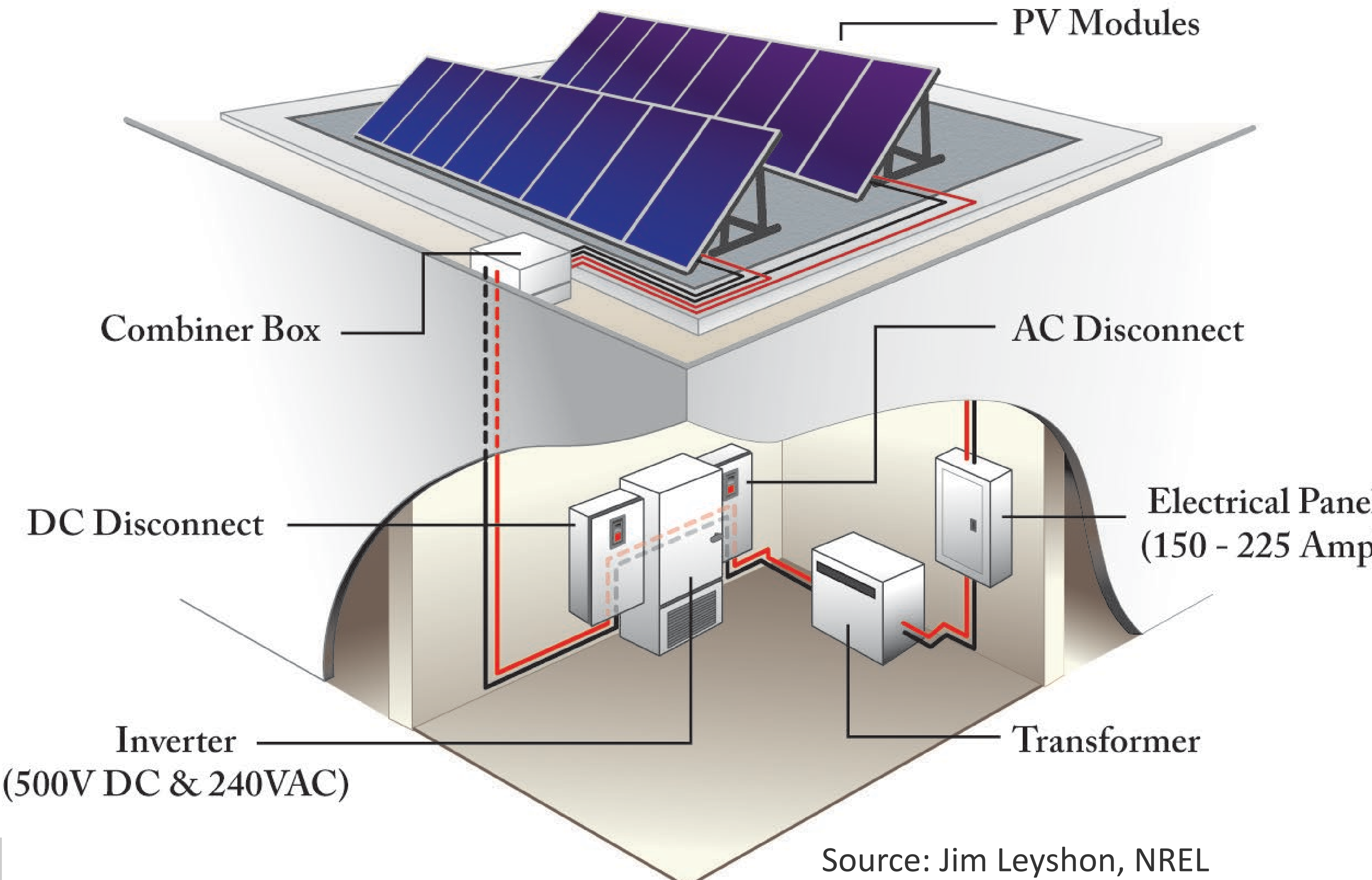
Photovoltaics





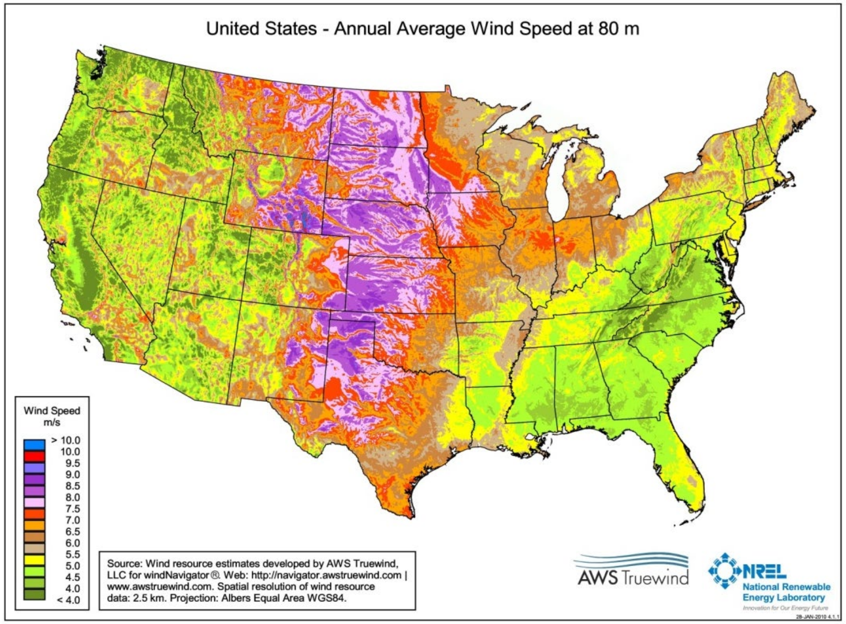


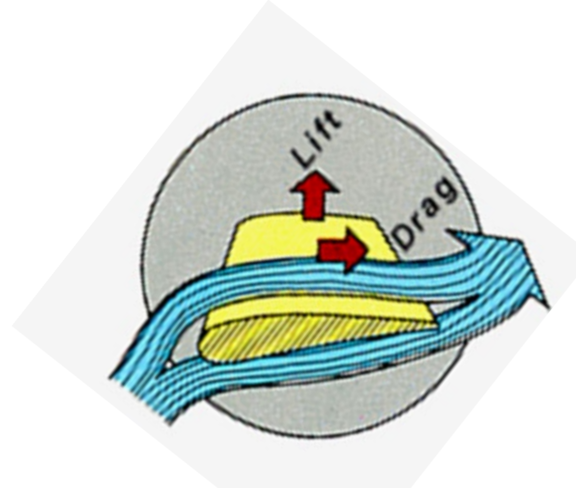
Photovoltaics System (grid connected)

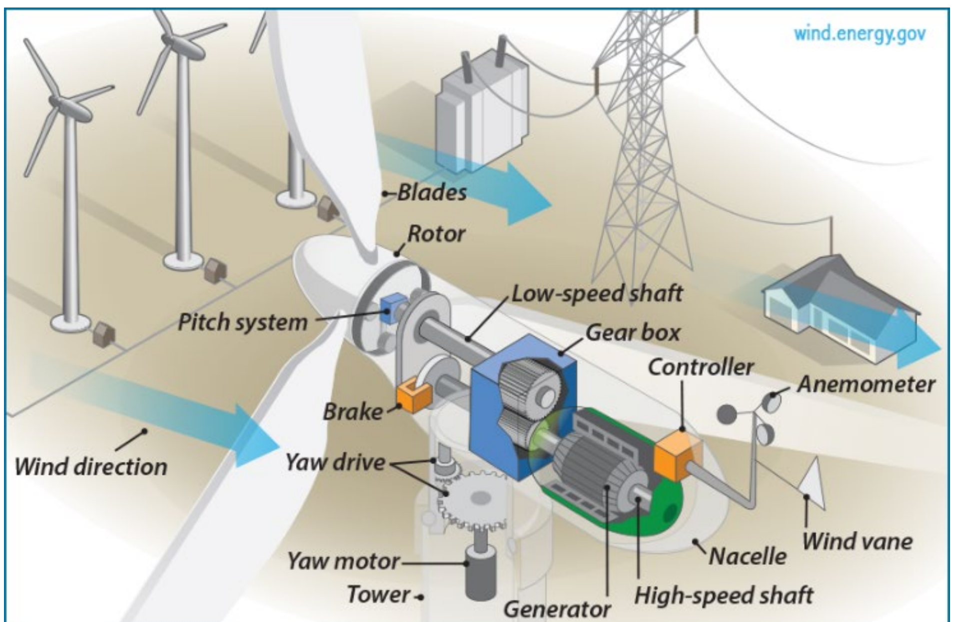


Source: Jim Leyshon, NREL

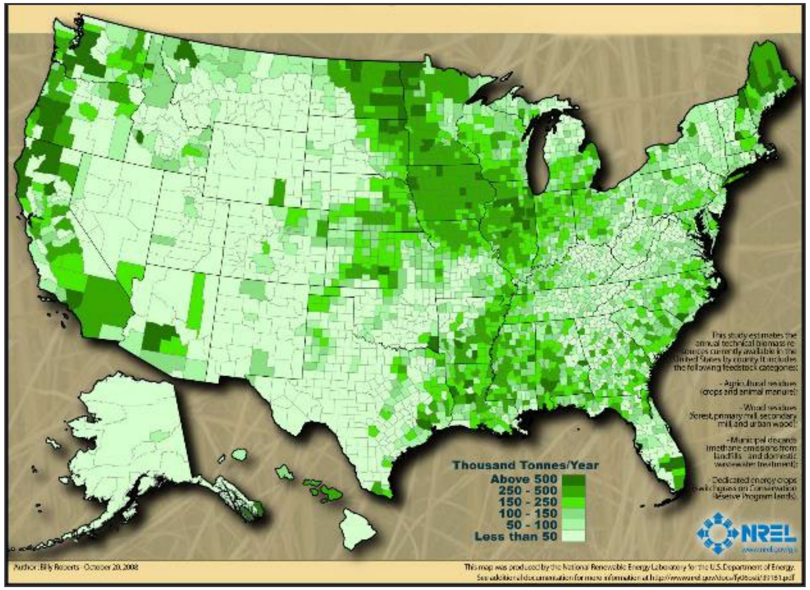
Wind Power

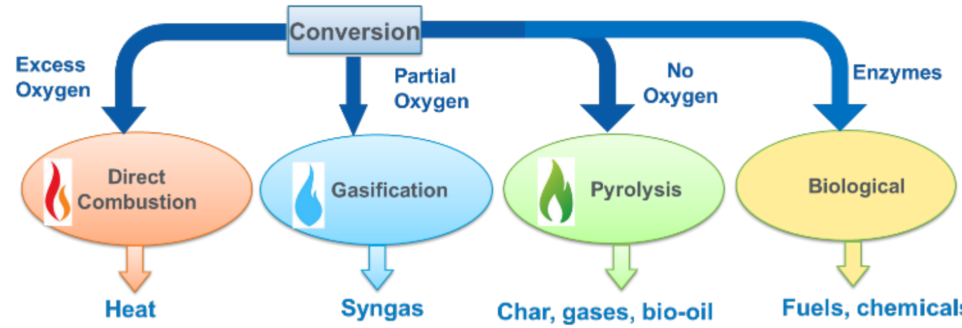

United States - Annual Average Wind Speed at 80 m
Wind Speed m/s
> 10.0
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
< 4.0
Source: Wind resource estimates developed by AWS Truewind, LLC for windNavigator®. Web: http://navigator.awstruewind.com | www.awstruewind.com. Spatial resolution of wind resource data: 2.5 km. Projection: Albers Equal Area WGS84.
AWS Truewind
NREL National Renewable Energy Laboratory

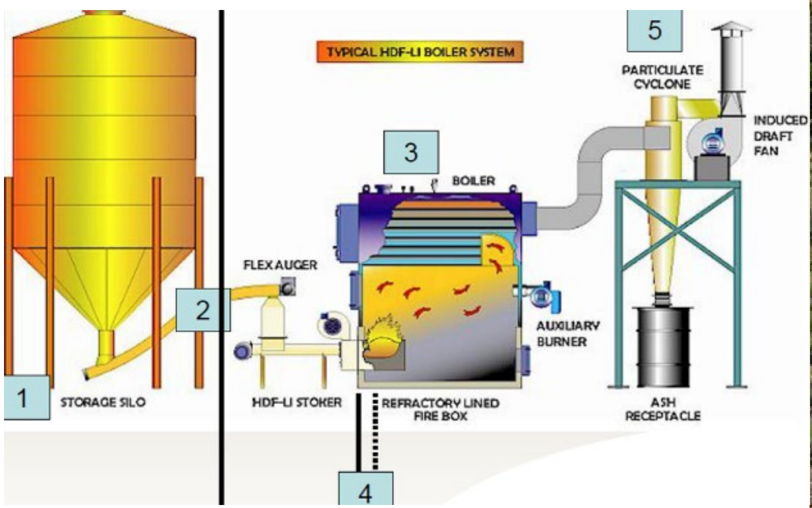

Lift
Drag


wind.energy.gov
Blades
Rotor
Low-speed shaft
Pitch system
Gear box
Controller
Anemometer
Brake
Wind direction
Yaw drive
Wind vane
Nacelle
Yaw motor
Tower
Generator
High-speed shaft

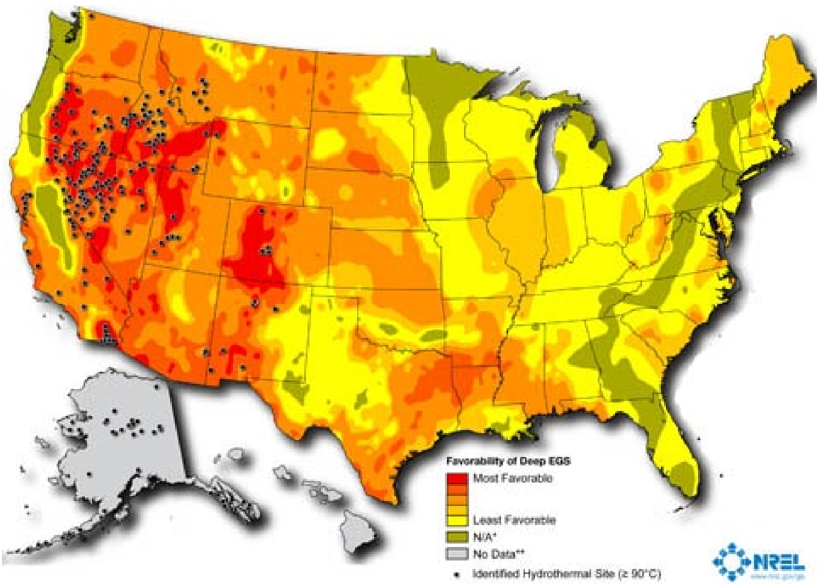
Biomass Energy

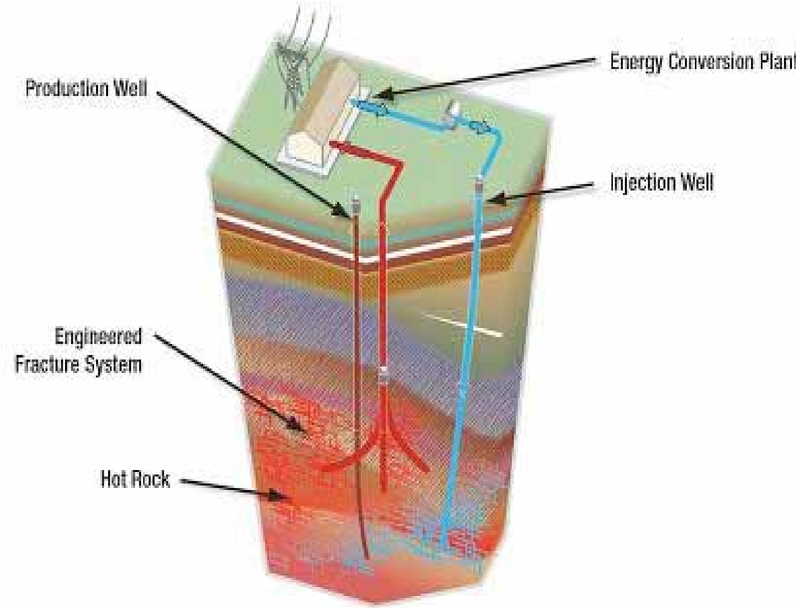


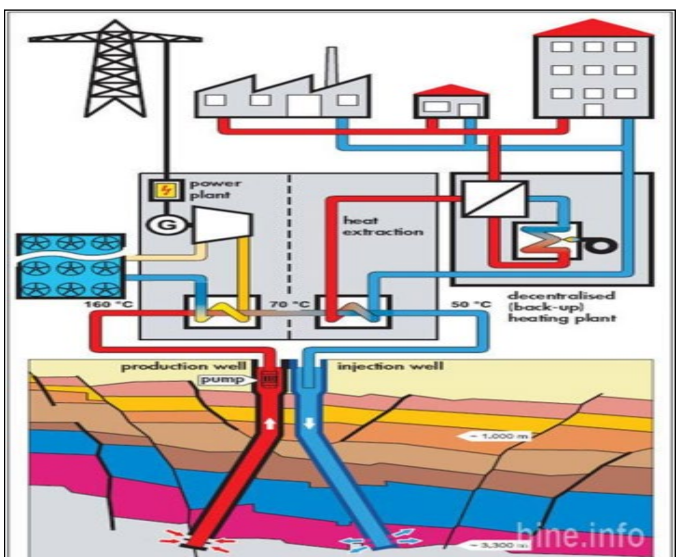




Geothermal Power







Definitions

- Capacity: rated power output (kW)
- CAPEX: Capital Cost per kW of Capacity ($/kW)
- Capacity Factor: CF=Annual Energy Delivery (kWh/year) /Capacity (kW) /Time (hours/year)
- LCOE: Levelized Cost of Energy; (Life Cycle Cost)/(Life Cycle Energy Production)

- The following graphs are CAPEX, CF, and LCOE from Annual Technology Baseline

https://atb.nrel.gov/electricity/2022/index

Return to Summ..

Technology
Multiple values

Parameter
CAPEX

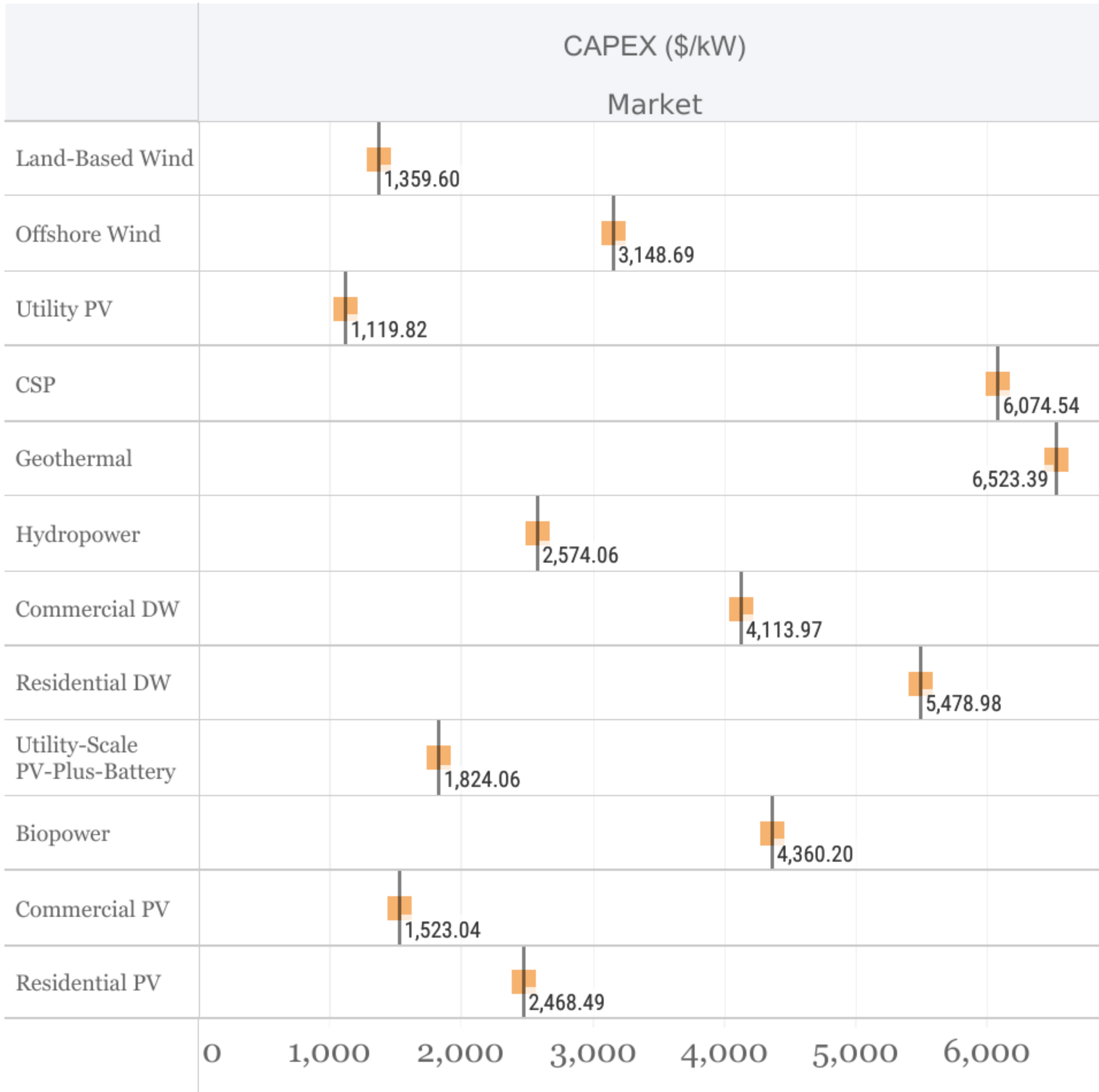
Scenario
Advanced
Conservative
Moderate

Case
Market
R&D

Cost Recovery Period
20 years

Year
2022

Default Technology De..



NREL

ATB data for technologies on the website: https://atb.nrel.g..

Return to Summ..

Technology
Multiple values

Parameter
CF

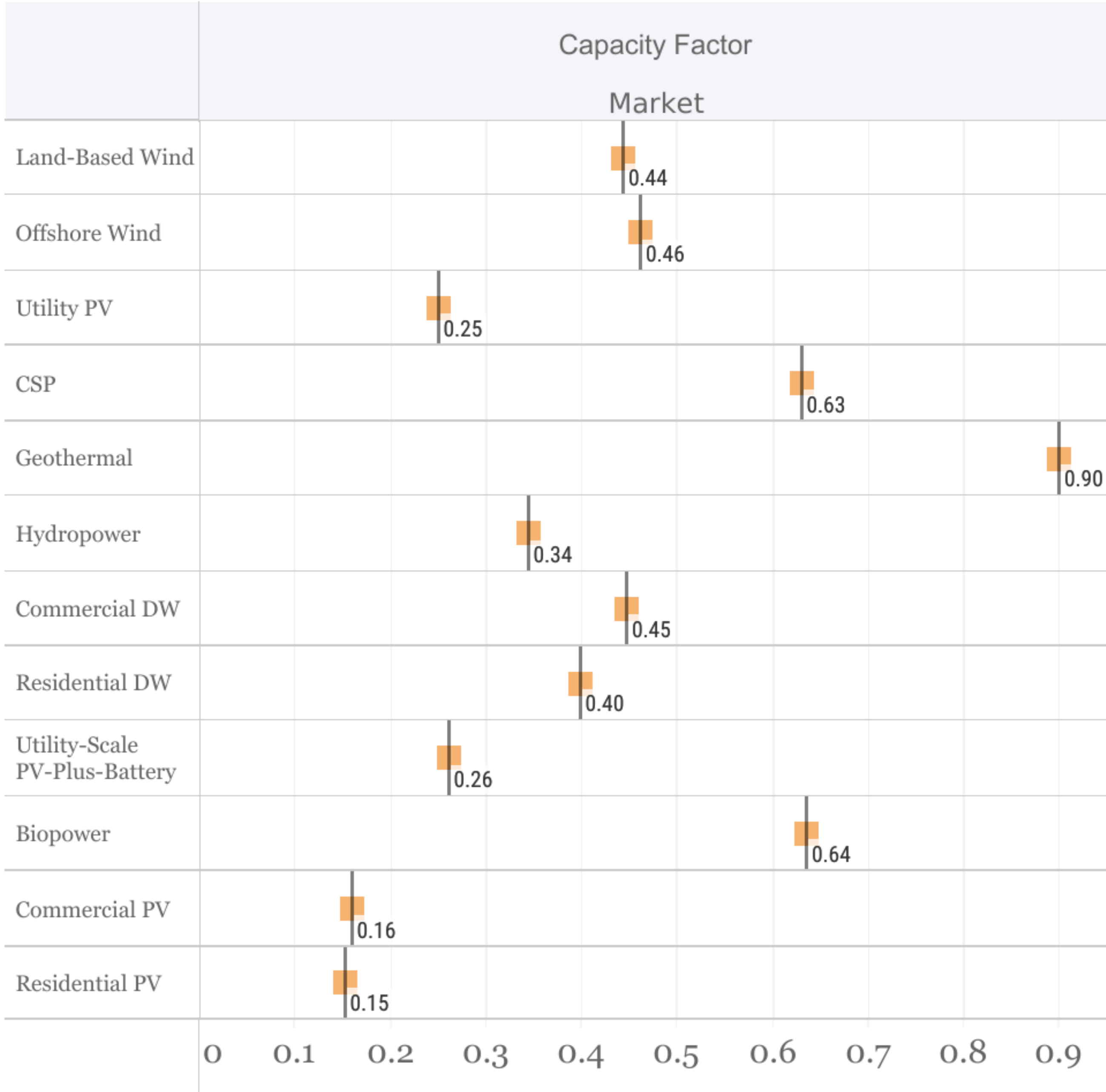
Scenario
- ◯ Advanced
- ◯ Conservative
- ◉ Moderate

Case
- ◉ Market
- ◯ R&D

Cost Recovery Period
20 years

Year
2022

Default Technology De..



NREL

ATB data for technologies on the website: https://atb.nrel.g..

Return to Summ..

Technology
Multiple values

Parameter
LCOE

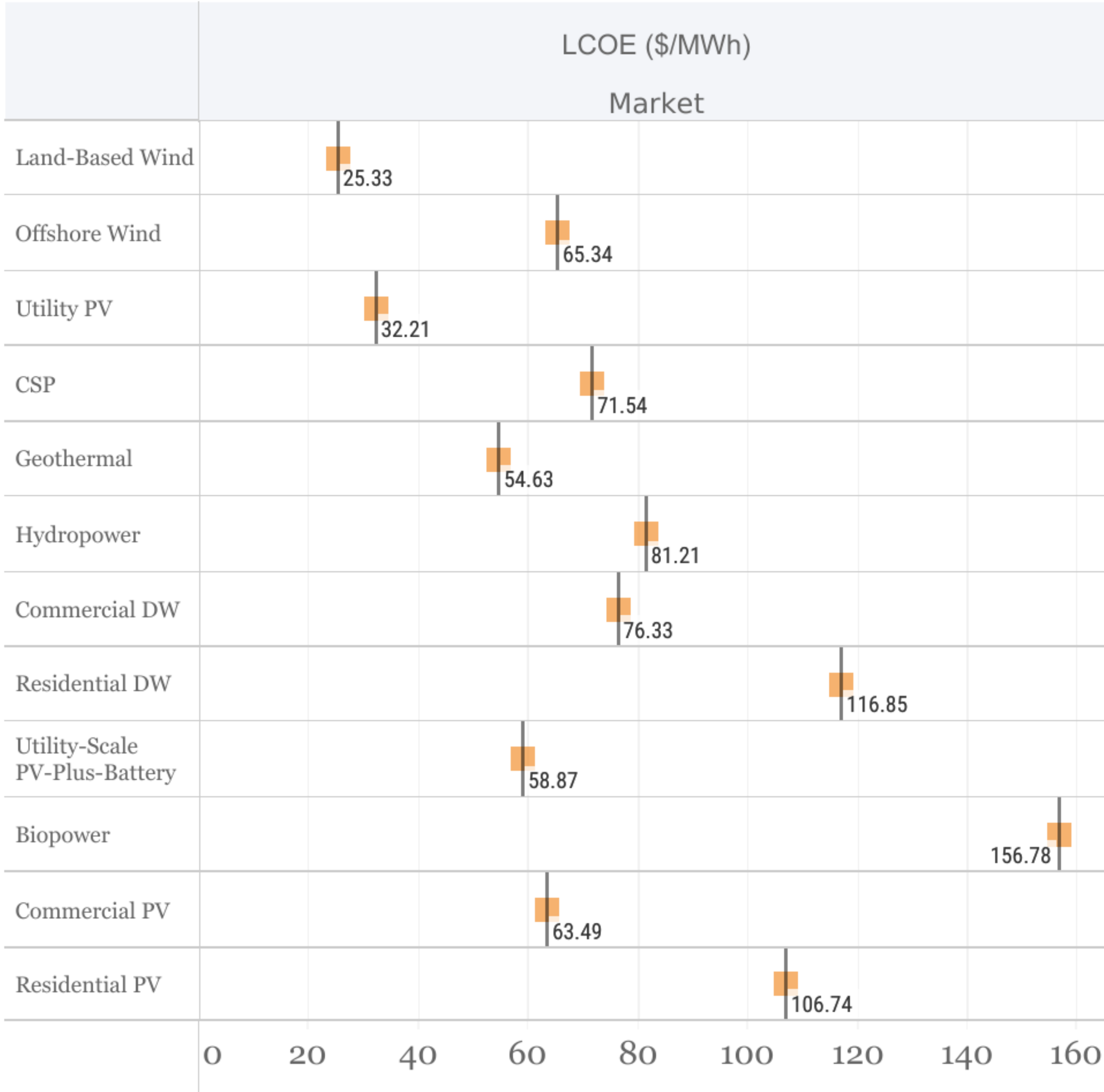
Scenario
◯ Advanced
◯ Conservative
◉ Moderate

Case
◉ Market
◯ R&D

Cost Recovery Period
20 years

Year
2022

Default Technology De..



NREL

ATB data for technologies on the website: https://atb.nrel.g..

Leading States for Each RE Technology

Hydropower
1 Washington
2 California
3 Oregon
4 New York
5 Alabama

Wind
1 Texas
2 Iowa
3 Oklahoma
4 California
5 Kansas

Solar PV[1]
1 California
2 North Carolina
3 Arizona
4 Massachusetts
5 New Jersey

Biomass Energy
1 Florida
2 California
3 Virginia
4 Georgia
5 Maine

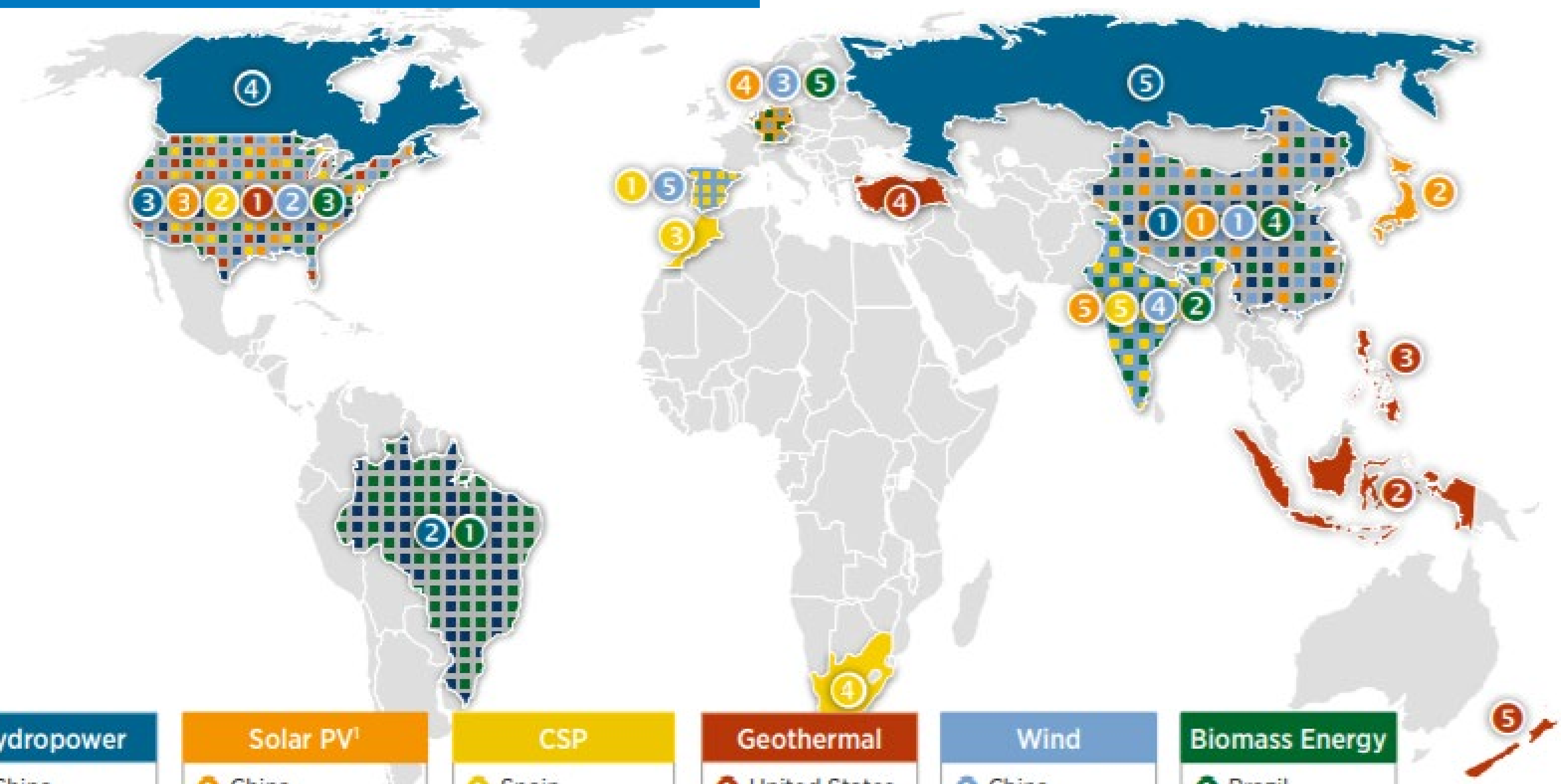
Geothermal
1 California
2 Nevada
3 Utah
4 Hawaii
5 Oregon

CSP
1 California
2 Arizona
3 Nevada

Sources: EIA, LBNL, and SEIA/GTM

https://www.nrel.gov/docs/fy20osti/75284.pdf

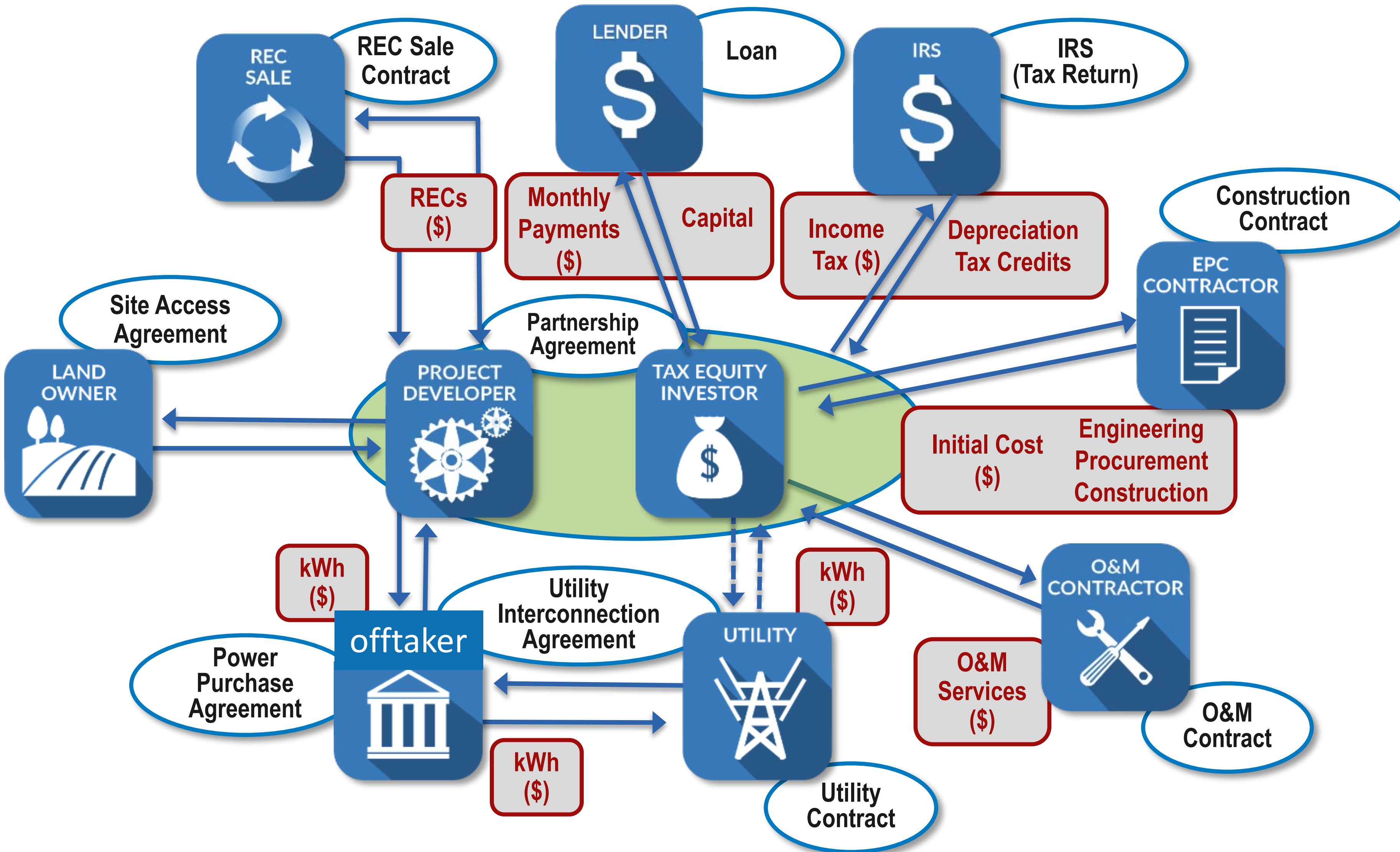
Leading Countries



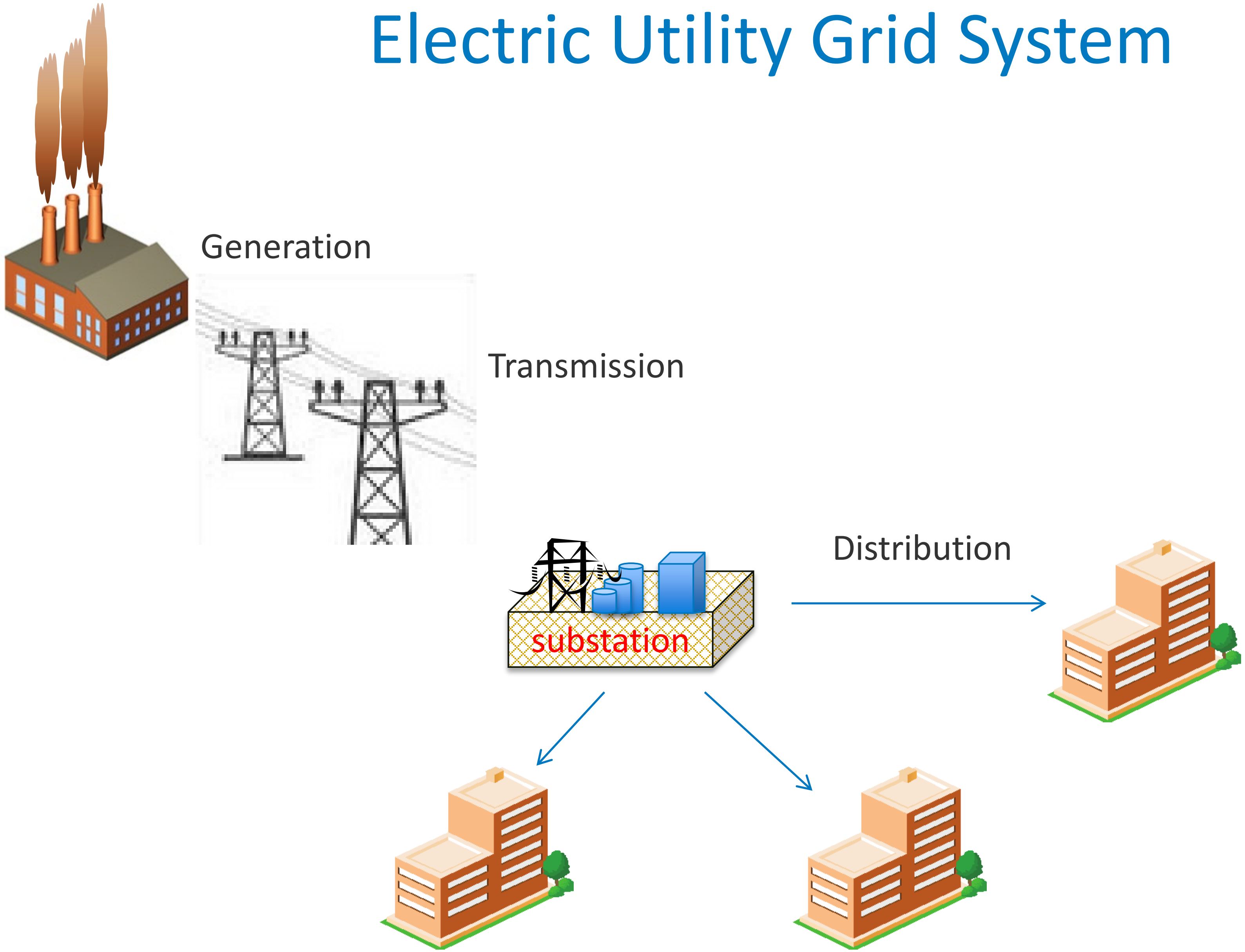
Hydropower	Solar PV[1]	CSP	Geothermal	Wind	Biomass Energy
1 China	1 China	1 Spain	1 United States	1 China	1 Brazil
2 Brazil	2 Japan	2 United States	2 Indonesia	2 United States	2 India
3 United States	3 United States	3 Morocco	3 Philippines	3 Germany	3 United States
4 Canada	4 Germany	4 South Africa	4 Turkey	4 India	4 China
5 Russia Fed	5 India	5 India	5 New Zealand	5 Spain	5 Germany

https://www.nrel.gov/docs/fy20osti/75284.pdf

Economic Feasibility



Electric Utility Grid System



Energy Systems Integration

Building Level

- Sizing of Electrical System to Building
- Overcurrent Protection on Electrical Service
- Voltage Regulation
- Reactive Power, power factor

Substation Level

- Substation bus arrangement, intertie
- Network Protectors in Network Systems

Grid level

- Line Capacity; Balancing Areas
- Voltage Stability of Electric Grid

Generation

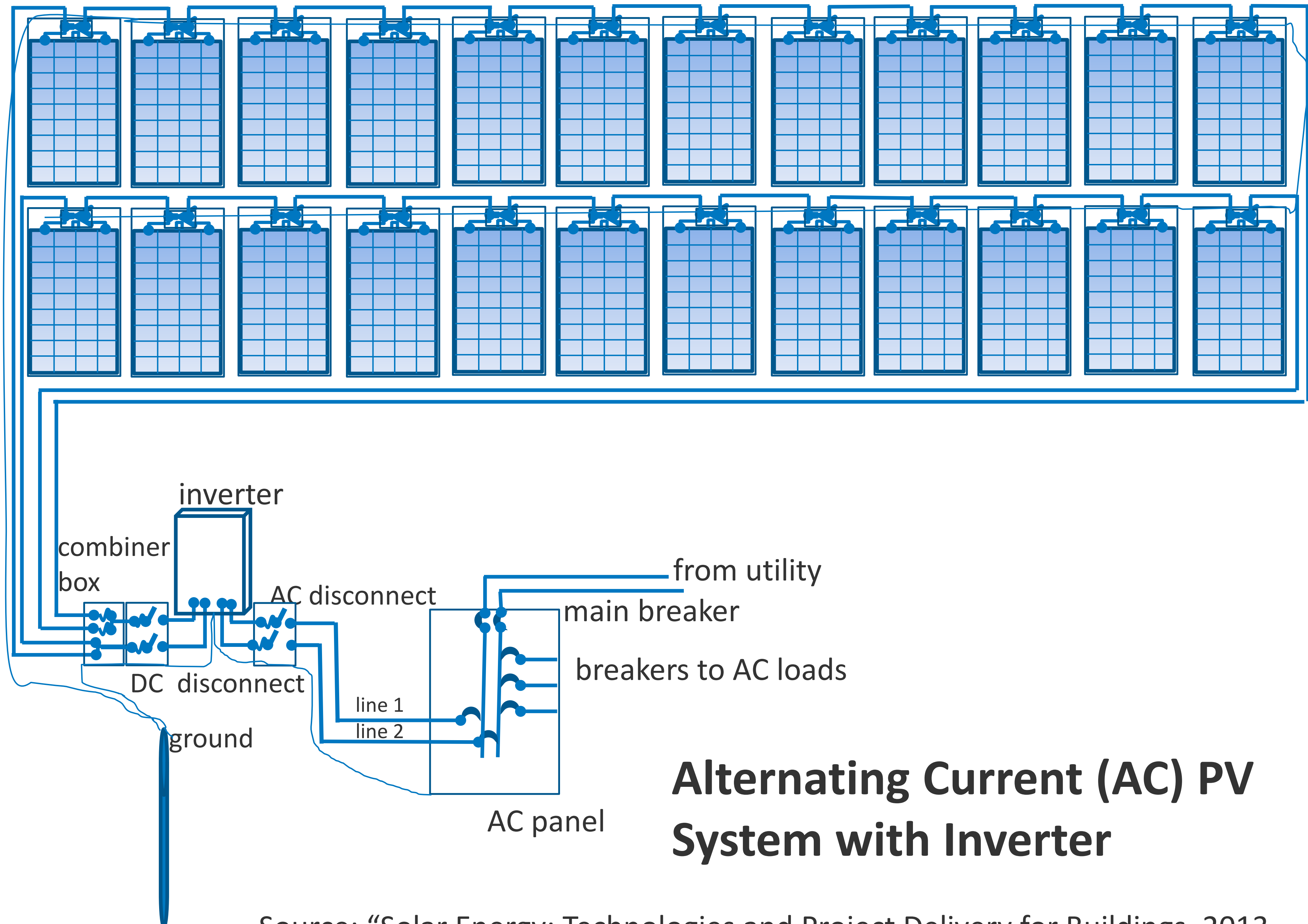
- Spinning Reserve
- Ramp Rates

Utility and Social Economics

- Allocating Utility Costs and Resources
- Investment and Employment Opportunities
- Siting and Environmental Justice

<u>Old obsolete goals:</u>
MWh Annual RE production
“Net” Zero Annual Energy Use

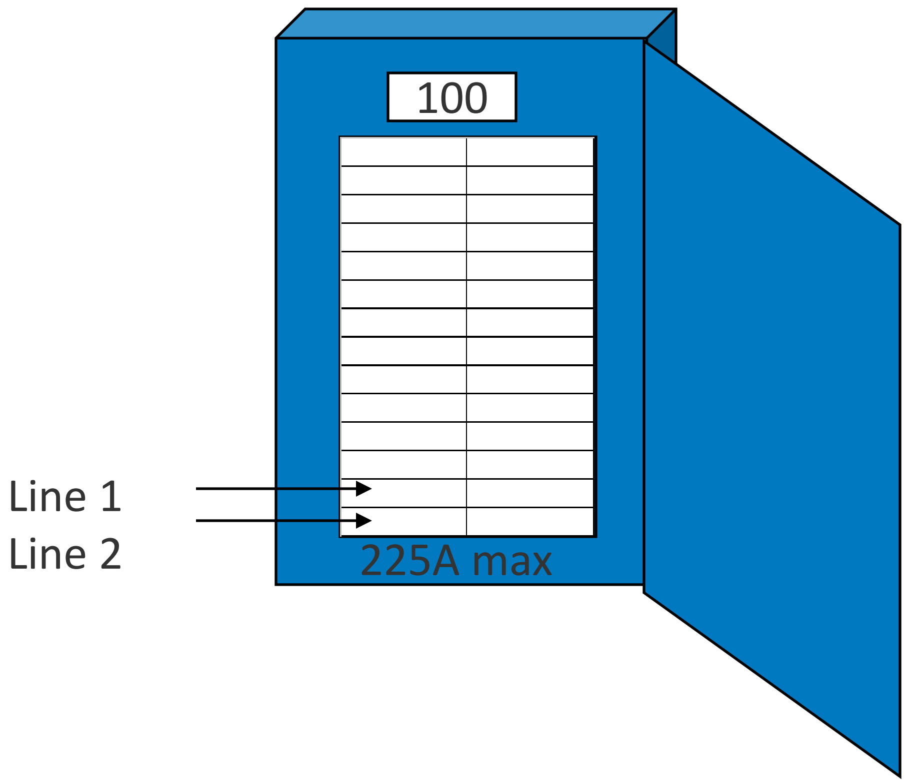
<u>New goals:</u>
Minimize site- and location-specific utility cost and environmental impacts (utility circuit; time-of-day; day-of-year)



Alternating Current (AC) PV System with Inverter

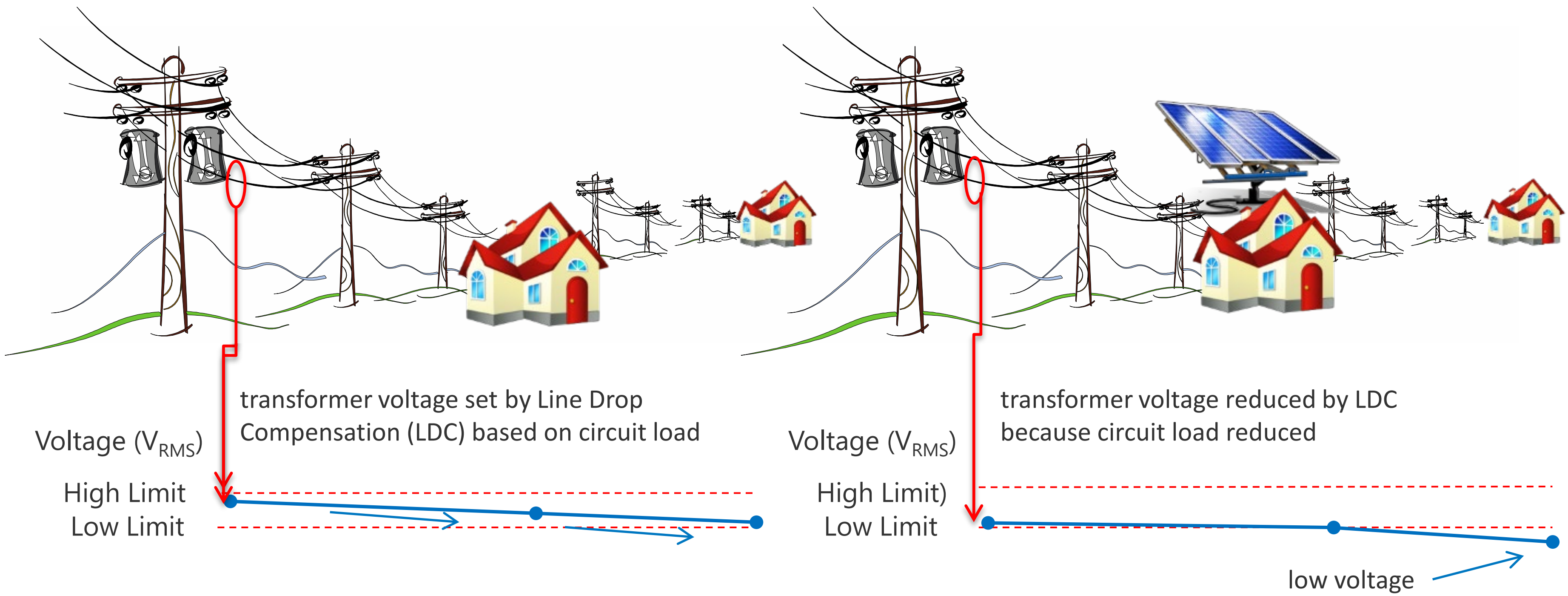
Source: “Solar Energy: Technologies and Project Delivery for Buildings, 2013

Challenge: Utility Interconnection- Point of Interconnection



- **Backfeed Breaker in Building Panel (Main Breaker and PV breaker< 120% of panel rating for commercial building**
- **PV too big?**
  - Survey Loads and reduce main breaker rating
  - Upgrade Panel
  - Line-side-tap
  - Upgrade Electrical Service
  - Controls to curtail PV output to not exceed limit

Challenge: Voltage Regulation

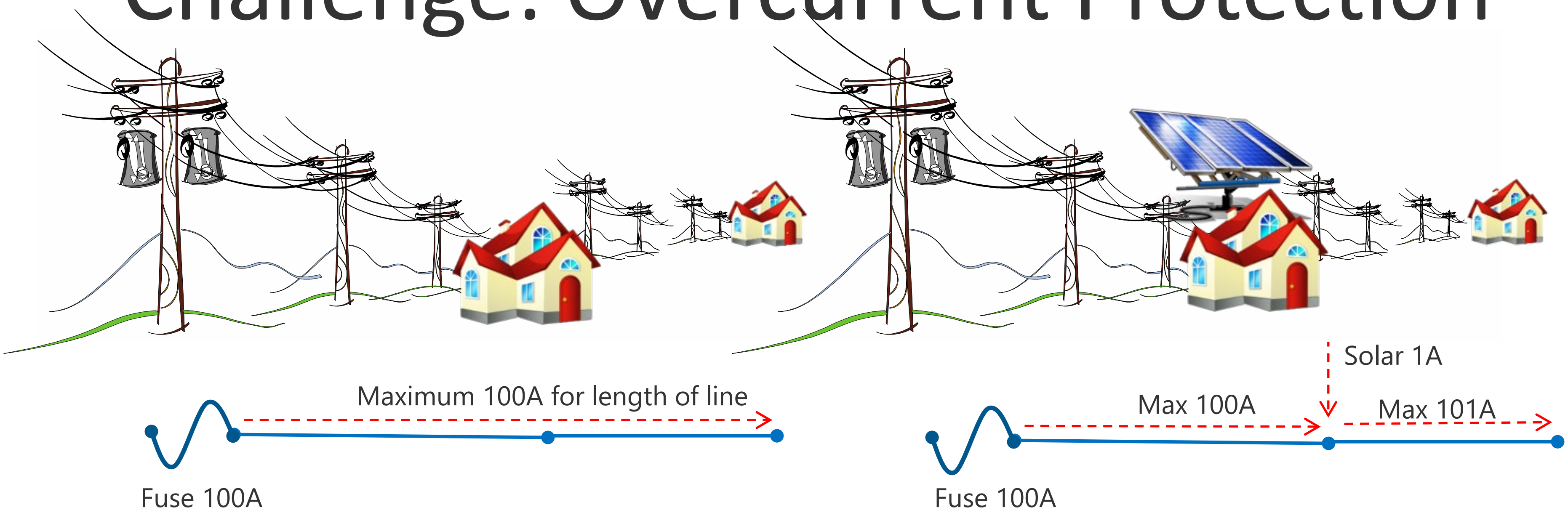


Intermittent PV on the distribution system can affect the existing voltage regulation scheme based on Line Drop Compensation, which does not actually measure voltage at loads

Hierarchy of Solutions

- Adjust voltage setting of LDC
- Adjust delay setpoints of LDC
- Replace old LDC system with new control system based on measured voltage (Smart Meters; SCADA system)
- Voltage Regulators to actively adjust local voltage

Challenge: Overcurrent Protection

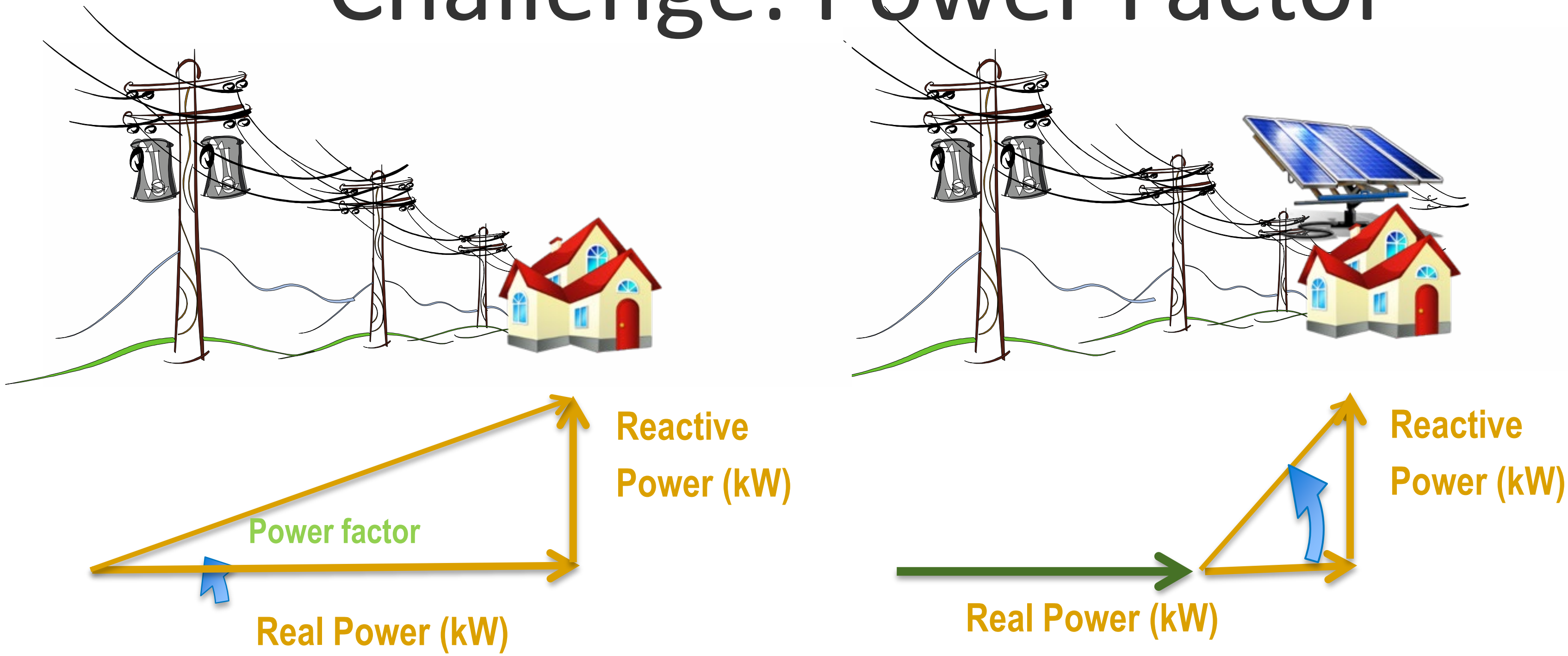


Overcurrent Protection: A generator on the distribution system can defeat the existing overcurrent protection scheme.

Hierarchy of Solutions

- Survey loads and reduce rating of transformer fuse so not exceed line rating (amps)
- Replace line to accommodate new amount of current required.

Challenge: Power Factor



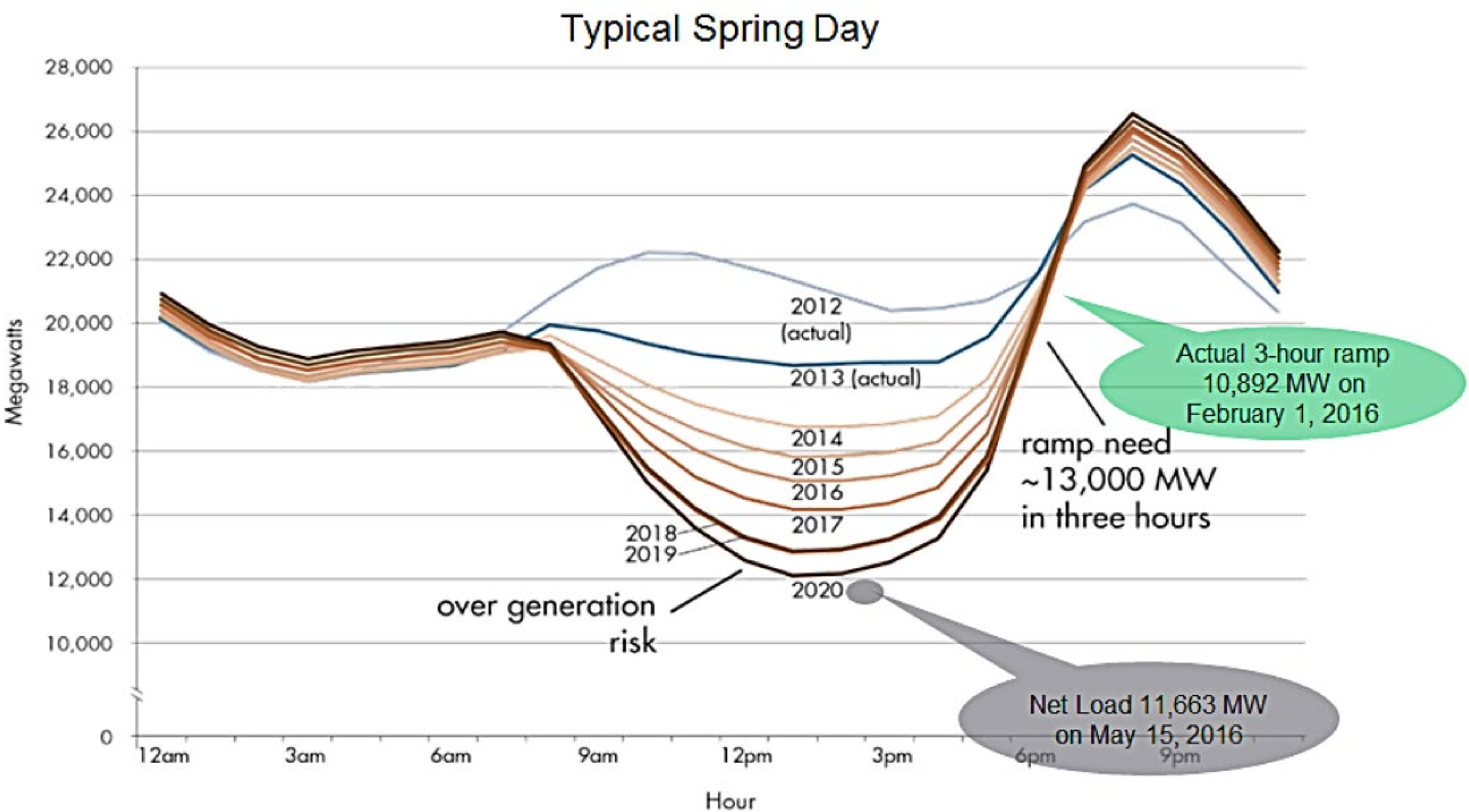
Power Factor: By delivering only real power, a generator on the distribution system can worsen the power factor seen by the utility

- New features with IEEE 1547:
  - VAR Control: Non-Unity Power Factor
  - Low Voltage Ride Through
  - Dynamic Control
    - Ramp rate and curtailment of real power
    - Communication allows PV to be part of the utility system

Challenge: Impacts on Generation

- Savings in cost and emissions depend on
  - Baseload Generator
    - Coal, nuclear
  - Peaking Generator
    - Gas turbine
- Ramp rates and turn-down limits
- Spinning Reserve
  - Unloaded but spinning generator uses fuel and per-run-time maintenance
  - Without solar, spinning reserve provides for fluctuations in the load
  - With solar, spinning reserve must cover BOTH fluctuations in the load and in the solar resource AT THE SAME TIME

Figure 2: The duck curve shows steep ramping needs and overgeneration risk



https://www.caiso.com/Documents/FlexibleResourcesHelpRenewables_FastFacts.pdf

Challenge: Utility Bill Details

16 **Electric**			
Meter - 012345678	**Duke Energy** 17		
	Rate DS01 - Distribution Service		
Multipliers - 160			
kWh Usage - 19,200	Distribution-Customer Chg	$ 40.00	
Demand Read - 00.28	Delivery Charges		
Actual kW - 44.80	Distribution-Demand Chg		
	57.12 kW @ $4.68480000	267.60	
Billed kW - 57.12 *	Delivery Riders	195.22	
	Total Delivery Charges	$ 462.82	
Jan 03 - Feb 01	Generation Charges		
29 Days	Generation Riders	157.05	
	Total Generation Charges	$ 157.05	659.87
	Alternative Electric Supplier 18		
* Based on 85% of Previous Maximum Actual Demand of 67.20 kW Billed in Aug 11.	Rate DE29 - Alternative Electric Supplier		
	Supplier Energy Charge		
	19,200 kWh @ $0.05490000	$ 1,054.08	1,054.08
	Total Current Electric Charges		**$ 1,713.95** 19

Ratchet on Demand

Customer charges

Demand charges (usually not on a residential bill)

Energy charges

- Energy (c/kWh)
- Demand ($/kW/month)
- Time of Use (higher in day), Seasonal (higher in summer)
- Demand Ratchet
- Fixed customer charges and other riders

Source: Duke Energy, "Understanding your utility bill: a guide for businesses in Ohio. http://www.duke-energy.com/pdfs/Understand-Bill-Guide-OH-WEB.pdf

Utility Economic Concerns

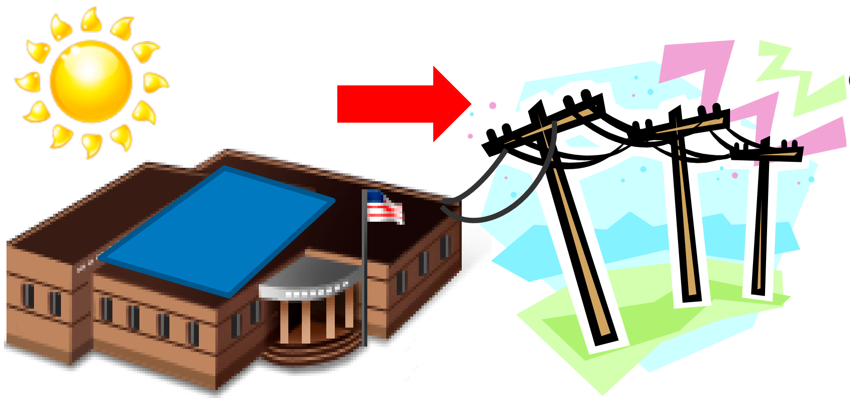
- Renewable Energy must be evaluated in terms of:
  - Impact on utility revenue (reduced energy sales)
  - Impact on utility costs (fuel savings, deferred investment)

- Solutions: disaggregate blended rate ($/kWh) so that customers with distributed renewable energy pay for the utility services that they use on a daily basis
  - Fixed Charges ($/month)
  - Demand Charges ($/kW)
  - No net metering (retail rate versus buy-back rate)
  - Stand-by charges

Social Issues, Energy Equity and Justice

- Business case for RE is a large capital investment returned by utility cost savings or power-sales revenue
- Low-income communities may lack
  - Large amounts of money to invest in on-site RE
  - Tax liability to monetize tax credit and depreciation
  - Ownership or right to improve the property
- Policies that incentivize RE can reduce a utility bill to nearly zero, leaving non-RE customers to pay more for utility operations
- Solutions such as "Community Solar" may enable low income communities to benefit from distributed renewable energy projects.
- Operation and Maintenance of distributed renewable energy is necessarily local and an employment opportunity for disadvantaged communities.

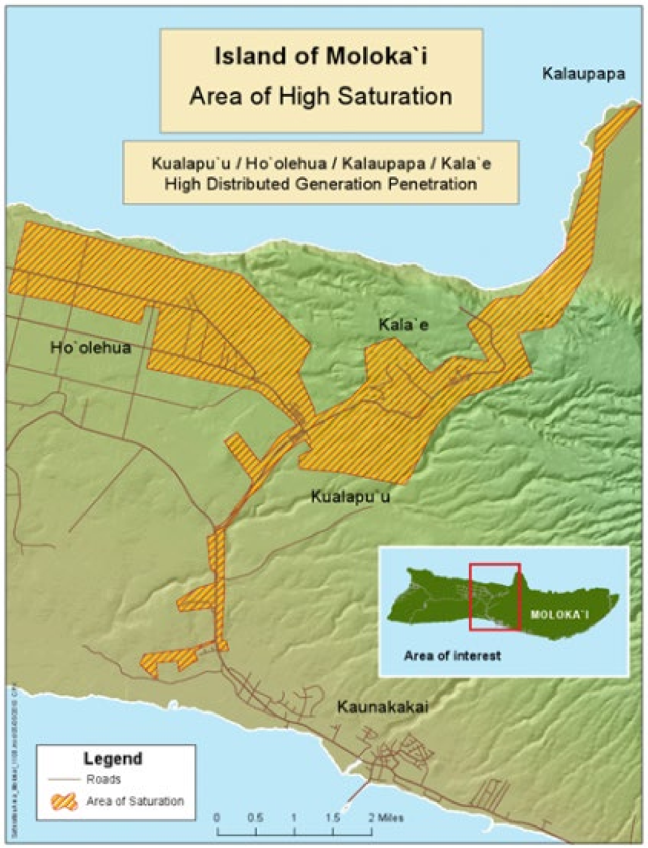
“Net Metering”



- Solar Power in excess of the Load flows TO Utility
- Load in excess of Solar Power flows FROM Utility
- Utility Bill is calculated on the “net” difference between the two on a monthly or yearly basis

"Net Metering"

- Benefits of Net Metering include utility fuel savings and possible deferred investment in infrastructure to serve growing load



- Problems with Net Metering
  - Limits to Fuel Savings (spinning reserve)
  - Doesn't save any other utility operating costs
  - RE may be curtailed; limits on installations (e.g. 15% in HI) [*Hawaii has eliminated net metering*]
  - Socio-economic problem: foists utility costs on those least able to afford it.
- Utility Cost Recovery
  - Retail/buy-back spread (c/kWh)
  - Stand-by Charges ($/kW/month)

Strategies for Increasing amounts of Variable Renewable Energy Generation on the Utility Grid

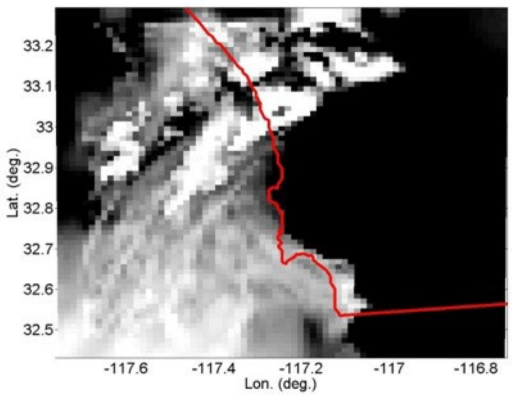
- Reconfigure circuits, network protectors, voltage regulation, and overcurrent protection
- Distribute PV over a larger geographical area to smooth cloud cover
- Tracking mounts and different PV orientations to smooth daily delivery
- Advanced inverter features
  - Low voltage ride-through
  - Low frequency ride-through
  - Power-factor correction
  - Curtail RE output
- Forecasting of RE plant output

- Control of demand for non-critical loads, Electric Vehicle Charging, Hydrogen production
- Energy Storage
- Evolving ways for utility companies and regulators to allocate cost of operating the utility system

Improved Forecasting of Performance

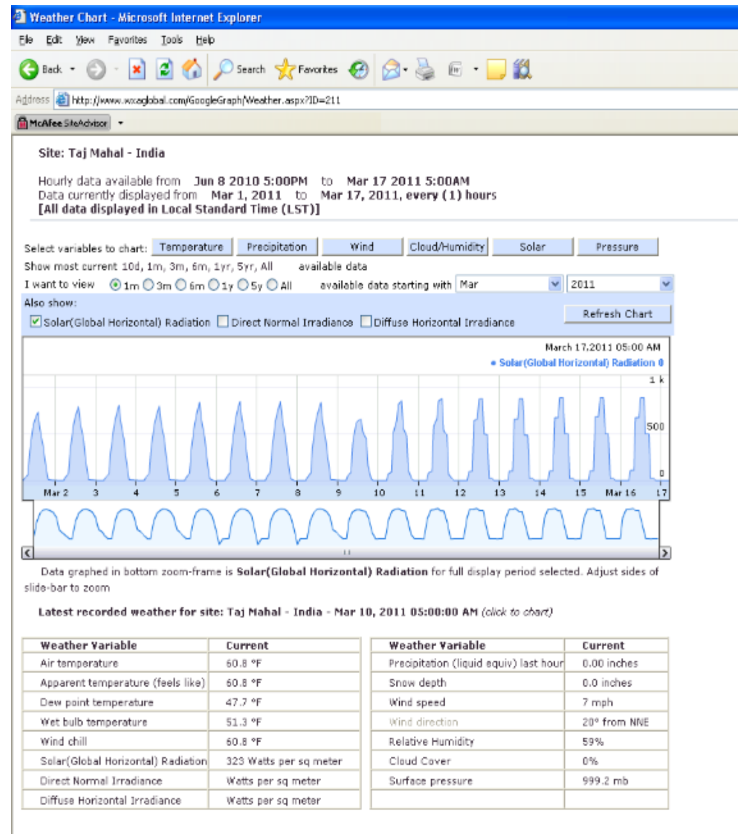
1) Astronomical Forecast: time-of-day; day-of-year; latitude; (well-known)
2) Weather Forecast

Modeling



Sky Imaging

Weather Forecast Data



Weather Variable	Current	Weather Variable	Current
Air temperature	60.8 °F	Precipitation (liquid equiv) last hour	0.00 inches
Apparent temperature (feels like)	60.8 °F	Snow depth	0.0 inches
Dew point temperature	47.7 °F	Wind speed	7 mph
Wet bulb temperature	51.3 °F	Wind direction	20° from NNE
Wind chill	60.8 °F	Relative Humidity	59%
Solar(Global Horizontal) Radiation	323 Watts per sq meter	Cloud Cover	0%
Direct Normal Irradiance	Watts per sq meter	Surface pressure	999.2 mb
Diffuse Horizontal Irradiance	Watts per sq meter		

172 hour forecast example
http://weatheranalytics.com/renewableforecast.html

Demand Control

Examples of non-critical loads

- irrigation
- air conditioning
- water heating

Small loads networked together and controlled to aggregate demand reduction

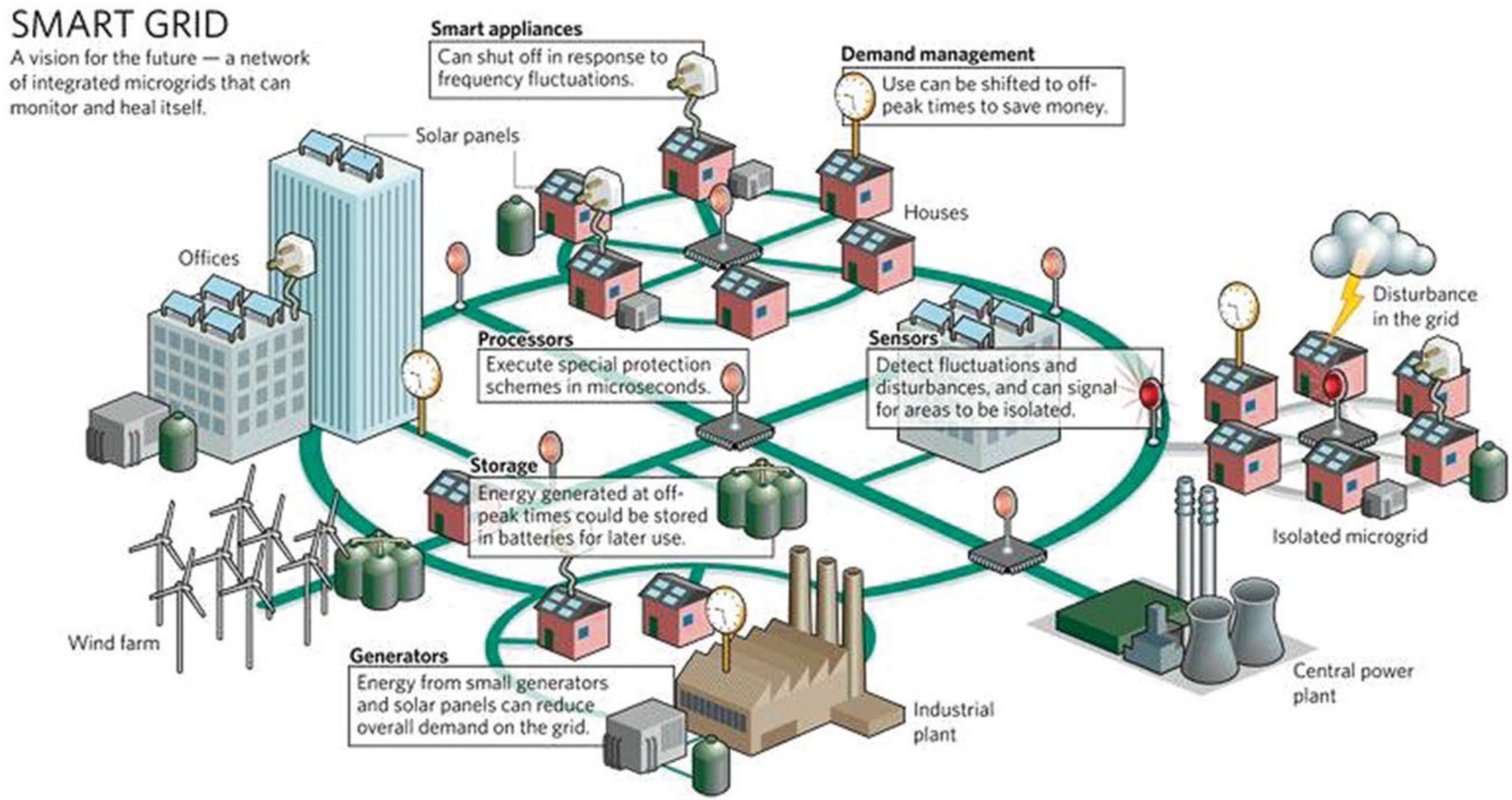
- internet or radio control

“Negawatts” bid into power market like a generator

Storage

- Couple intermittent RE generation with load
- Consider forecasting and demand control first
- Consider non-electric storage such as:
  - store treated potable water or store water to be pumped or treated
  - store chilled water or ice for air conditioning
- Batteries cost around $400/kWh, but economy of scale and technology could reduce to $150/kWh
- Safety and environmental concerns

Smart Grid!



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Thank You!

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