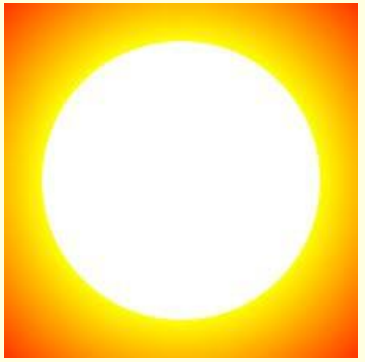
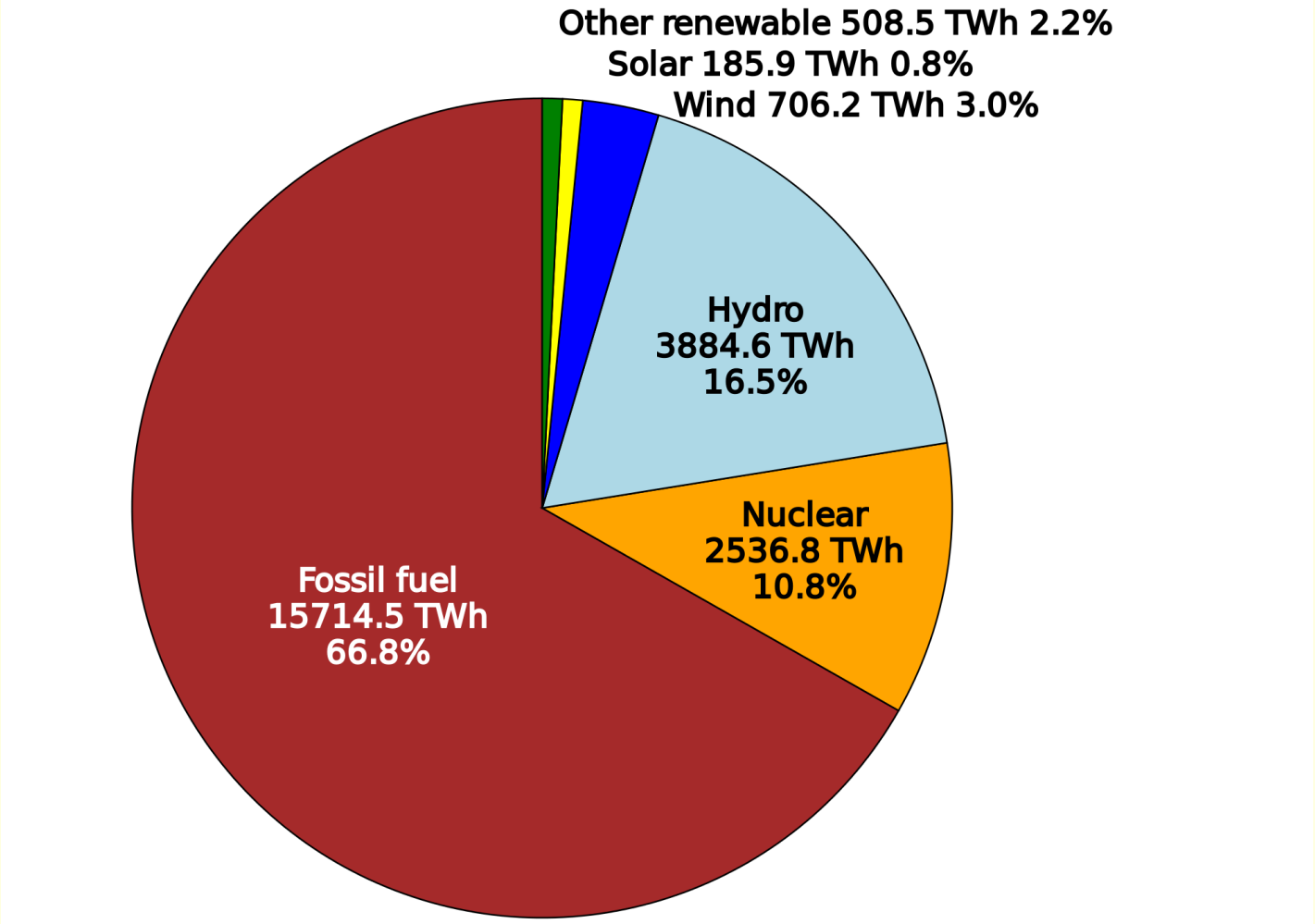
Renewable Energy Resources – an Overview Part I



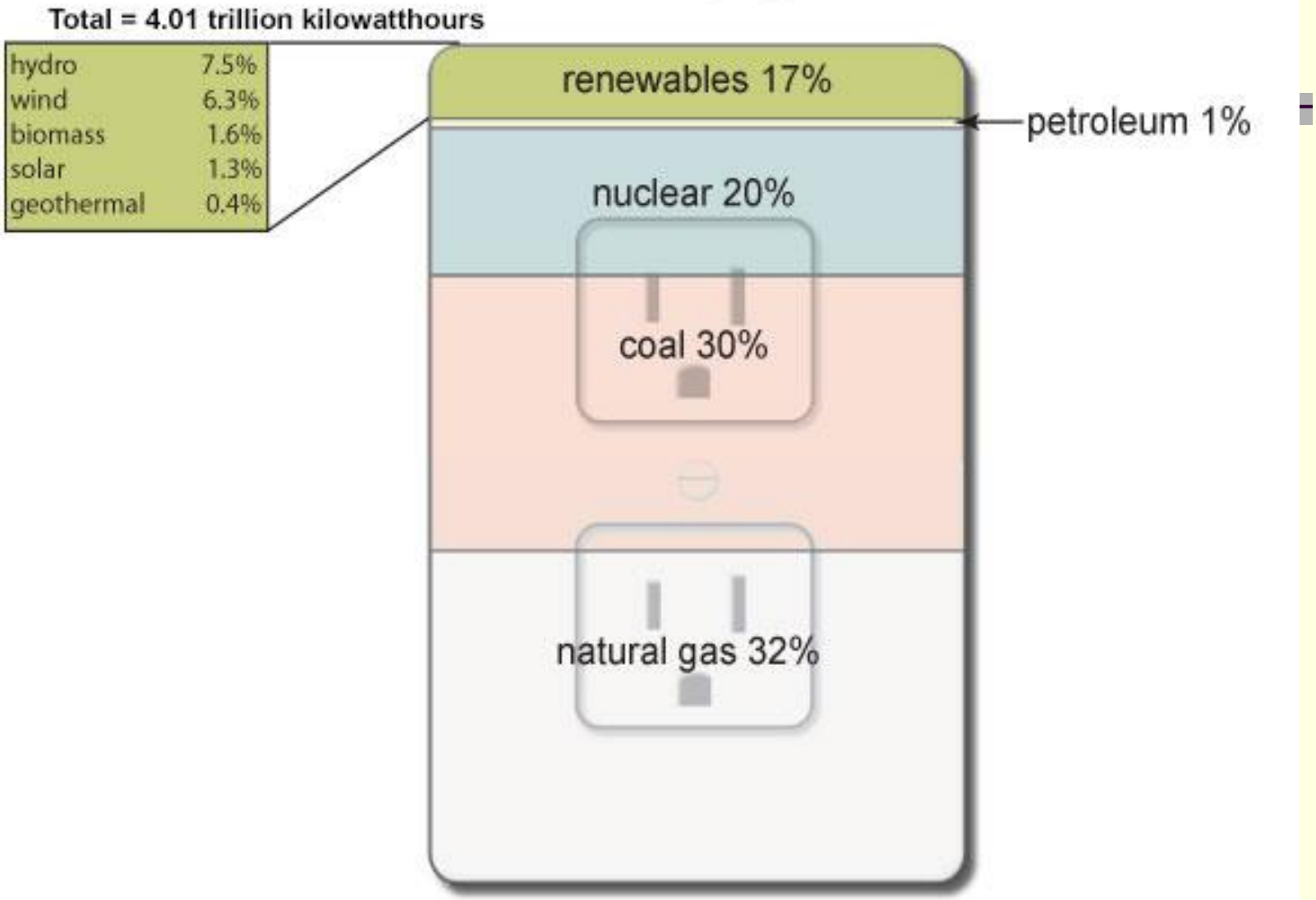
Y. Baghzouz
Professor of Electrical Engineering

World Electricity Generation by Source (2015)



Source: US Energy Information Administration (EIA)

US Sources of Electricity Generation, 2017



Note: Electricity generation from utility-scale facilities.

Source: U.S. Energy Information Administration, *Electric Power Monthly*, February 2018, preliminary data

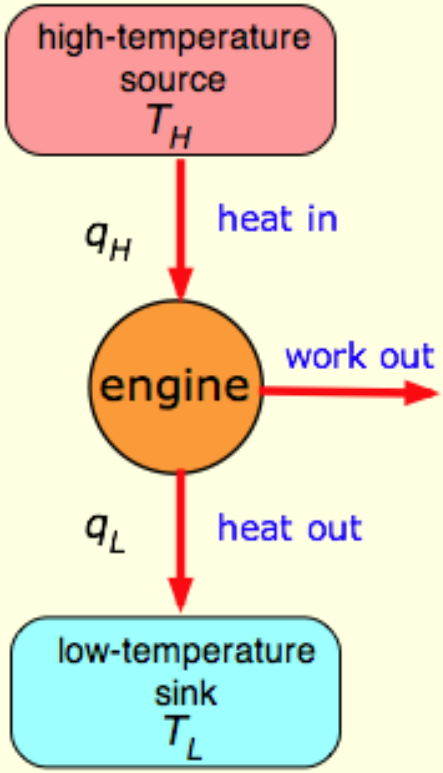
US Sources of Electricity Generation, 2018

U.S. electricity generation by source, amount, and share of total in 2018[1]		
Energy source	**Billion kWh**	**Share of total**
Total - all sources	4,178	
Fossil fuels (total)	2,651	63.5%
Natural gas	1,468	35.1%
Coal	1,146	27.4%
Petroleum (total)	25	0.6%
Petroleum liquids	16	0.4%
Petroleum coke	9	0.2%
Other gases	12	0.3%
Nuclear	807	19.3%
Renewables (total)	713	17.1%
Hydropower	292	7.0%
Wind	275	6.6%
Biomass (total)	63	1.5%
Wood	41	1.0%
Landfill gas	11	0.3%
Municipal solid waste (biogenic)	7	0.2%
Other biomass waste	3	0.1%
Solar (total)	67	1.6%
Photovoltaic	63	1.5%
Solar thermal	4	0.1%
Geothermal	17	0.4%
Pumped storage hydropower[3]	-6	-0.1%
Other sources	13	0.3%

Source: https://www.eia.gov/tools/faqs/faq.php?id=427&t=3

Efficiency of Heat Engines

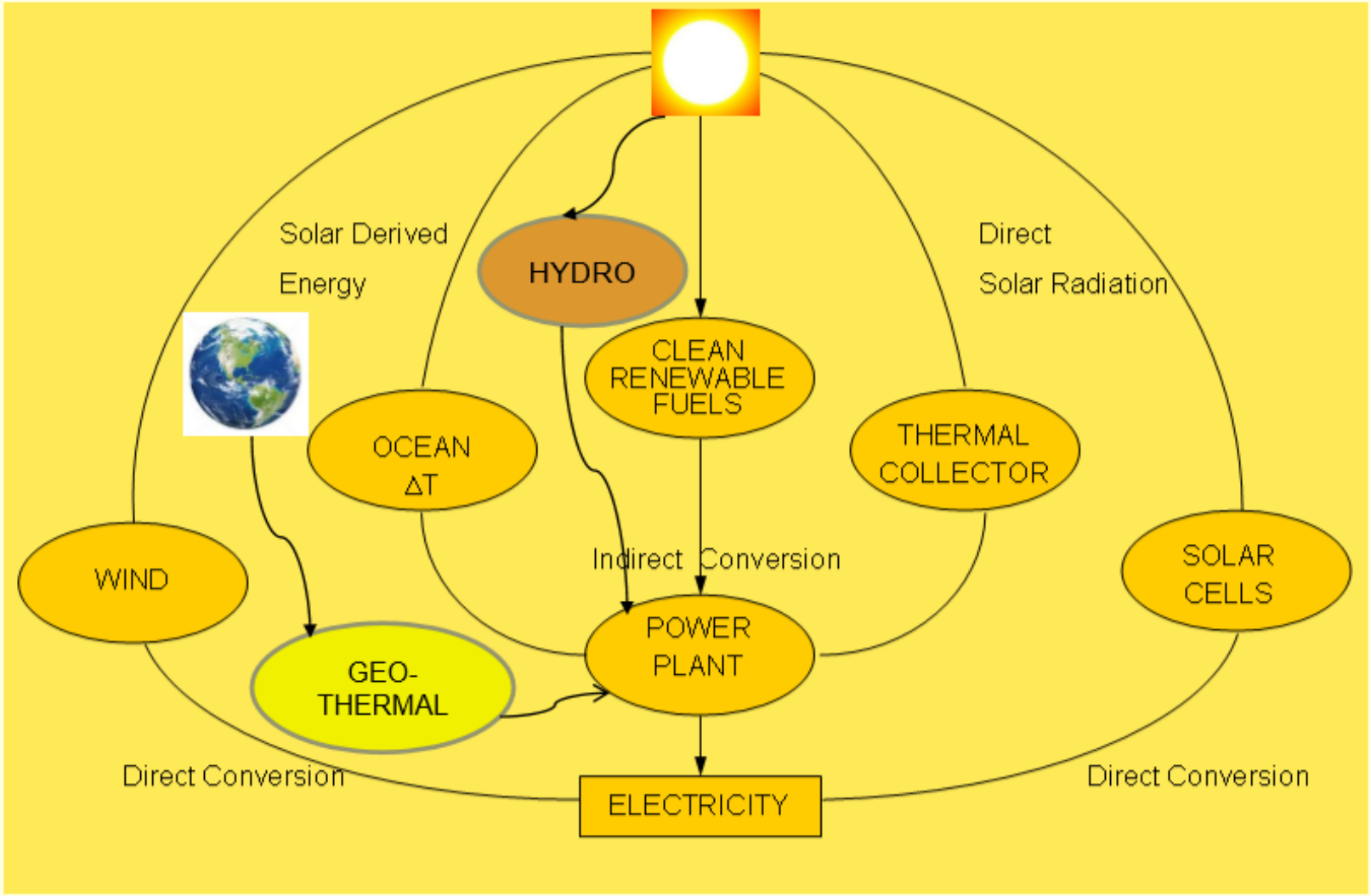
- Note that nearly 80% of the US electricity is generated in power plants that convert heat into mechanical power.
- A heat engine extracts heat q_H from a high-temperature source, converts part of it into work w, and rejects the remaining heat q_L into a low-temperature sink.
- Thermal efficiency $= \frac{q_H - q_L}{q_H} = \frac{w}{q_H}$
- Maximum possible efficiency $= \frac{T_H - T_L}{T_H}$ (where T is in ^oK)
- The average thermal efficiency of a thermal power plant is around 30%, while the maximum possible (Carnot) efficiency is nearly double this amount.



Overview

- Solar-derived renewables
  - Photovoltaic (PV)
  - Concentrating Power Systems
  - Biomass
  - Ocean Power
  - Wind Power
  - Hydro Power
- Earth derived renewables
  - Geothermal

Electricity production from renewables

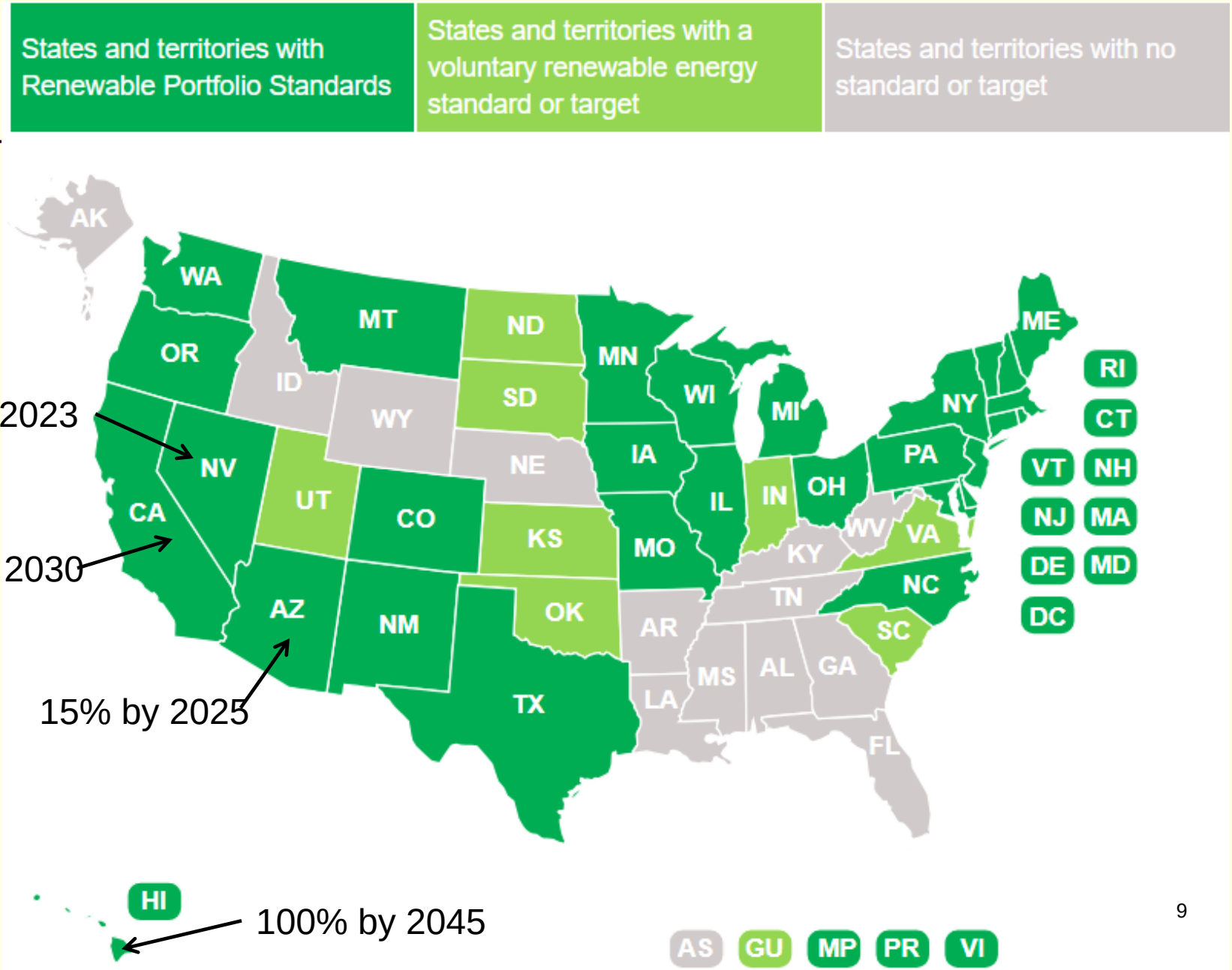


What is driving the fast growth?

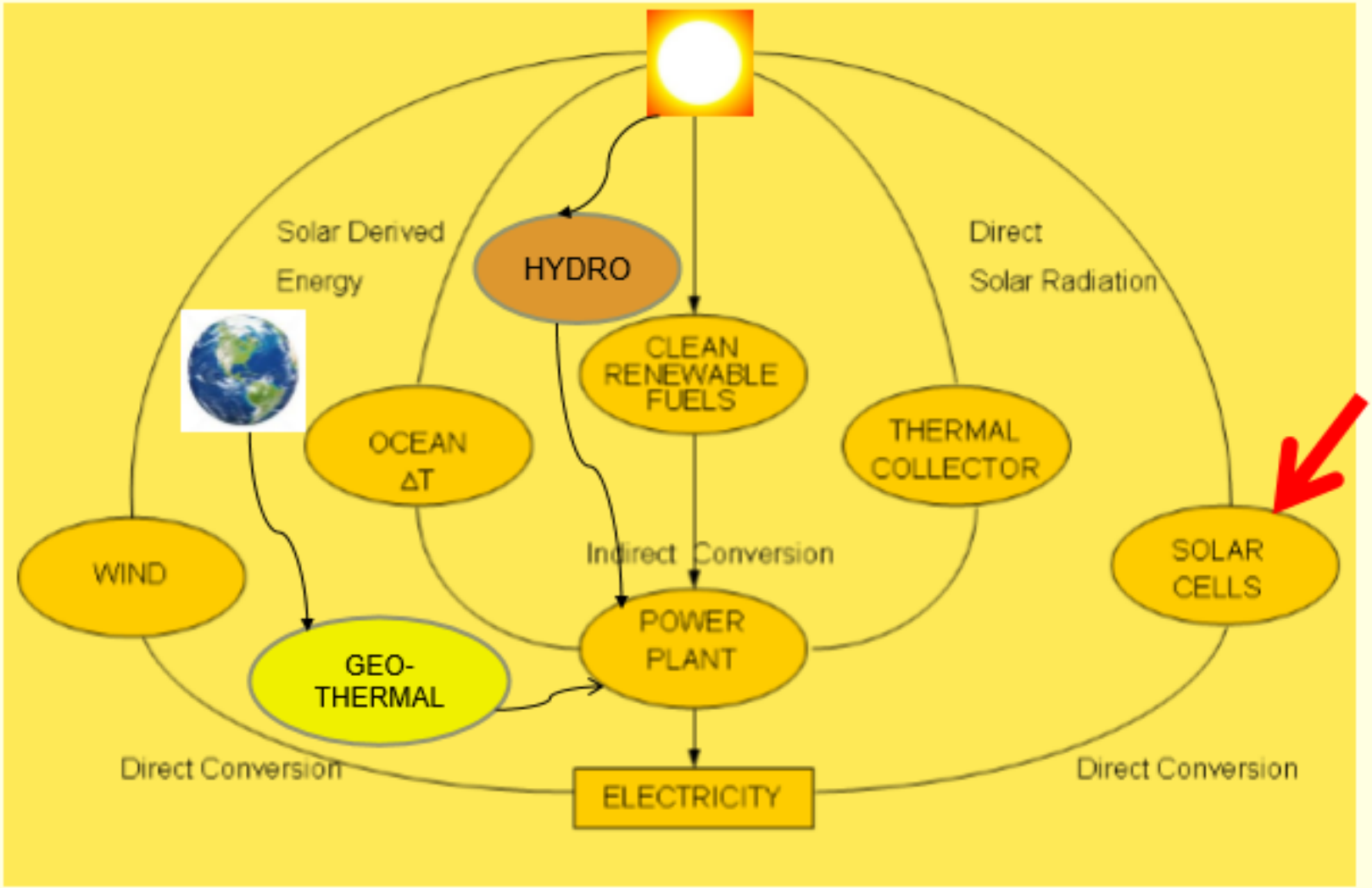
The growth in renewables over the past decade is driven mainly by the following:

- Global concern over the environment. Furthermore, fossil fuel resources are being drained.
- Renewable technologies are becoming more efficient and cost effective.
- The Renewable Electricity Production Tax Credit, a federal incentive, encourages the installation of renewable energy generation systems.
- Many countries have Renewable Portfolio Standards (RPS), which require electricity providers to generate or acquire a percentage of power generation from renewable resources.

States with RPS

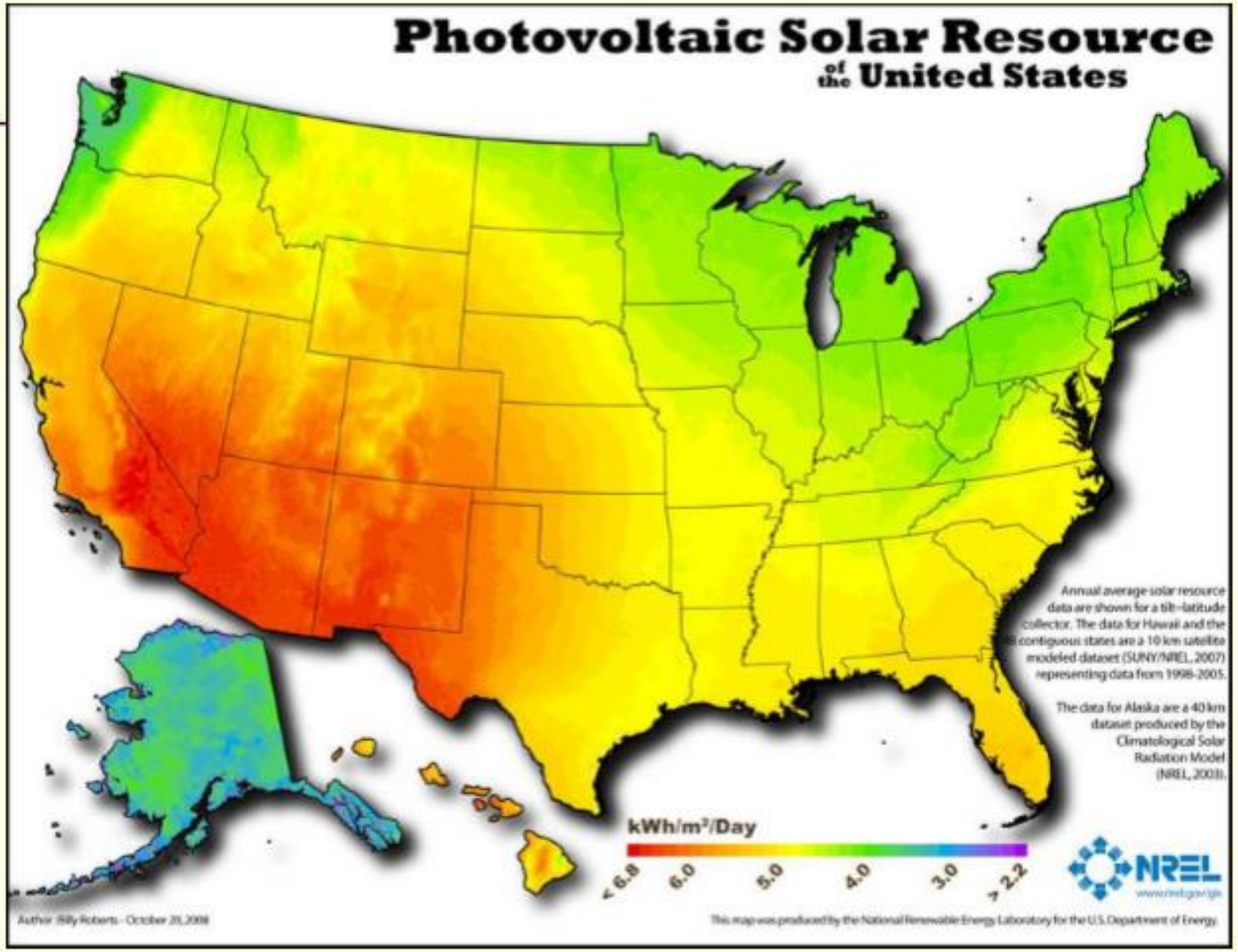


Electricity production from renewables



Primary Resource on Photovoltaics

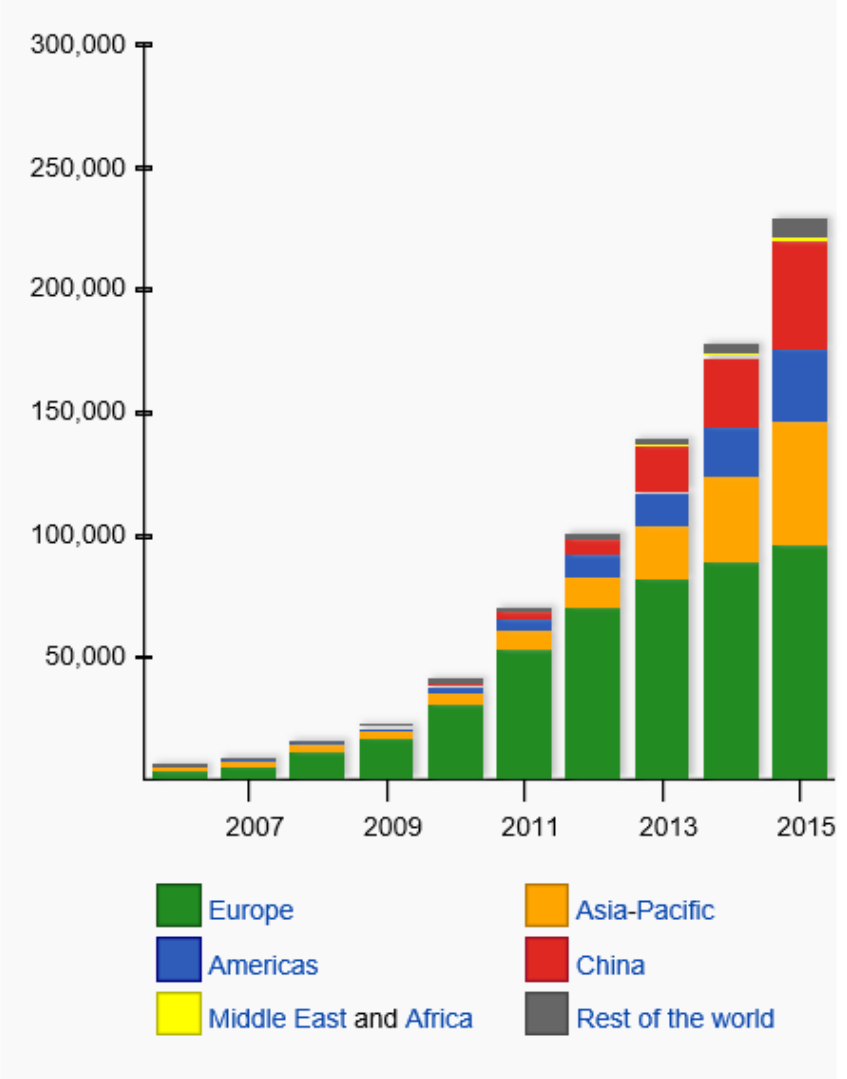
- https://www.energy.gov/articles/energy-101-solar-photovoltaics


Photovoltaic Solar Resource
of the United States
Annual average solar resource data are shown for a tilt=latitude collector. The data for Hawaii and the 48 contiguous states are a 10 km satellite modeled dataset (SUNY/NREL, 2007) representing data from 1998-2005.
The data for Alaska are a 40 km dataset produced by the Climatological Solar Radiation Model (NREL, 2003).
kWh/m²/Day
< 6.8
6.0
5.0
4.0
3.0
> 2.2
NREL
Author: Billy Roberts - October 20, 2008
This map was produced by the National Renewable Energy Laboratory for the U.S. Department of Energy

Growth in Solar Photovoltaics

Top 10 countries in 2016 based on total PV installed

- China: 78,100 MW (25.8%)
- Japan: 42,800 MW (14.1%)
- Germany: 41,200 MW (13.6%)
- United States: 40,300 MW (13.3%)
- Italy: 19,300 MW (6.4%)
- United Kingdom: 11,600 MW (3.8%)
- India: 9,000 MW (3.0%)
- France: 7,100 MW (2.3%)

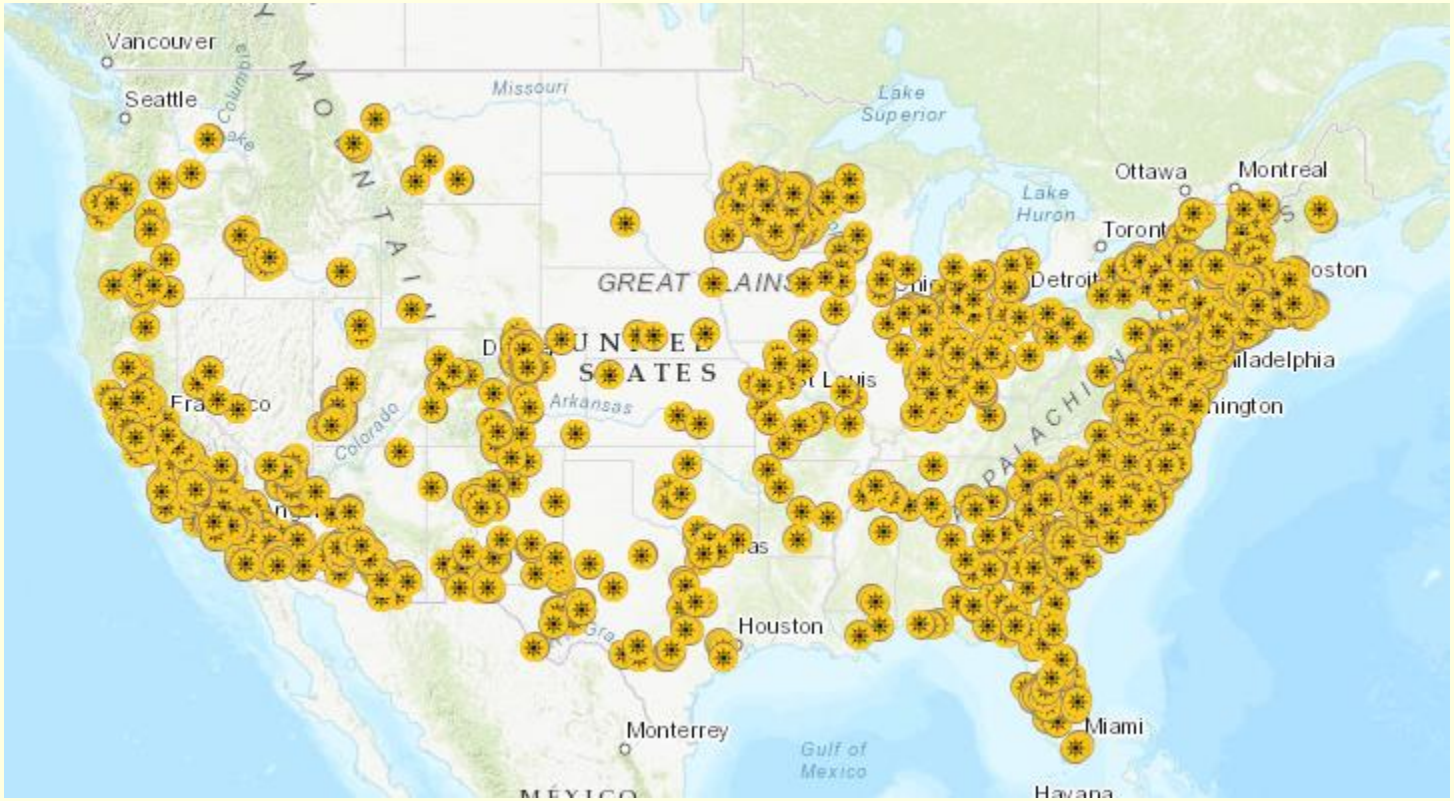


World's Largest PV Plants

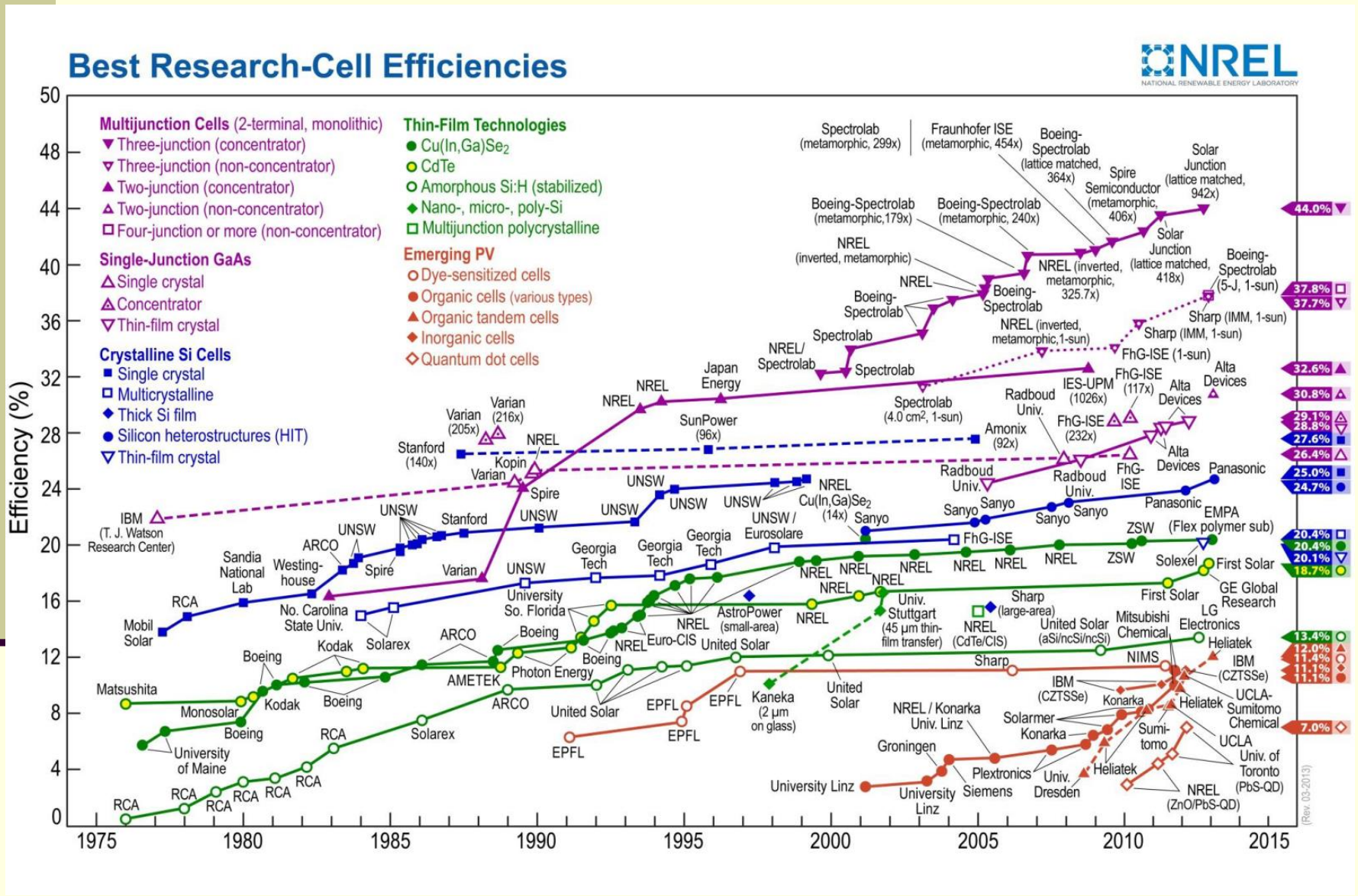
- https://en.wikipedia.org/wiki/List_of_photovoltaic_power_stations

Solar Power Plants in US

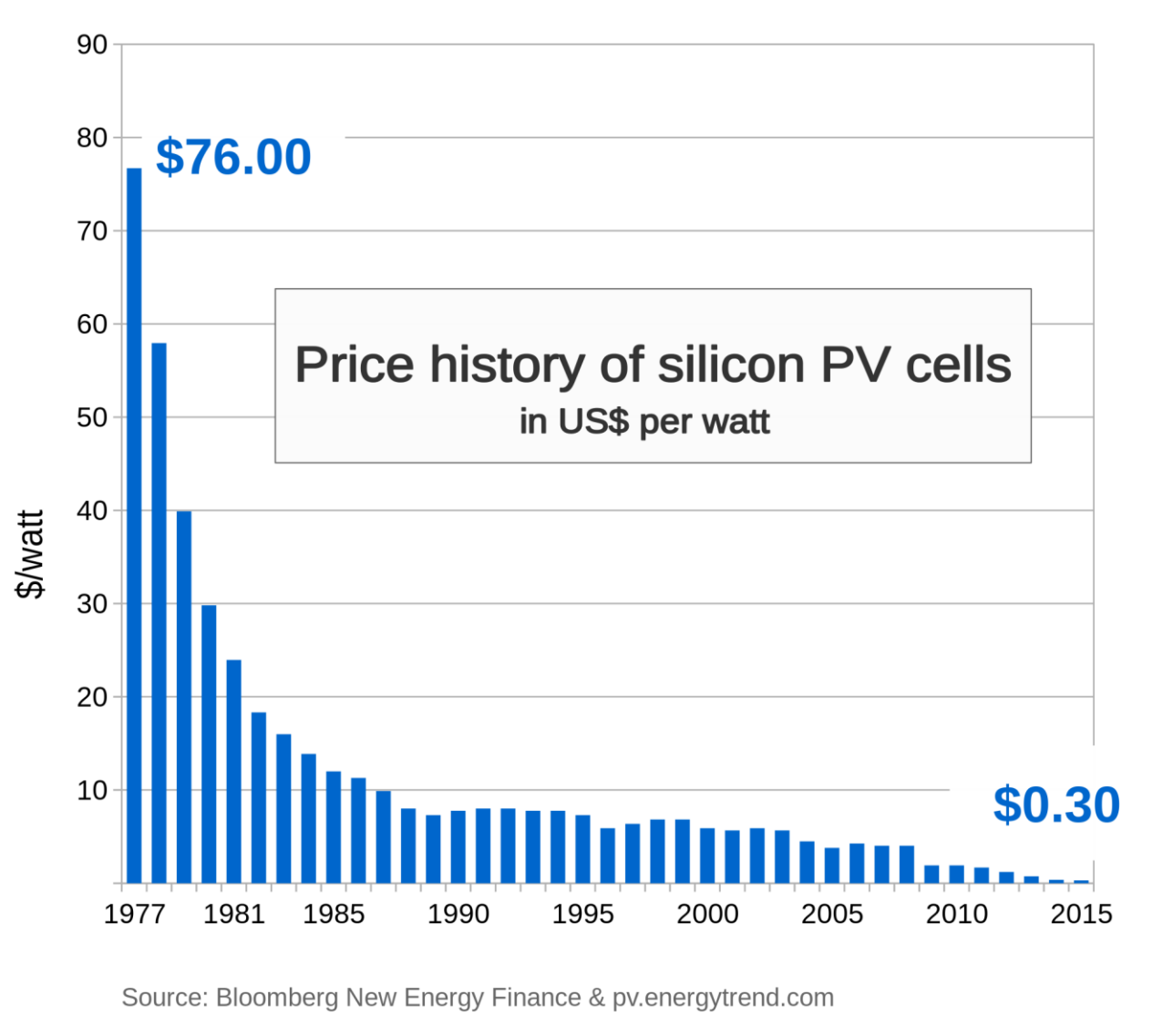
- https://www.eia.gov/state/maps.php



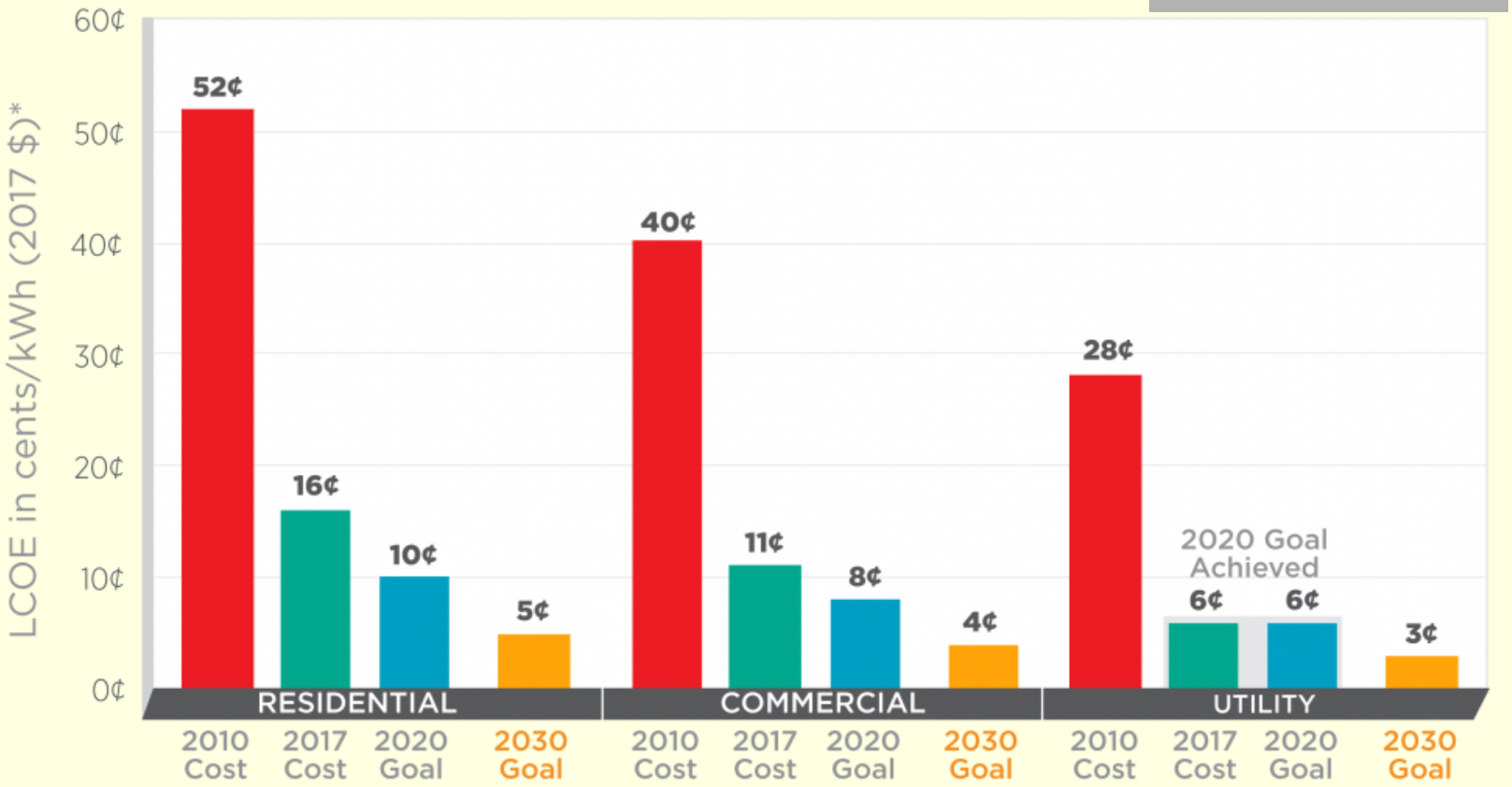
Trend of PV cell efficiencies



Trend of bulk PV price/watt (peak)

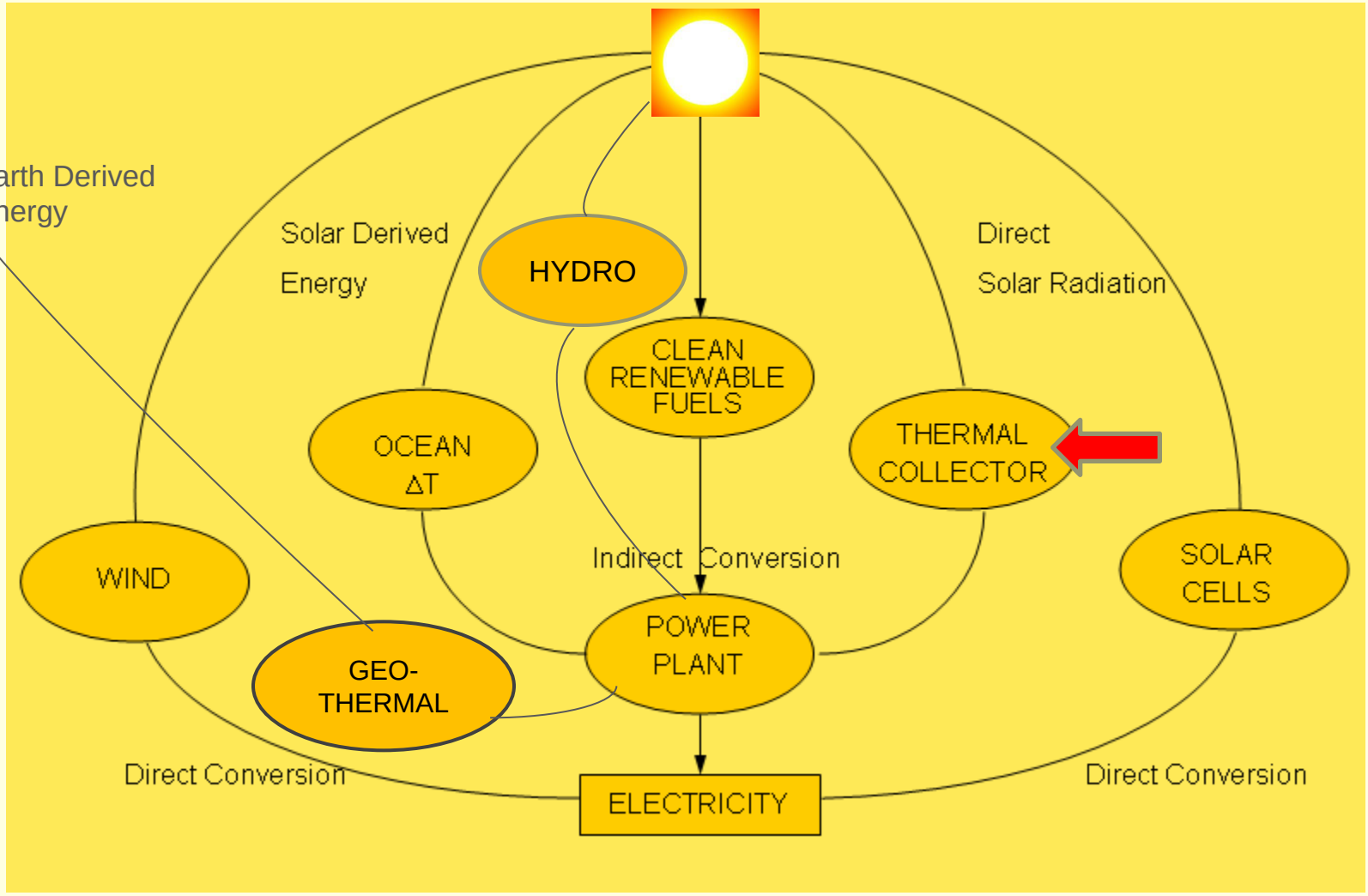


SunShot Progress and Goals



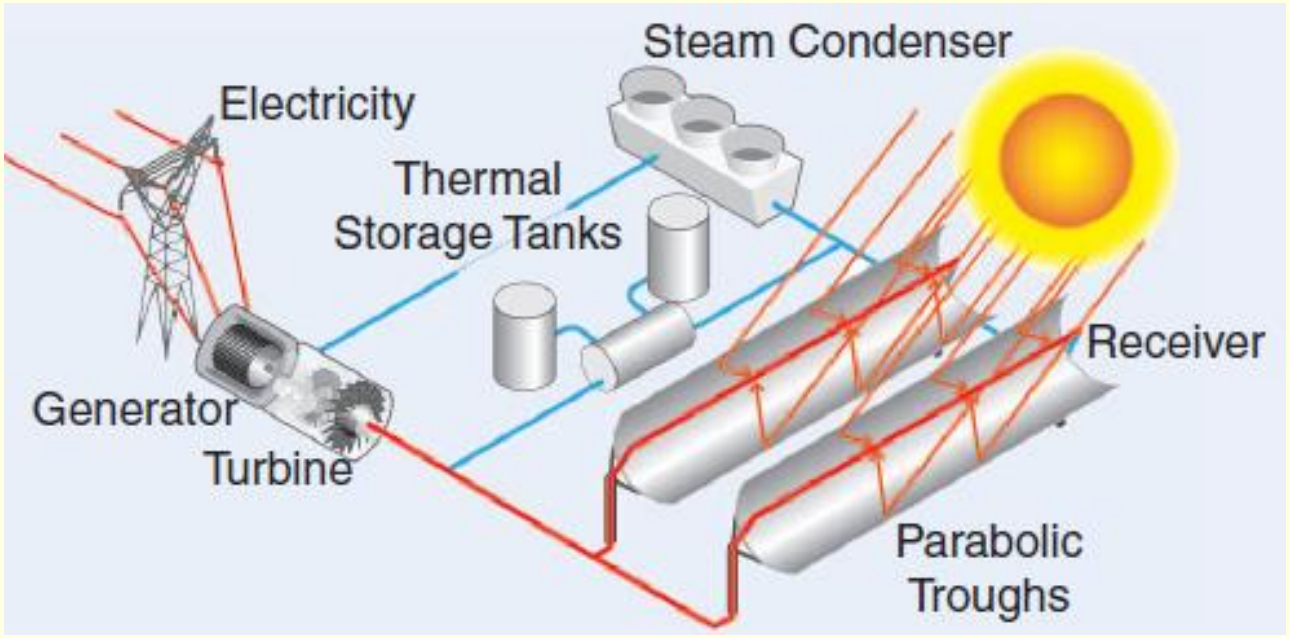
*Levelized cost of electricity (LCOE) progress and targets are calculated based on average U.S. climate and without the ITC or state/local incentives. The residential and commercial goals have been adjusted for inflation from 2010–17.

Renewable Resources



Linear CSP Systems

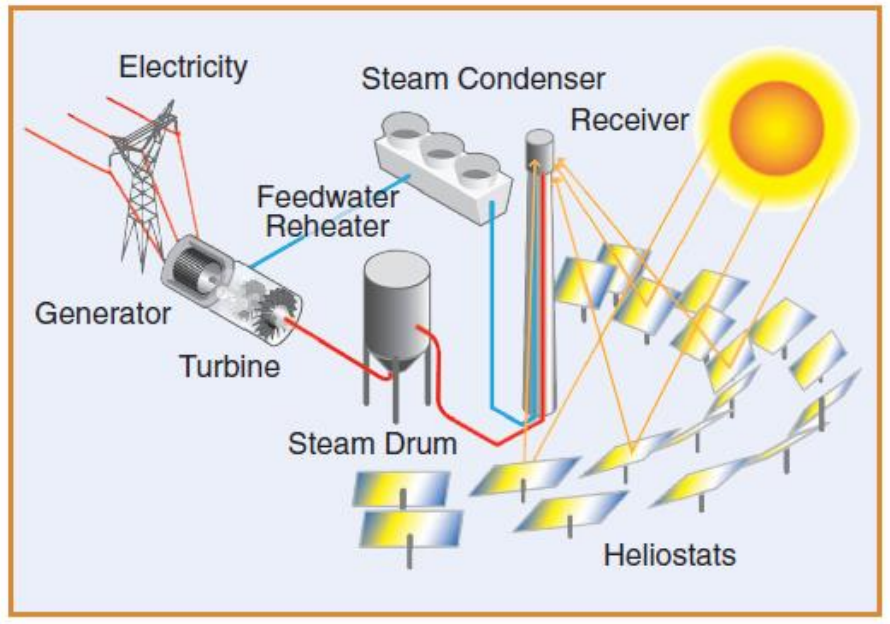
- Linear CSP collectors capture the sun's energy with large mirrors that reflect and focus the sunlight onto a linear receiver tube.
- The receiver contains a fluid that is heated by the sunlight and then used to create steam that spins a turbine driving a generator to produce electricity.



Linear CSP in Nevada: NV Solar I (65 MW)

Power Tower CSP Systems

- Sun-tracking mirrors (heliostats) focus sunlight onto a receiver at the top of a tower. A heat-transfer fluid heated in the receiver is used to generate steam, which in turn is used by turbine generator to produce electricity.
- Some power towers use water/steam as the heat transfer fluid. Other advanced designs are experimenting with molten nitrate salt because of its superior heat-transfer capabilities.

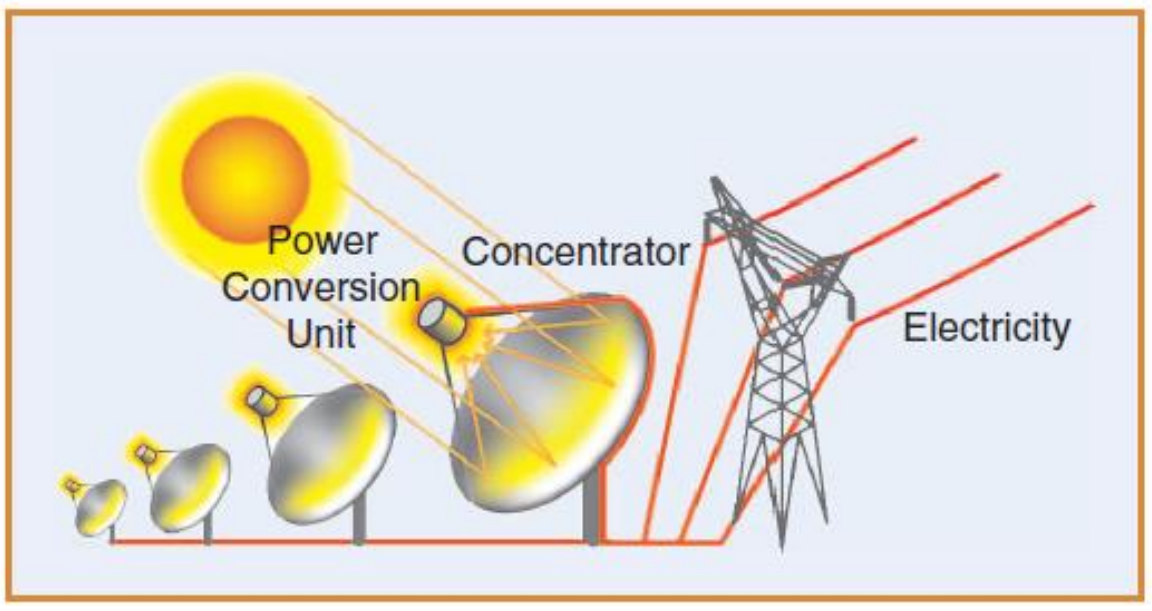


Power Tower CSP in Nevada: Tonopah – 110 MW

World’s largest - Ivanpah Solar: 350 MW

Dish/Engine CSP Systems

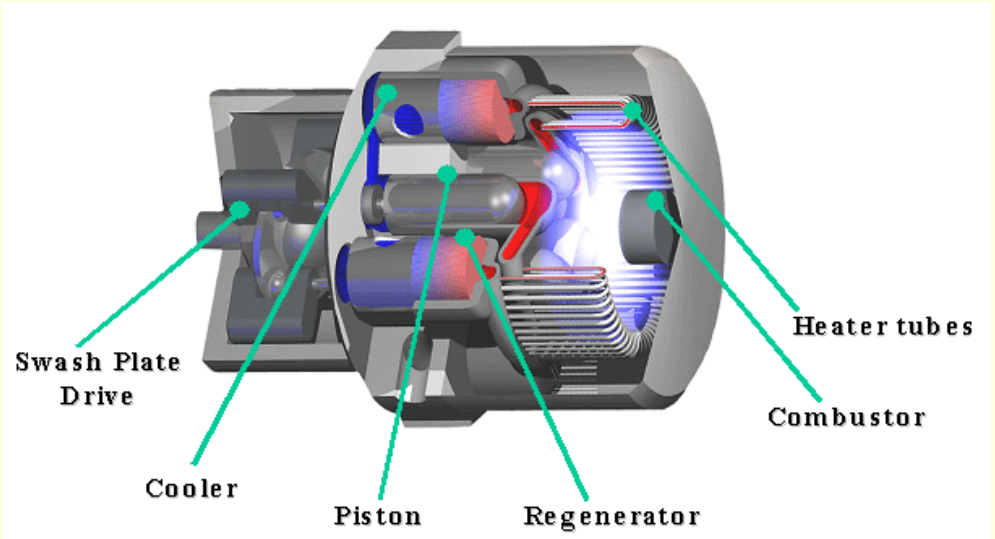
- A sun-tracking solar concentrator, reflects the beams sunlight onto a thermal receiver that collects the solar heat.
- The PCU includes the thermal receiver and the engine/generator. A thermal receiver can be a bank of tubes with a cooling fluid— usually hydrogen —that typically is the heat transfer medium and also the working fluid for an engine.



Dish CSP

- Currently, the most common type of heat engine used in dish/engine systems is the Sterling engine where the heated gas moves pistons and create mechanical power.
- Grid connection is through an induction machine.

Heat engine concept



Dish-Engine CSP Testing @ UNLV