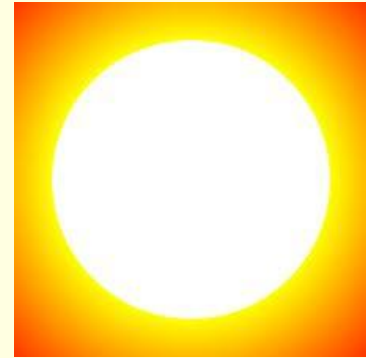




# Renewable Energy Resources – an Overview



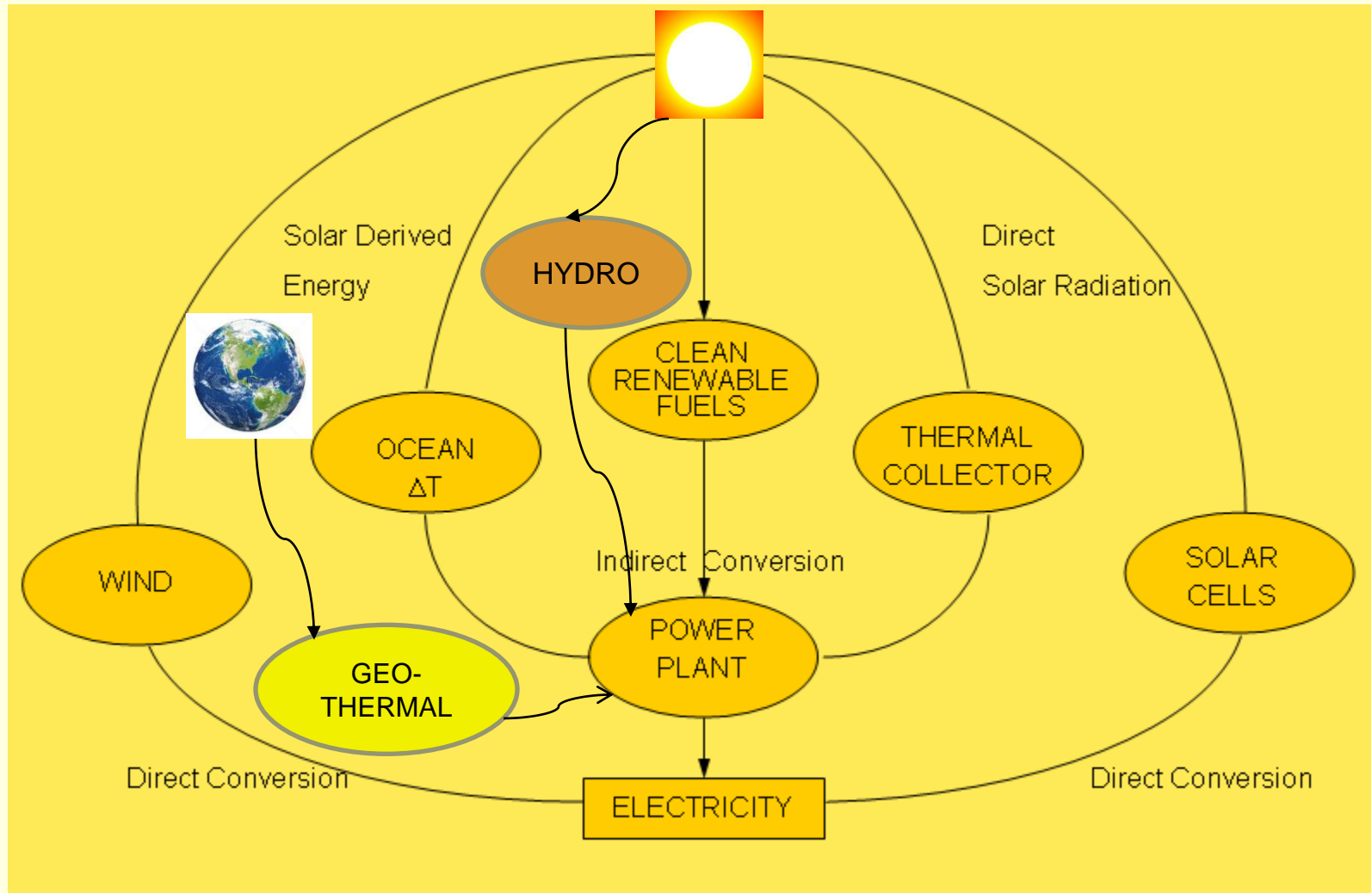
Y. Baghzouz  
Professor of Electrical Engineering

# Overview

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- 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?

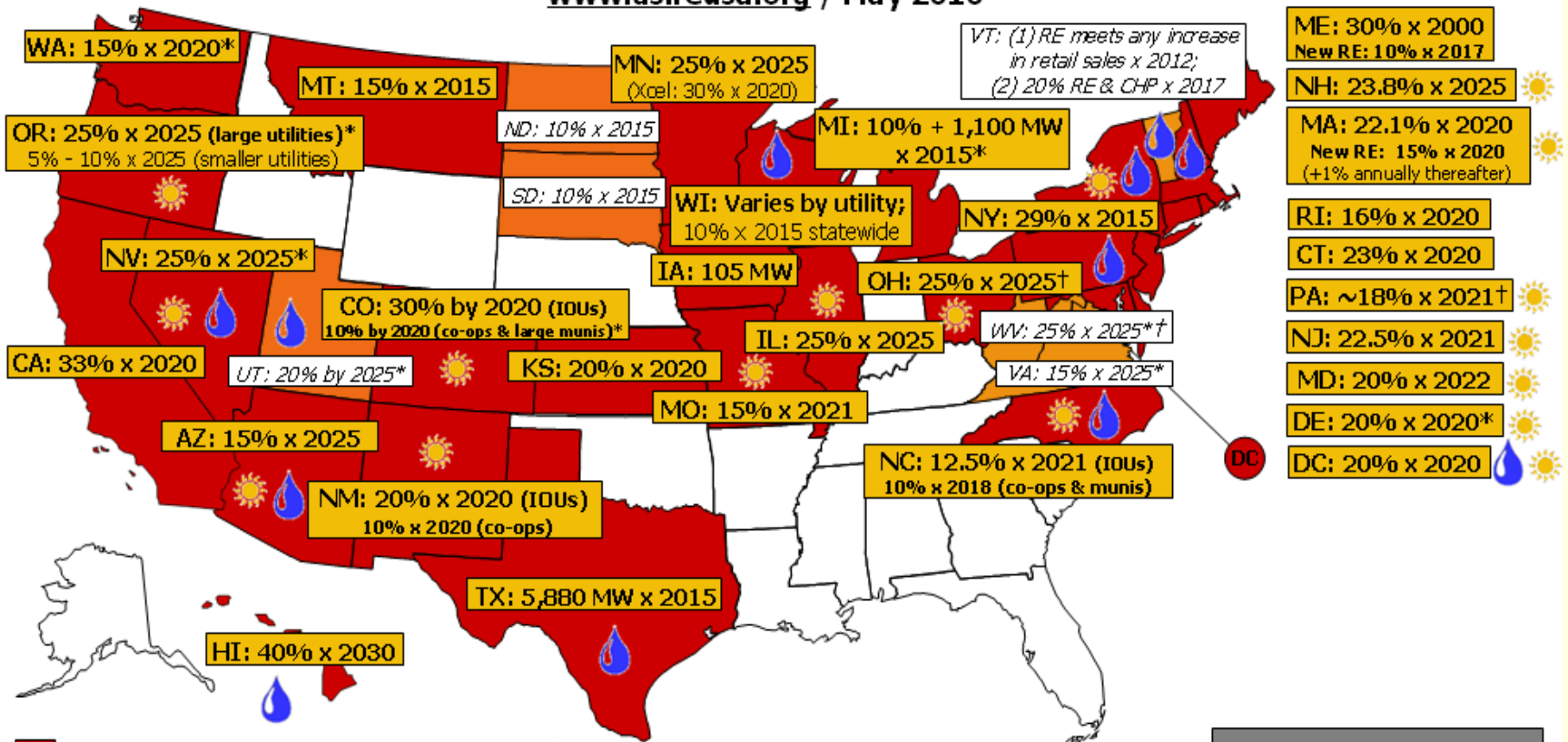
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The growth in renewables over the past decade is driven mainly by the following:

- Global concern over the environment. Furthermore, fossil fuel resources are 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.

# US States with Renewable Energy Portfolio Standards. (EU target: 20% by 2020)

www.dsireusa.org / May 2010



- State renewable portfolio standard
- State renewable portfolio goal
- Solar water heating eligible

- Minimum solar or customer-sited requirement
- Extra credit for solar or customer-sited renewables
- Includes non-renewable alternative resources

**29 states + DC have an RPS**  
(6 states have goals)

# Why not produce more renewable energy?

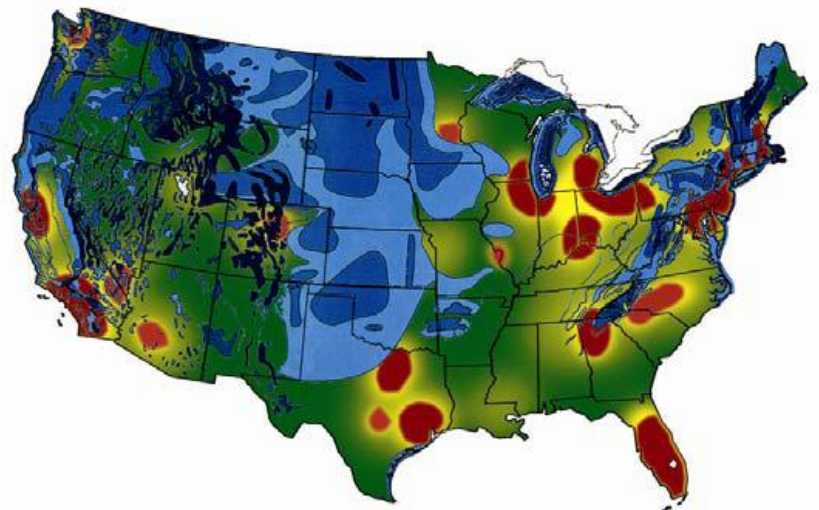
- **Renewable Energy Technologies Are Capital-Intensive:** Renewable energy power plants are generally more expensive to build and to operate than coal and natural gas plants. Recently, however, some wind-generating plants have proven to be economically feasible in areas with good wind resources.
- **Renewable Resources Are Often Geographically Remote:** The best renewable resources are often available only in remote areas, so building transmission lines to deliver power to large metropolitan areas is expensive.

## Wind Availability and Demand

Blue - high wind potential,

Brown - large demand centers, and

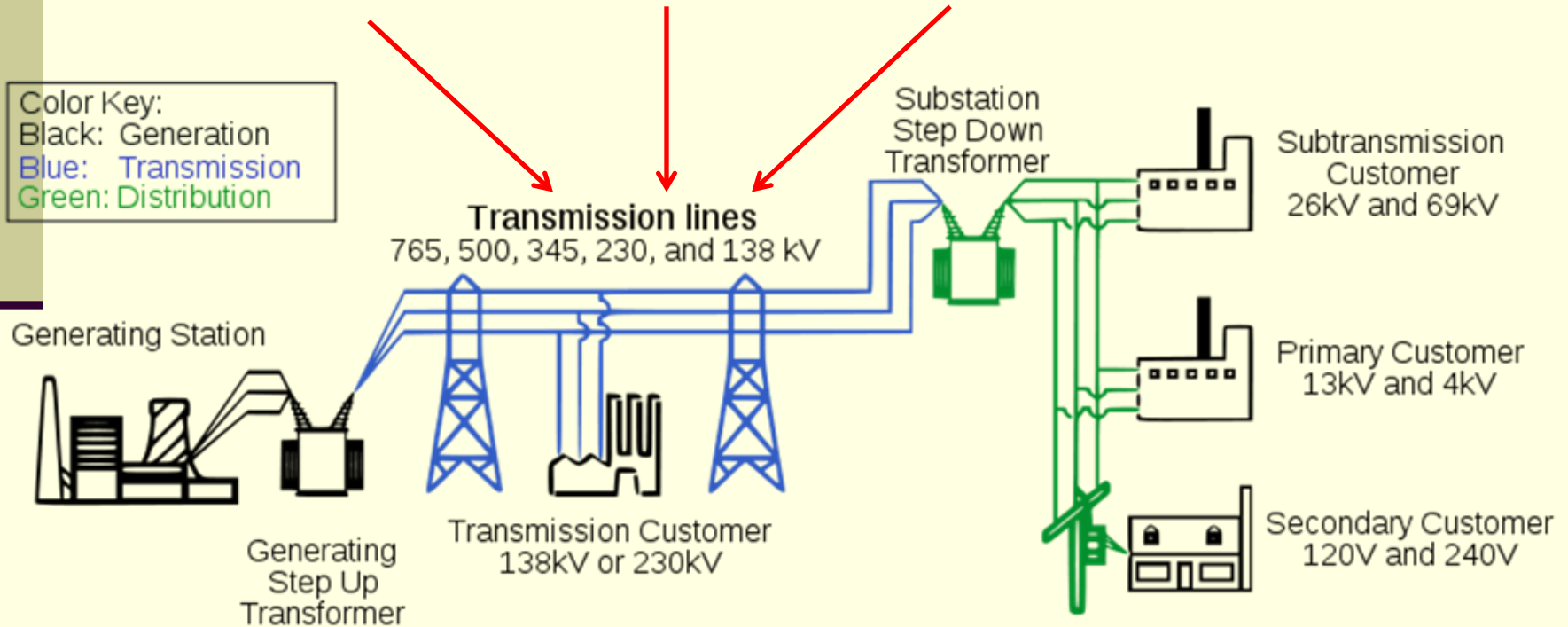
Green - little wind and smaller demand centers.



# Renewable Power Plants: Large plants are connected to the sub-transmission or transmission system



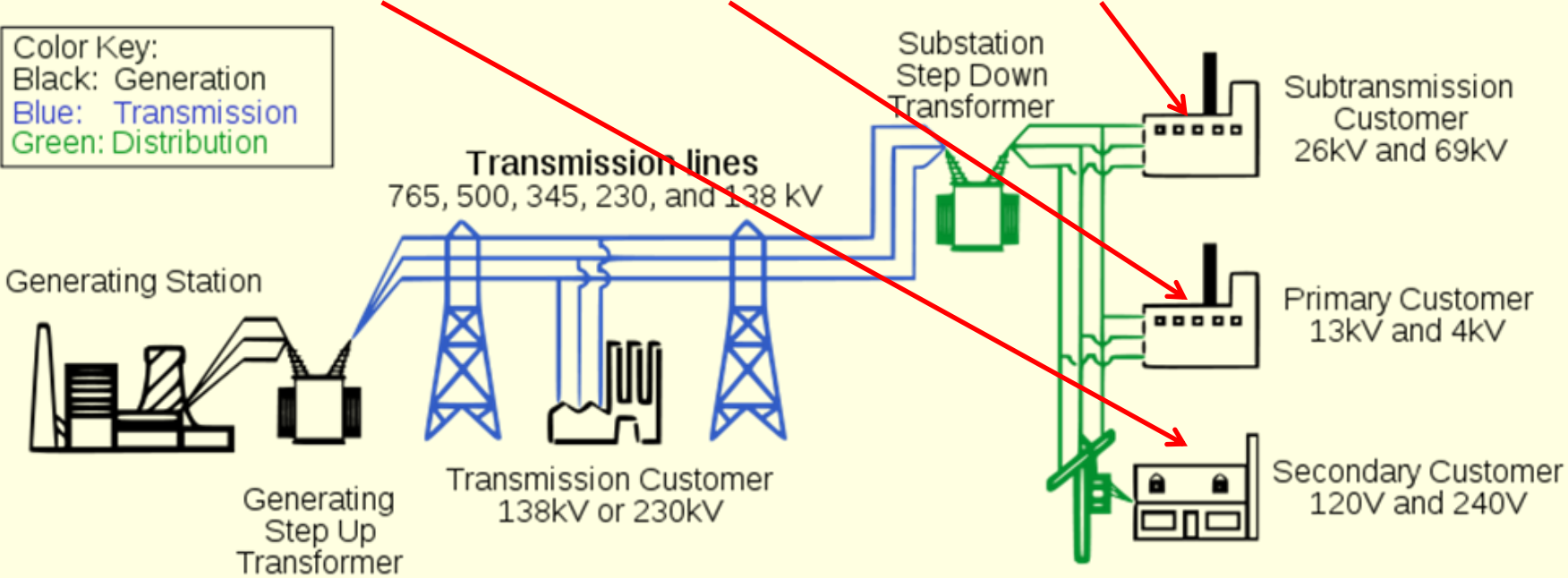
Color Key:  
Black: Generation  
Blue: Transmission  
Green: Distribution



# Renewable Power Plants: Small plants are connected to the distribution system (often on the load side)

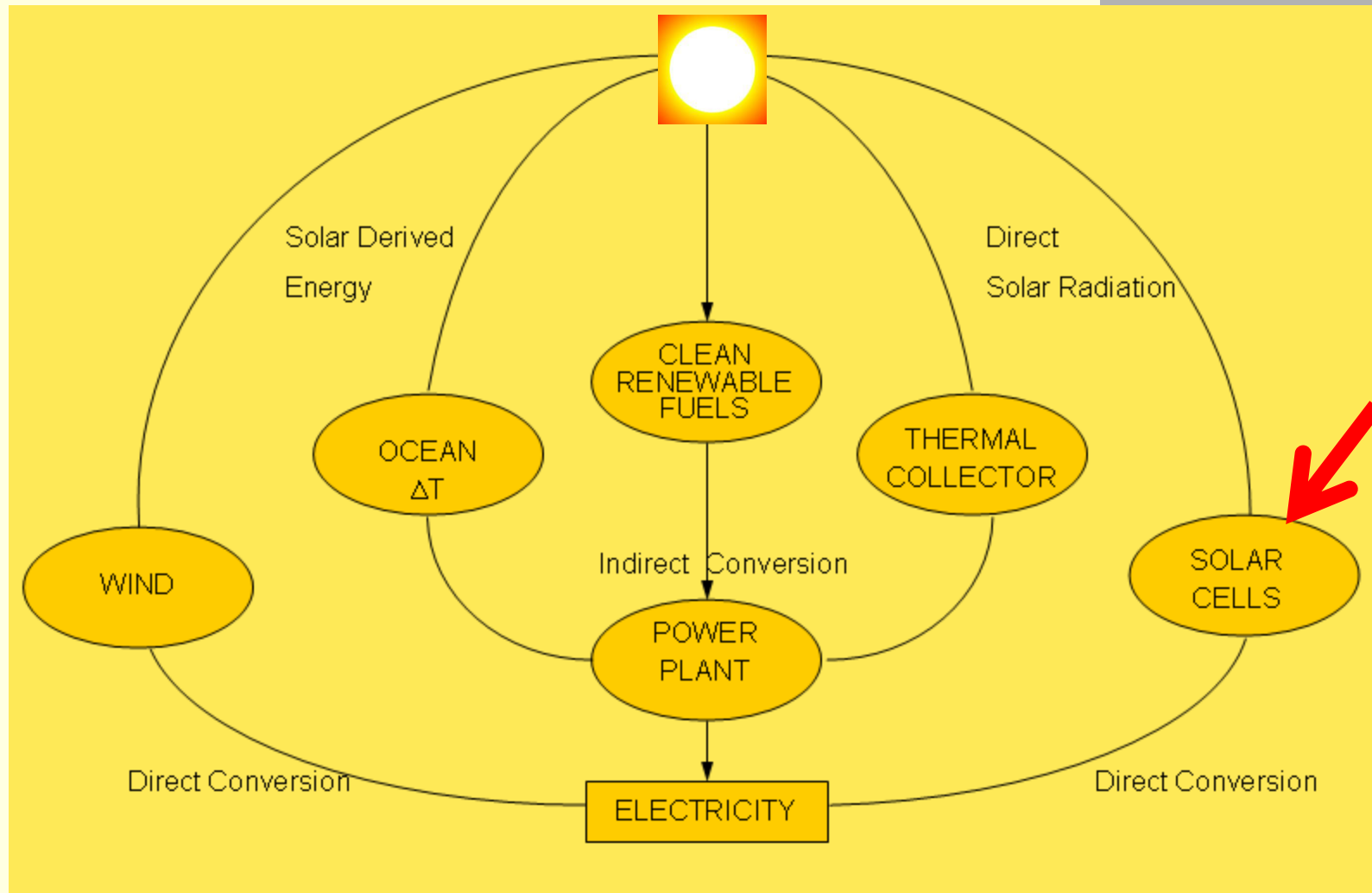


Color Key:  
Black: Generation  
Blue: Transmission  
Green: Distribution

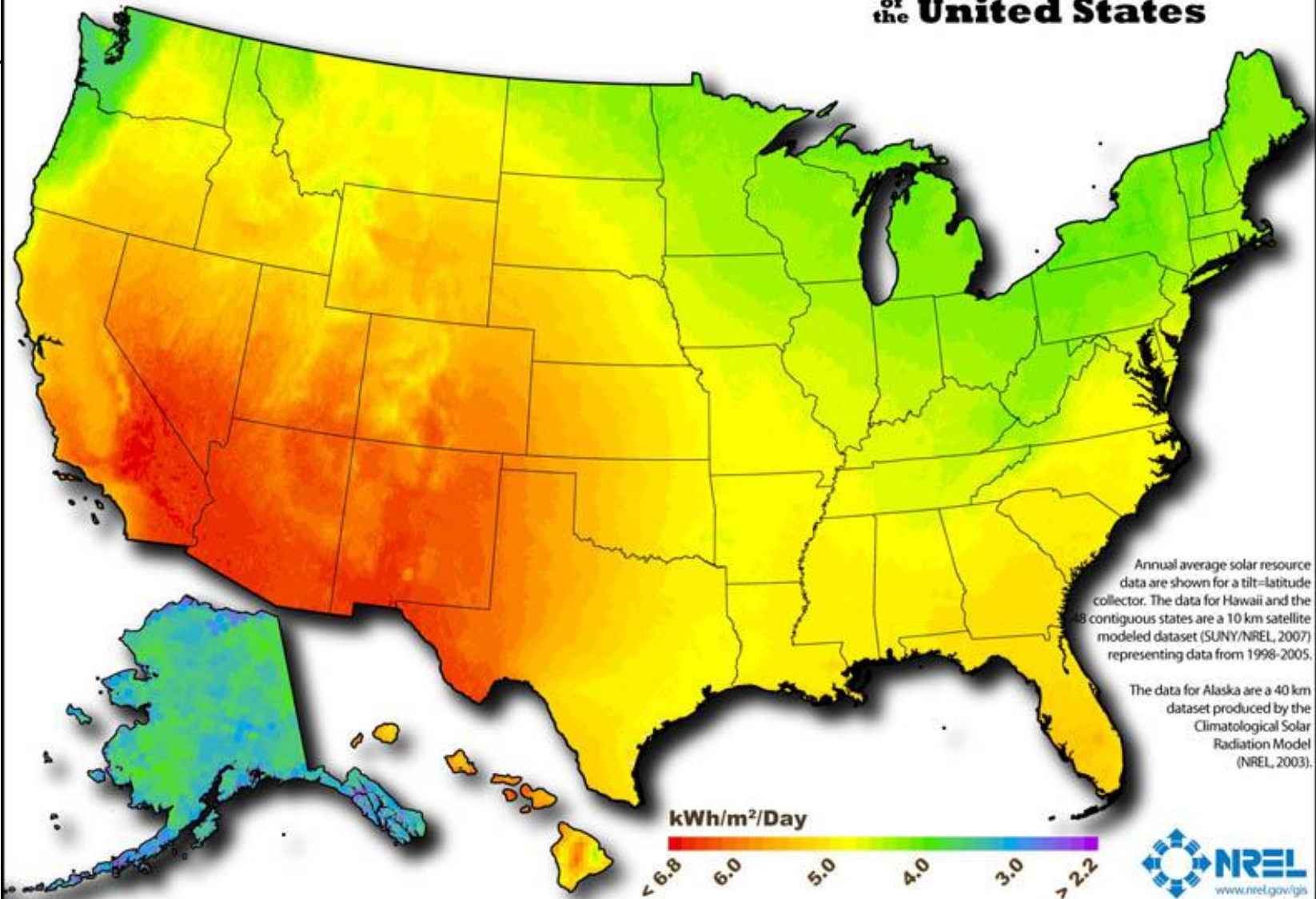




# Electricity production from renewables: Photovoltaics

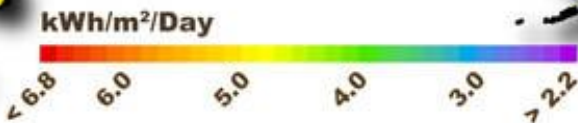


# Photovoltaic Solar Resource of the United States



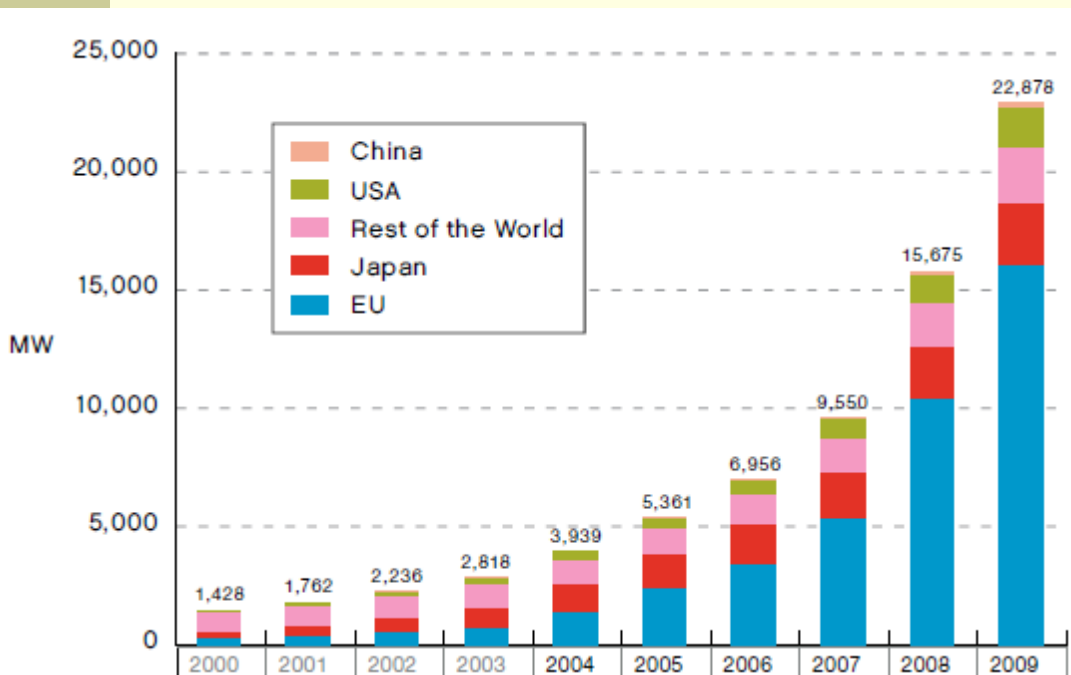
Annual average solar resource data are shown for a tilt-latitude collector. The data for Hawaii and the 48 contiguous states are a 10 km satellite modeled dataset (SUNY/NREL, 2007) representing data from 1998-2005.

The data for Alaska are a 40 km dataset produced by the Climatological Solar Radiation Model (NREL, 2003).



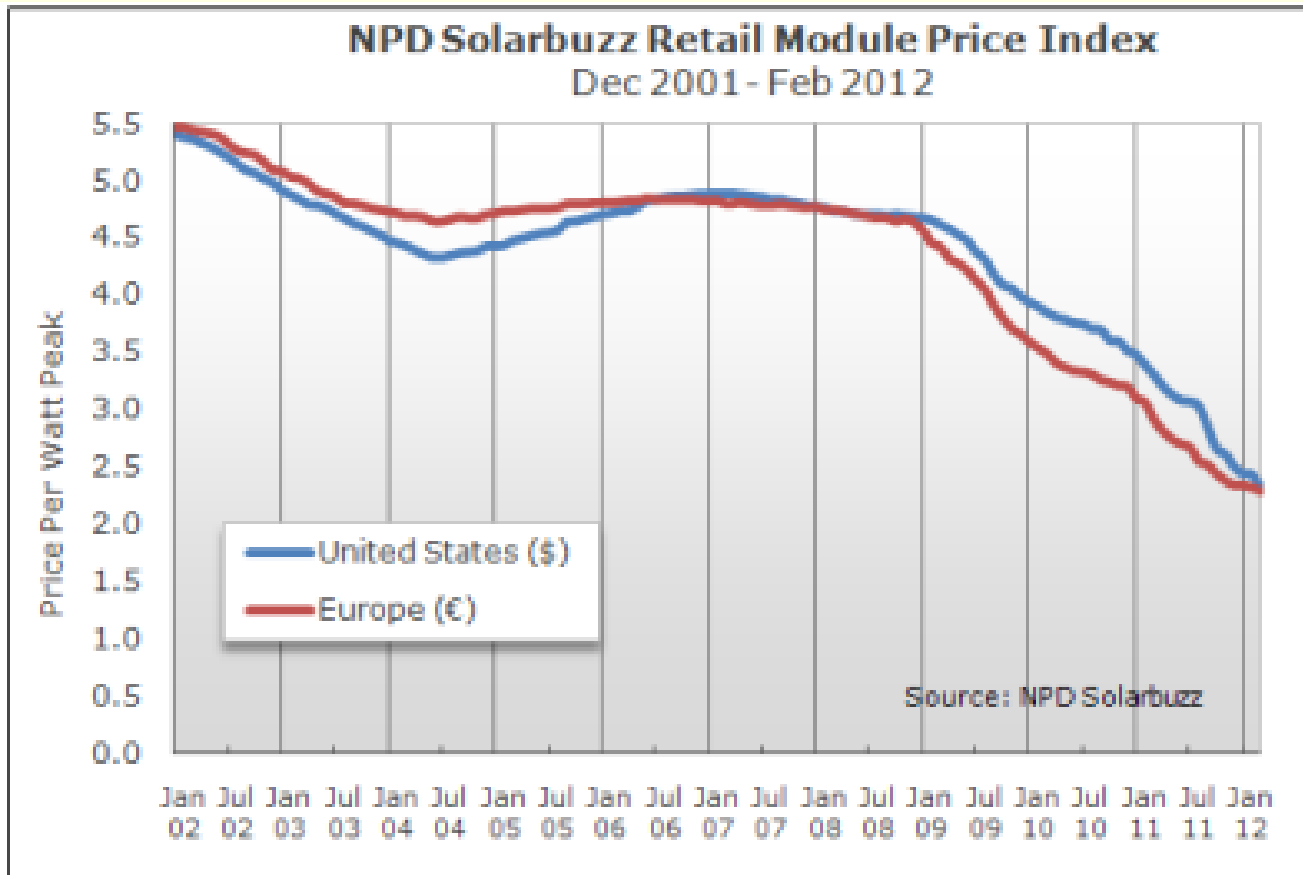
# Growth in Solar Photovoltaic

- The past decade has seen explosive growth in global solar photovoltaic installations.
- Countries with the most PV capacity in 2010-2011 (MWp) →



Country or Region	Total 2010	Total 2011 [44]
World	39,778	67,350
European Union	29,328	50,300
Germany	17,320	24,700
Italy	3,502	12,500
Japan	3,617	4,700
Spain	3,892	4,200
United States	2,519	4,200
China	893	2,900
France	1,025	2,500
Czech Republic	1,953	1,960
Belgium	803	1,500
Australia	504	1,200
United Kingdom	72	750
Greece	206	550

# Trend of average PV price/watt (peak)



A recent mailing from Affordable Solar indicates that they are selling PV panels @ \$0.87/Watt Peak (including free shipping) for a limited time!



# Largest PV systems to date



- As of July. 2012, the largest photovoltaic (PV) power plants in the world are
  - Charanka Solar Park (India, 214 MW)
  - Agua Caliente Solar Project (Yuma, AZ, 200 MW)
  - Golmud Solar Park (China, 200 MW),
  - Perovo Solar Park (Ukraine, 100 MW),
  - Sarnia Photovoltaic Power Plant (Canada, 97 MW),
  - Brandenburg-Briest Solarpark (Germany, 91 MW),
  - Solarpark Finow Tower (Germany, 84.7 MW),
  - Montalto di Castro Photovoltaic Power Station (Italy, 84.2 MW).
- A number of larger plants (in the 500 MW range) are under construction in CA, USA.

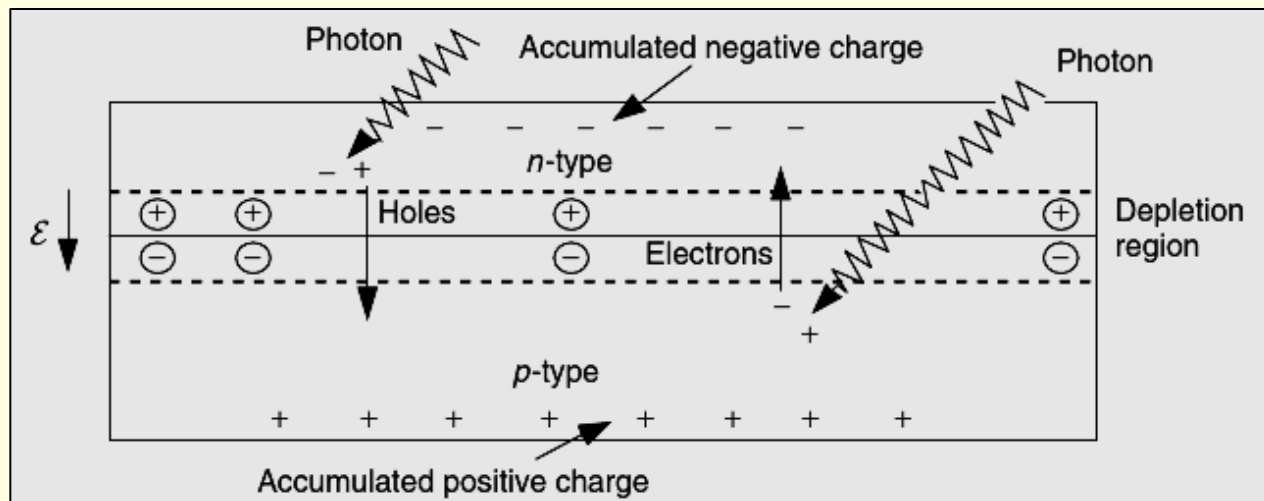
# PV Plants in Nevada:

- 50 MW (Eldorado Valley), 50 MW (Prim)
- 15 MW (1-axis) tracking @ NAFB
- Numerous distributed PV systems (few kW – 350 kW)



# Crystalline Silicon (first generation PV)

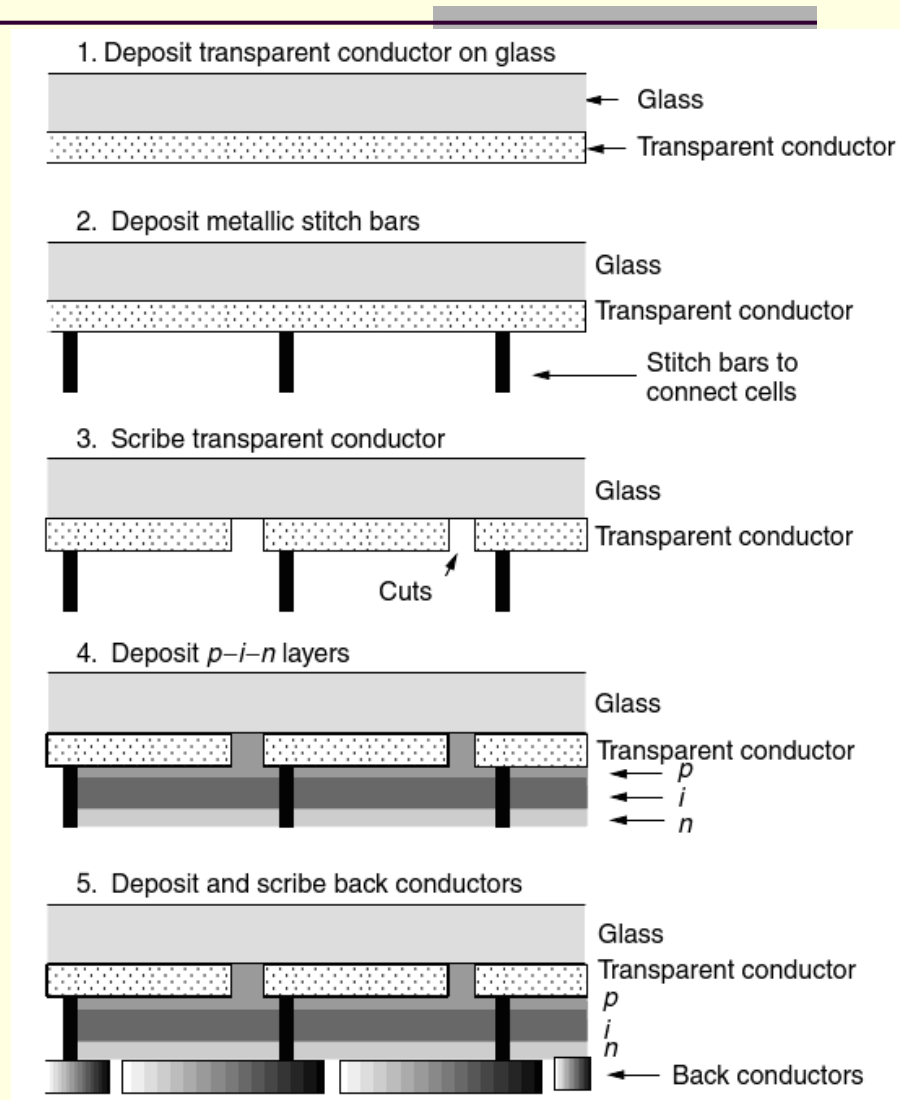
- Silicon cells continues to dominate the commercial solar cells at more than 90% of market share.
  - Pure silicon is “doped” with small amounts of other elements to produce p- and n- type semiconductor materials.
  - Putting the two materials in contact with one another creates an electric field, and when the material is illuminated, the energy of the sunlight forms an electron and a hole that get pushed to the top and bottom surface by the electric field.





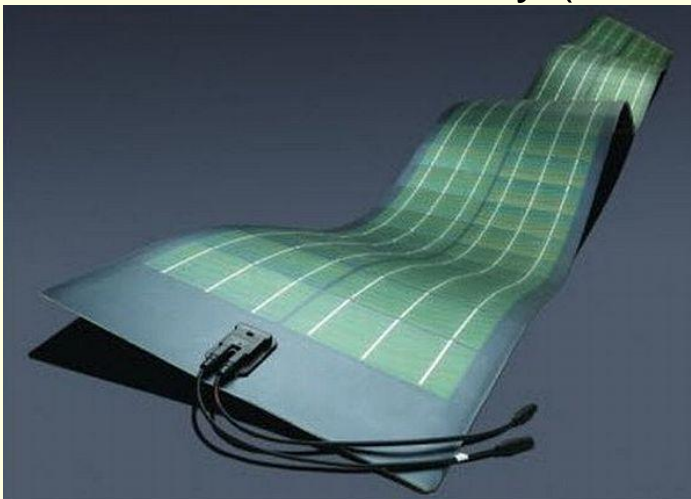
# Thin film (second generation PV)

- Second-generation PV devices rely on layers of semiconductor materials that are much thinner than those in silicon cells ( 2-3  $\mu\text{m}$  thick, compared to 170-200  $\mu\text{m}$ )
- If silicon is used, it is typically in the form of amorphous silicon (a-Si). But other thin-film materials, such as cadmium telluride (CdTe), have also been developed and commercialized.



# Thin film cells

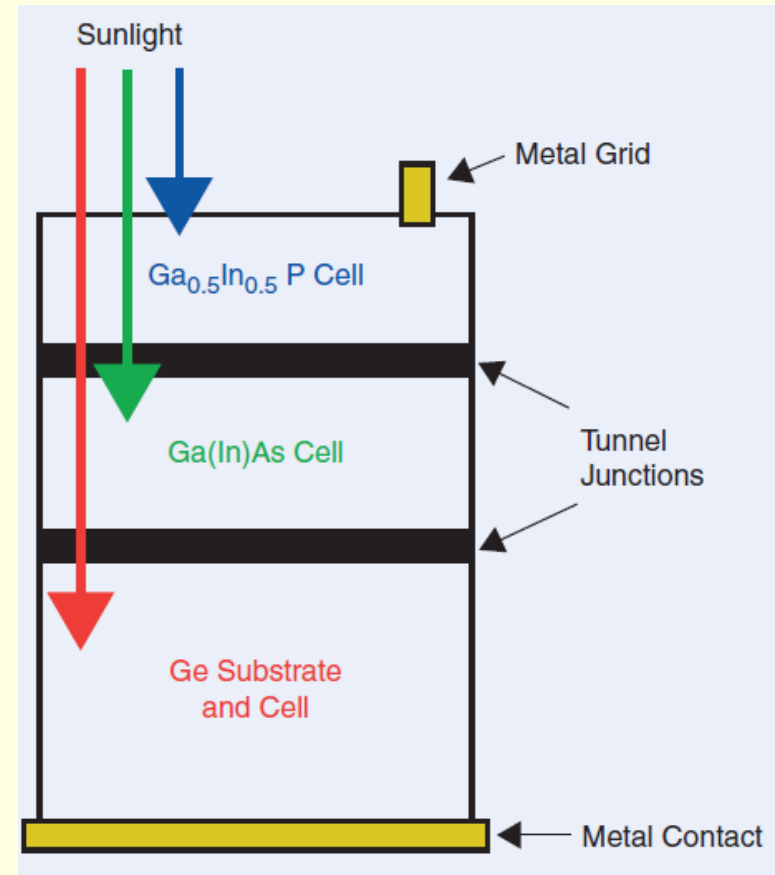
- The thin-film cell uses less material and can be deposited with a method that is much less energy intensive than silicon, hence lighter weight. Some thin-film technologies do not rely on rigid wafers; rather, they can be deposited on flexible substrates.
- Thin films generally have a lower solar conversion efficiency (in the 10% range).



# Multi-junction PV cells

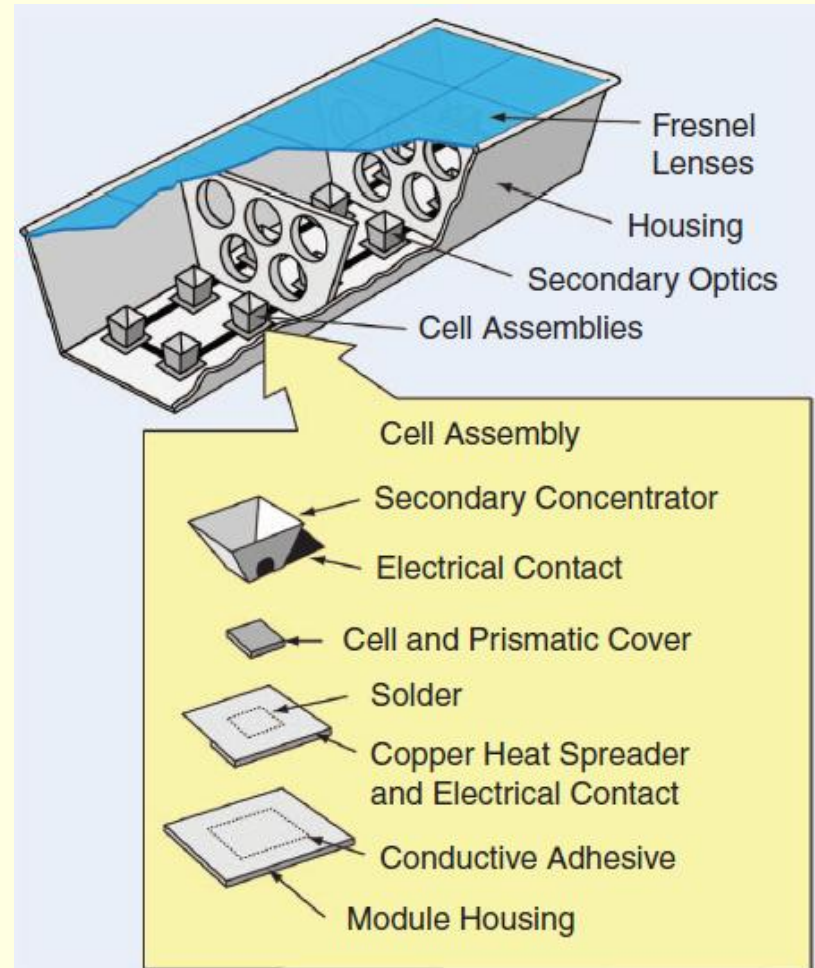
Another type of second-generation PV device is the high efficiency multi-junction cell that uses compounds from the group III and group V elements of the periodic table. For Example, a top layer of gallium arsenide, a middle layer of gallium indium phosphide, and a bottom layer of germanium.

- Very high efficiencies can be generated as each layer of the cell is designed to absorb a different portion of the solar spectrum.
- These materials are expensive to produce.

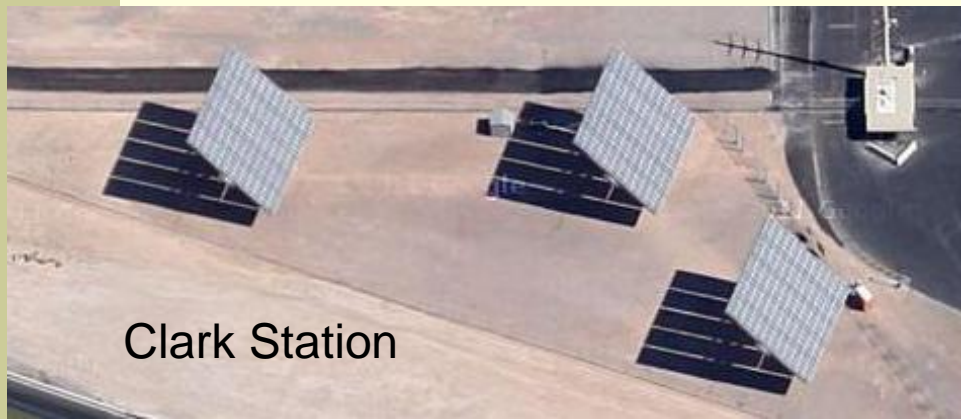


# Concentrating PV cells

- One way to overcome the cost issue is to use these cells in a concentrator system, in which a relatively inexpensive lens is used to focus sunlight on just a small area of cells.
  - If a 10x10 cm lens focuses this area of incident sun onto a 0.5x0.5 cm cell, the concentration factor is 400. This cell with the lens can produce as much power as a 10-by-10-cm cell without a lens, but at nearly 1/400 of the cell cost.



# Concentrating PV Systems in Southern Nevada:



Clark Station

## Concentrating PV System Testing @ UNLV

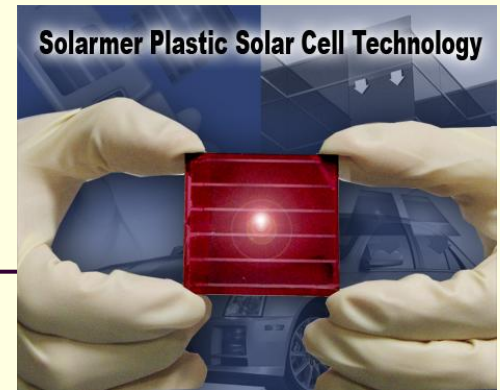


SNWA Pumping Station



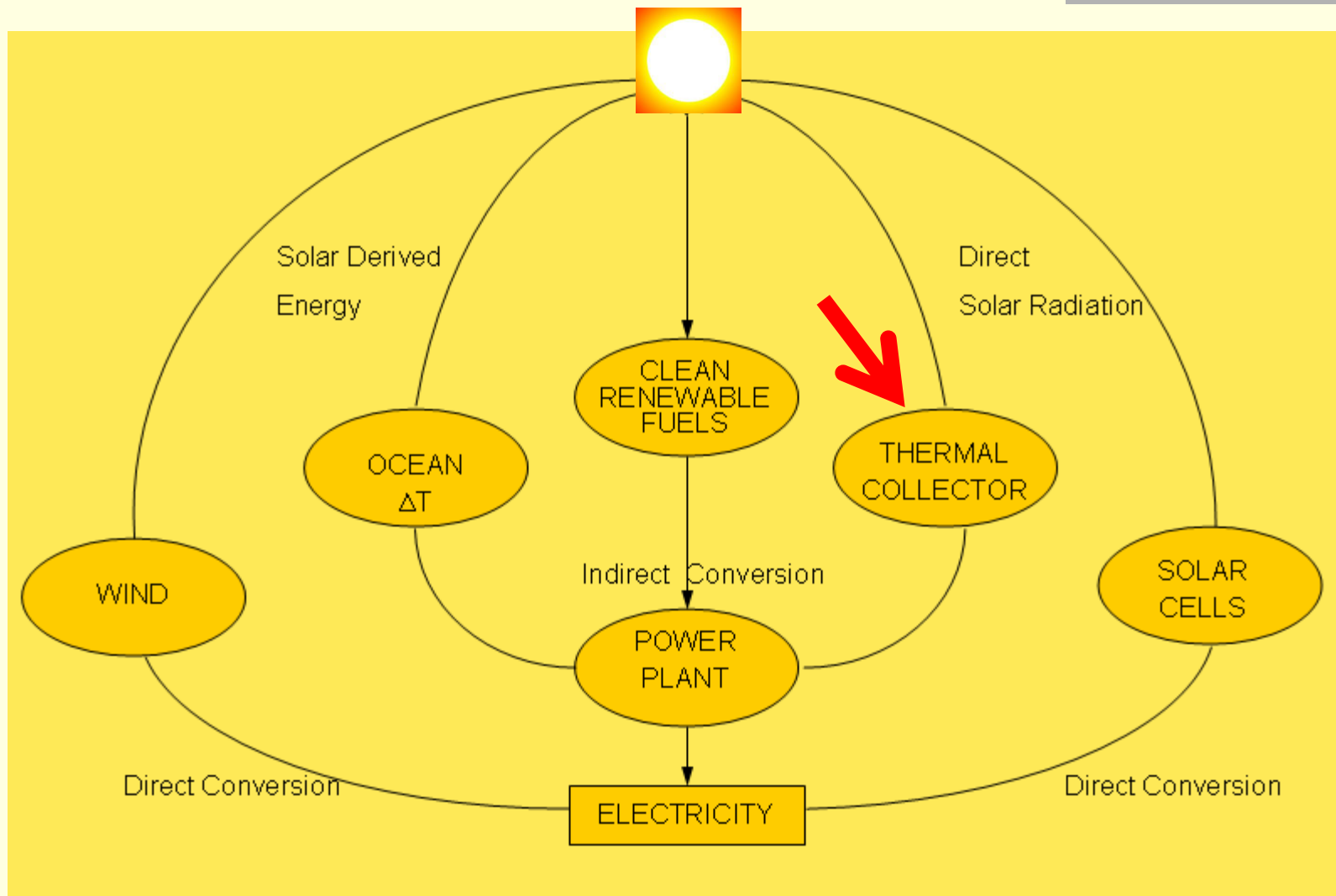
# Future (Third Generation) PV Technologies

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- The other pathway is that of **very low-cost cells**, but with lower efficiencies. An example is the so-called **dye sensitized cell** which has been able to generate electricity at efficiencies exceeding 10%. Simplicity of the materials and structure make the device very inexpensive to manufacture.
- Other third-generation solar cell approaches, some of which are still in the conceptual phase only, include the advanced cells based on **quantum dots, and organic PV cells**. Verified efficiencies are typically in the single digits. However, considerable opportunity for technological innovation has created a serious buzz about these technologies.

# Electricity production from renewables: concentrating Solar power



# Concentrating Solar Power (CSP)

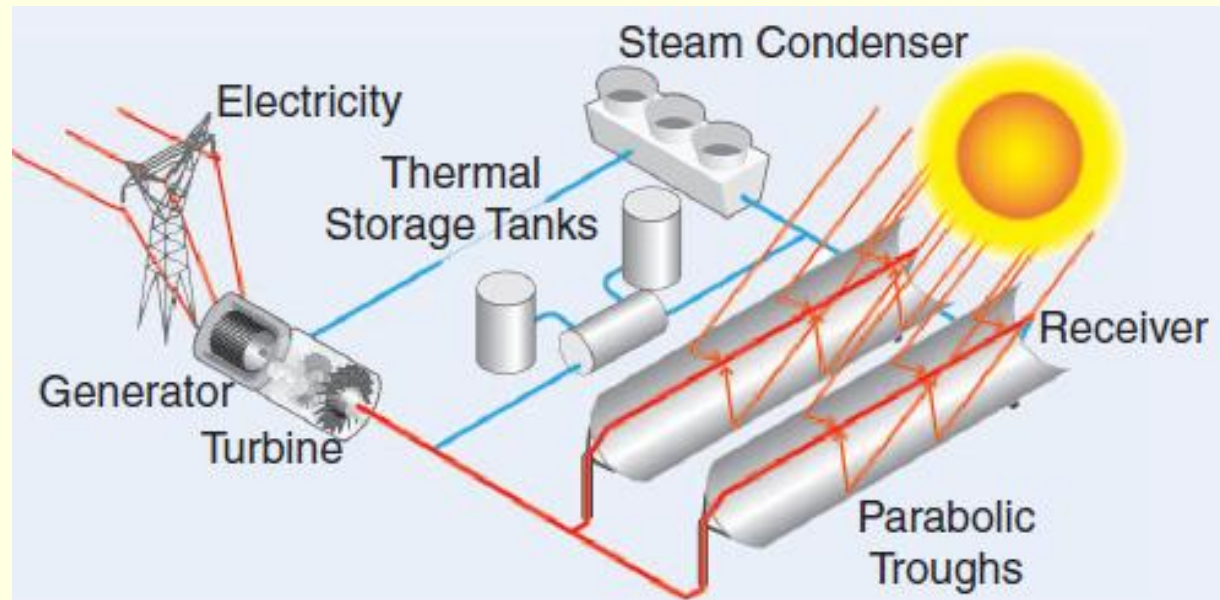
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- CSP technologies use mirrors to reflect and concentrate sunlight onto receivers that collect the solar energy and convert it into heat.
- This thermal energy can then be used to produce electricity via a steam turbine or heat engine driving a generator.
- CSP systems are typically classified by how the various systems collect solar energy. The three main systems are
  - The linear system
  - The tower system
  - The dish system.

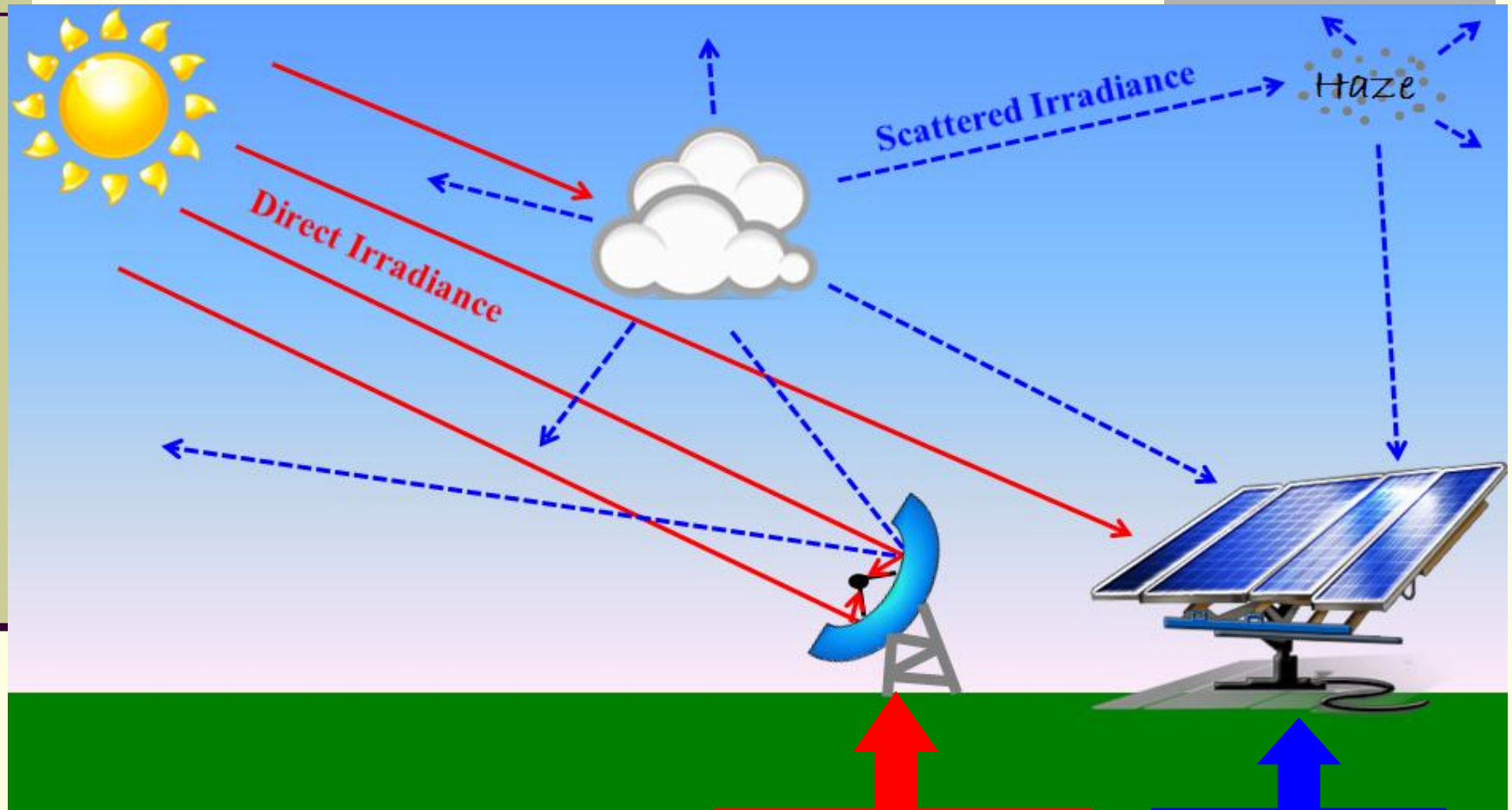


# Linear CSP Systems

- 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.



Unlike PV, concentrated solar thermal depend only on direct irradiance!

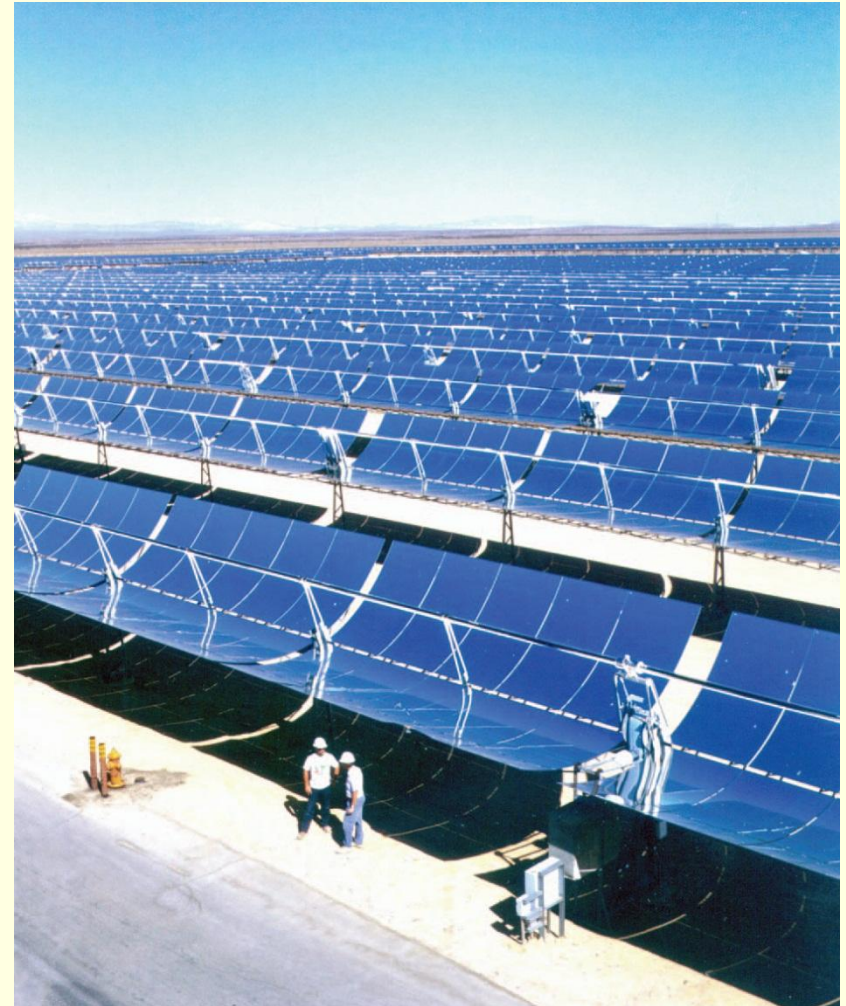


Solar thermal accepts only direct irradiance

PV accepts all solar irradiance

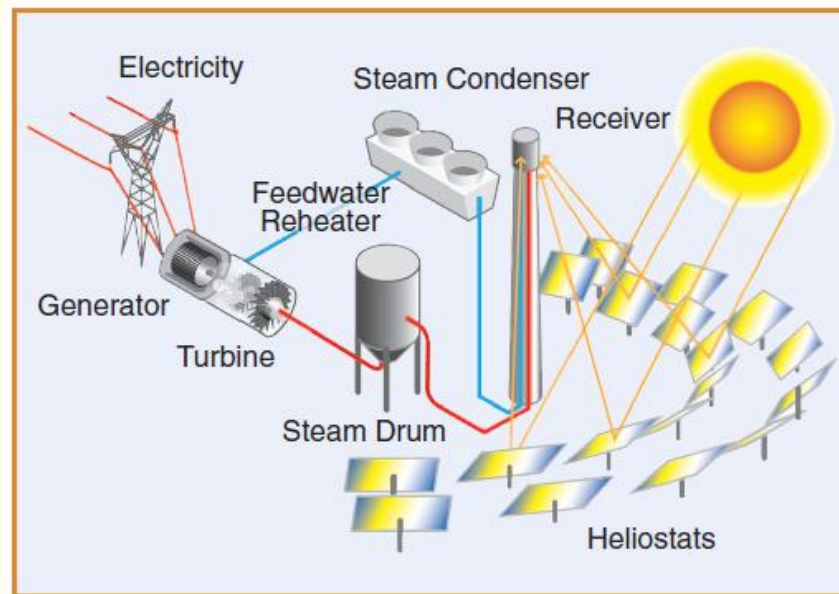
# Linear CSP in Nevada: Nevada Solar 1 (65 MW)

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# Power Tower CSP Systems

- Herein, numerous large, flat, 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 and energy-storage capabilities.



# Power tower CSP - Spain

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# Power Tower CSP in Nevada: Crescent Dunes – 110 MW

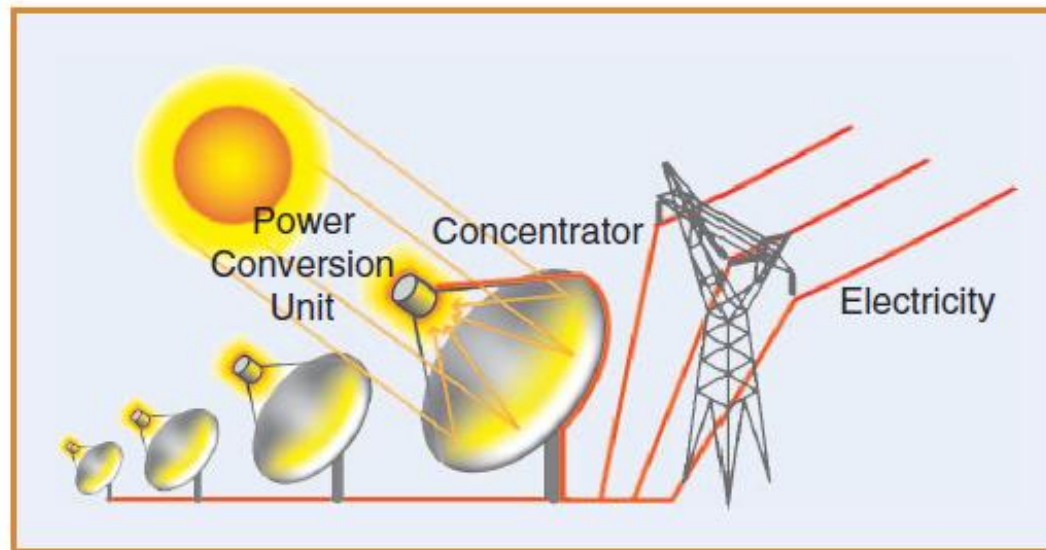
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- Location: near Tonopah, NV
- Completion date: 2014
- The system will use more than 17,000 heliostat mirrors to focus the sun's thermal energy to heat molten salt flowing from this 640-foot-tall solar power tower to underground storage tanks.



# Dish/Engine CSP Systems

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

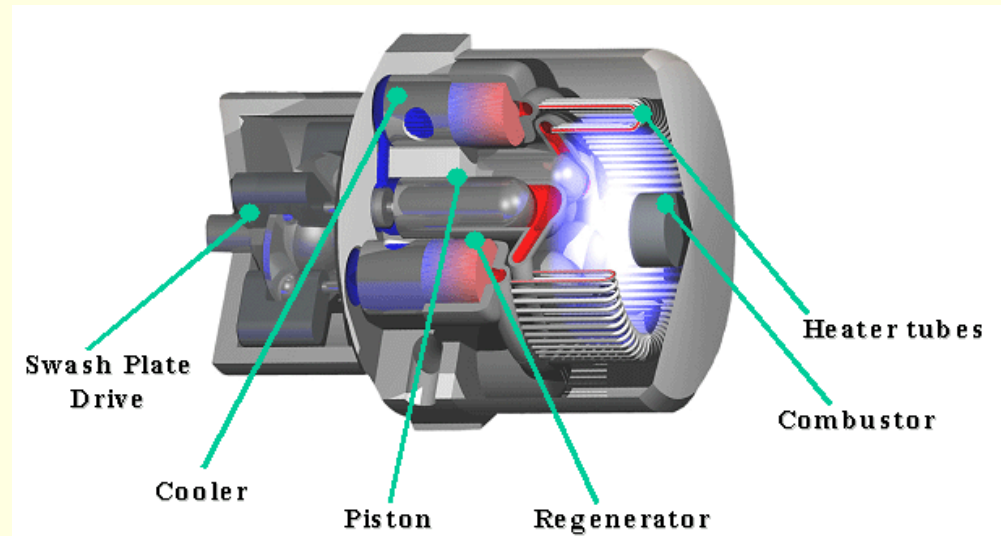


# Dish CSP

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



Heat engine concept

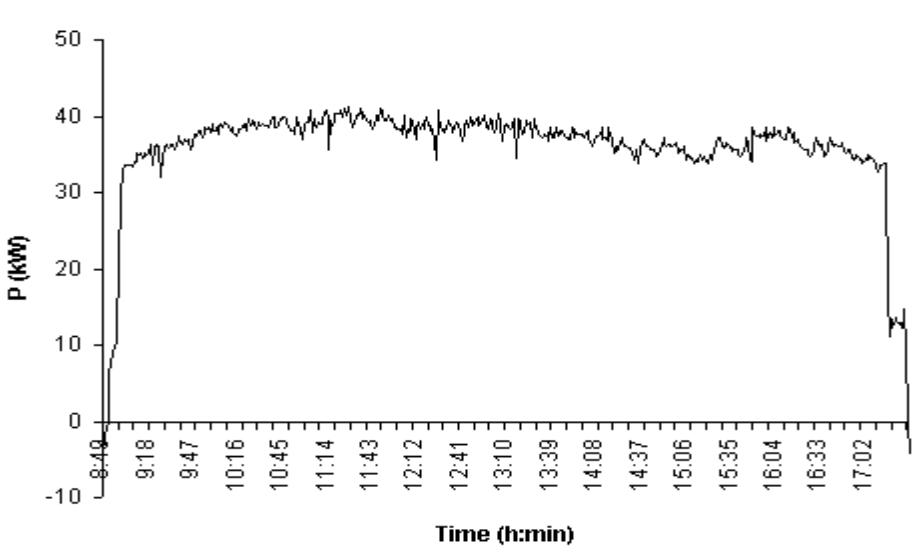




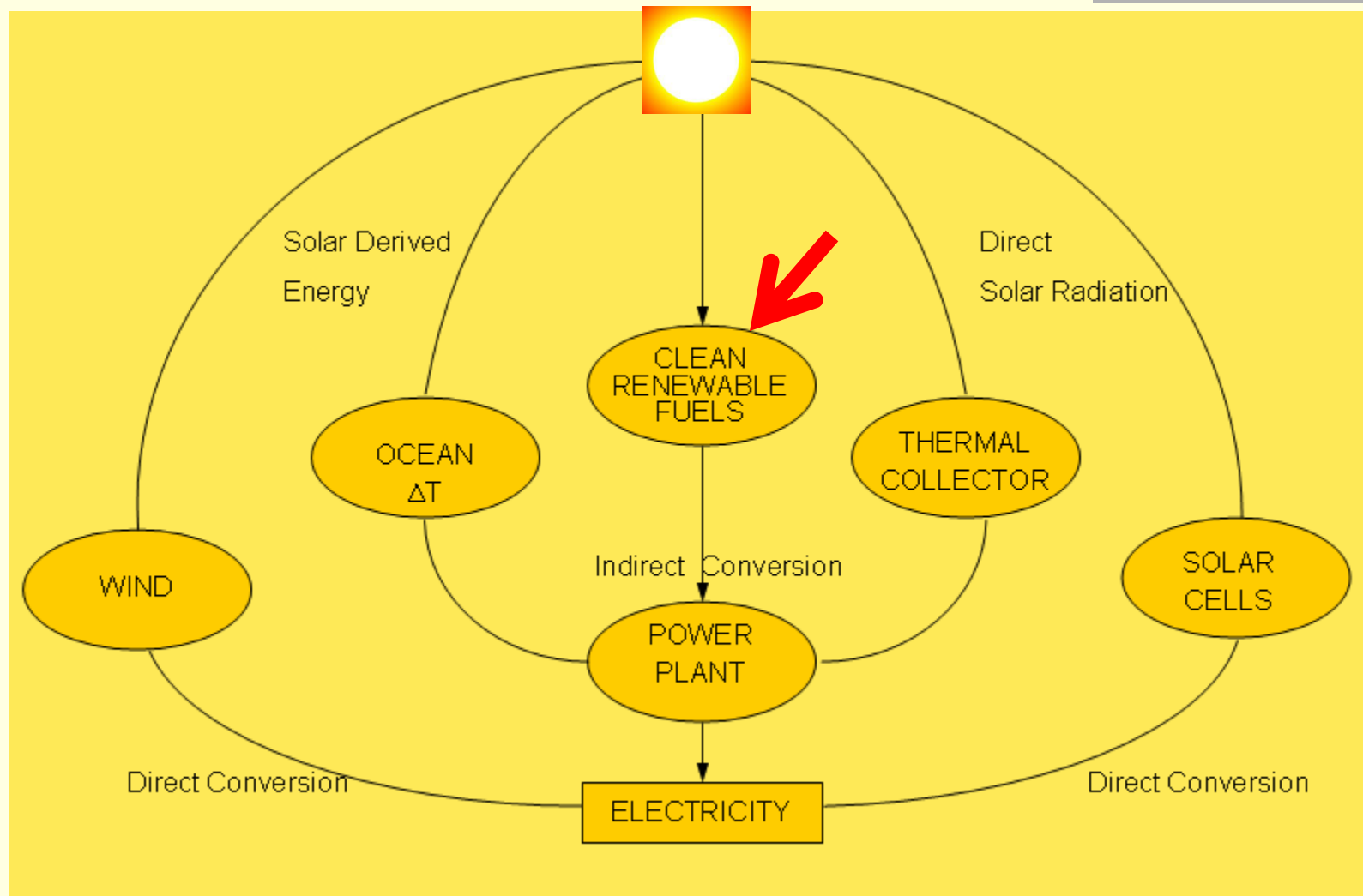
# Dish/Engine CSP Systems – (in AZ and NM)



# Dish-Engine CSP Testing @ UNLV

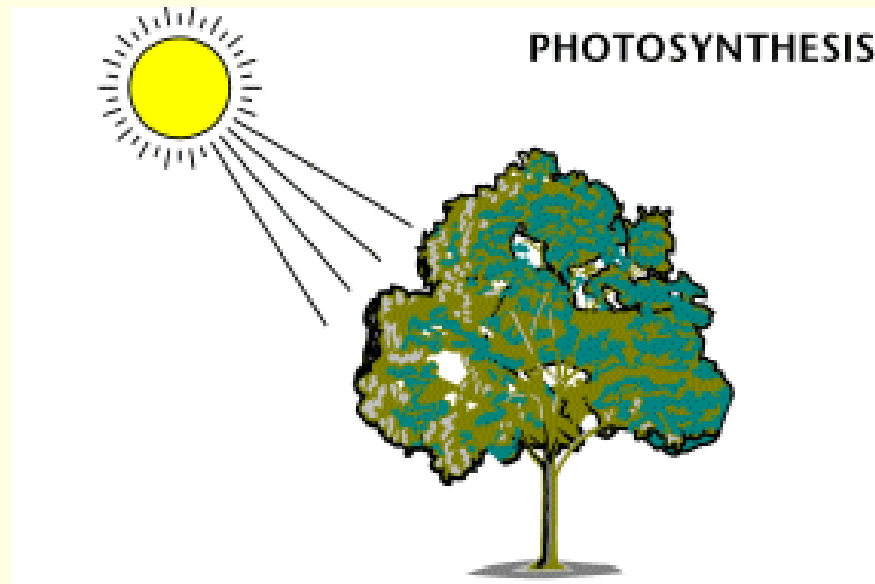


# Electricity production from renewables: Biomass



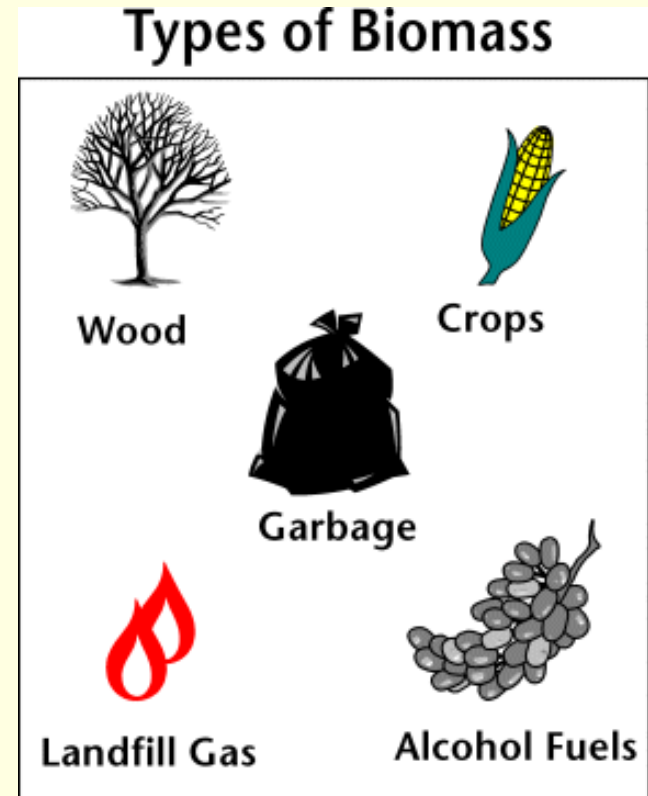
# Biomass

- Biomass is organic material made from plants and animals (micro-organisms).
- Biomass contains stored energy from the sun: Plants absorb the sun's energy through photosynthesis. The chemical energy in plants (in the form of glucose or sugar) gets passed on to animals and people that eat them.



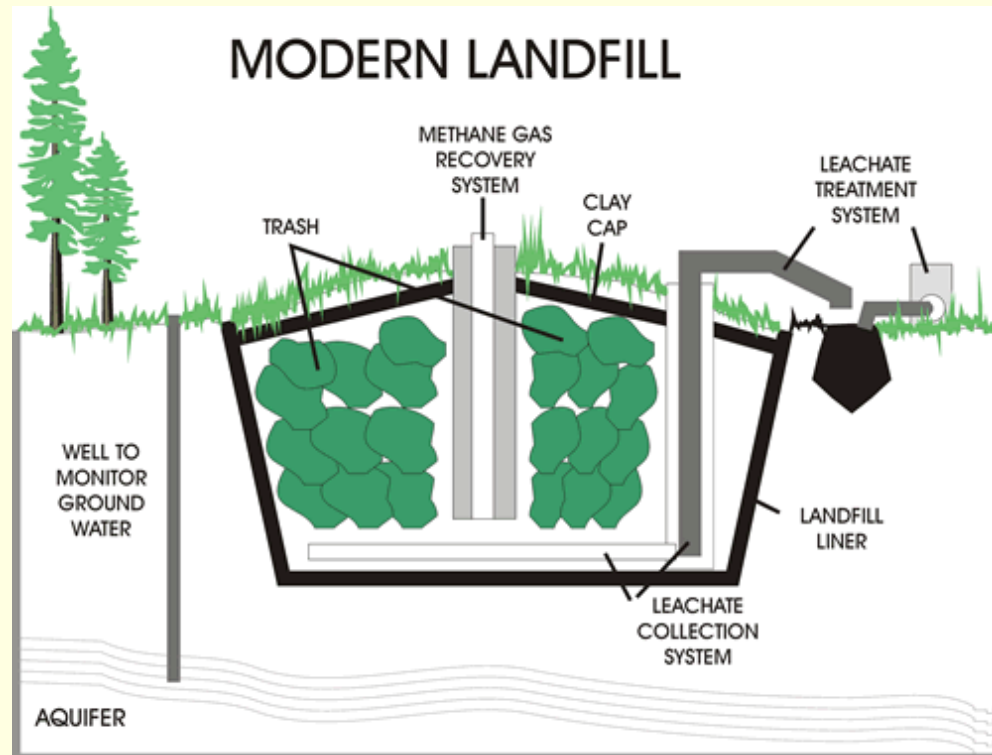
# Biomass Energy

- The most common form of biomass is wood. Wood was the main source of energy until the mid-1800s.
- Biomass can be used to make an energy-rich gas or biogas - like natural gas.
- Biomass can also be turned into a fuel like gasoline - corn and wheat can be made into ethanol.
- Biomass can also be used to make electricity. Many towns, instead of putting the garbage in landfills, they burn it to make electricity.
- Landfills can be a source of energy. Anaerobic bacteria that live in landfills decompose organic waste to produce methane gas.



# Biomass Energy from landfills

- As of 2011, over 550 landfills have operating gas to energy projects in the United States.



# Biomass in Nevada:

## CC Landfill Energy LLC :12.0 MW

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# Biomass energy from animal waste

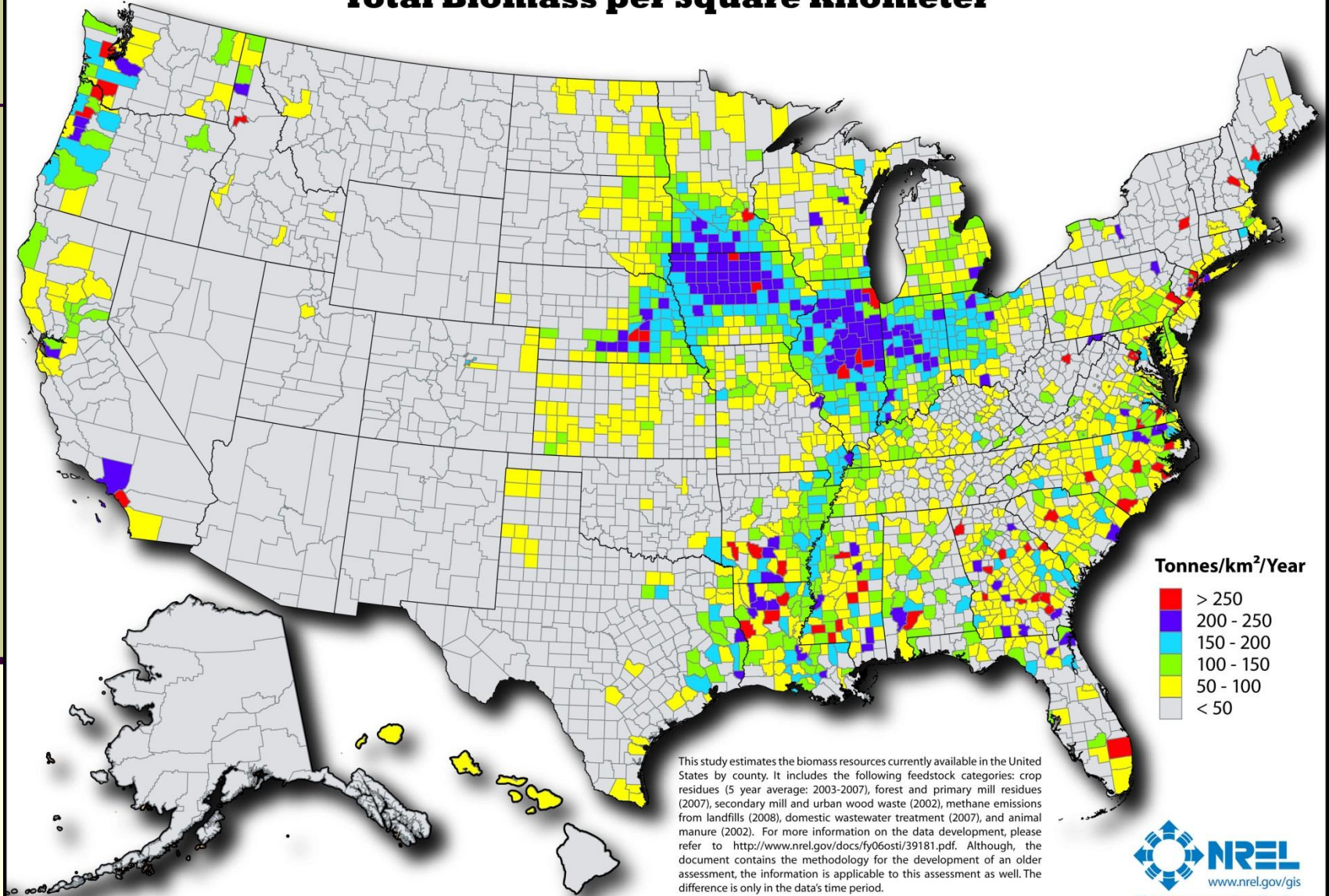
Some farmers produce biogas in large tanks called "digesters" where they put manure and bedding material from their barns. Some cover their manure ponds to capture biogas. Biogas digesters and manure ponds contain the same anaerobic bacteria in landfills.





# Biomass Resources of the United States

## Total Biomass per Square Kilometer

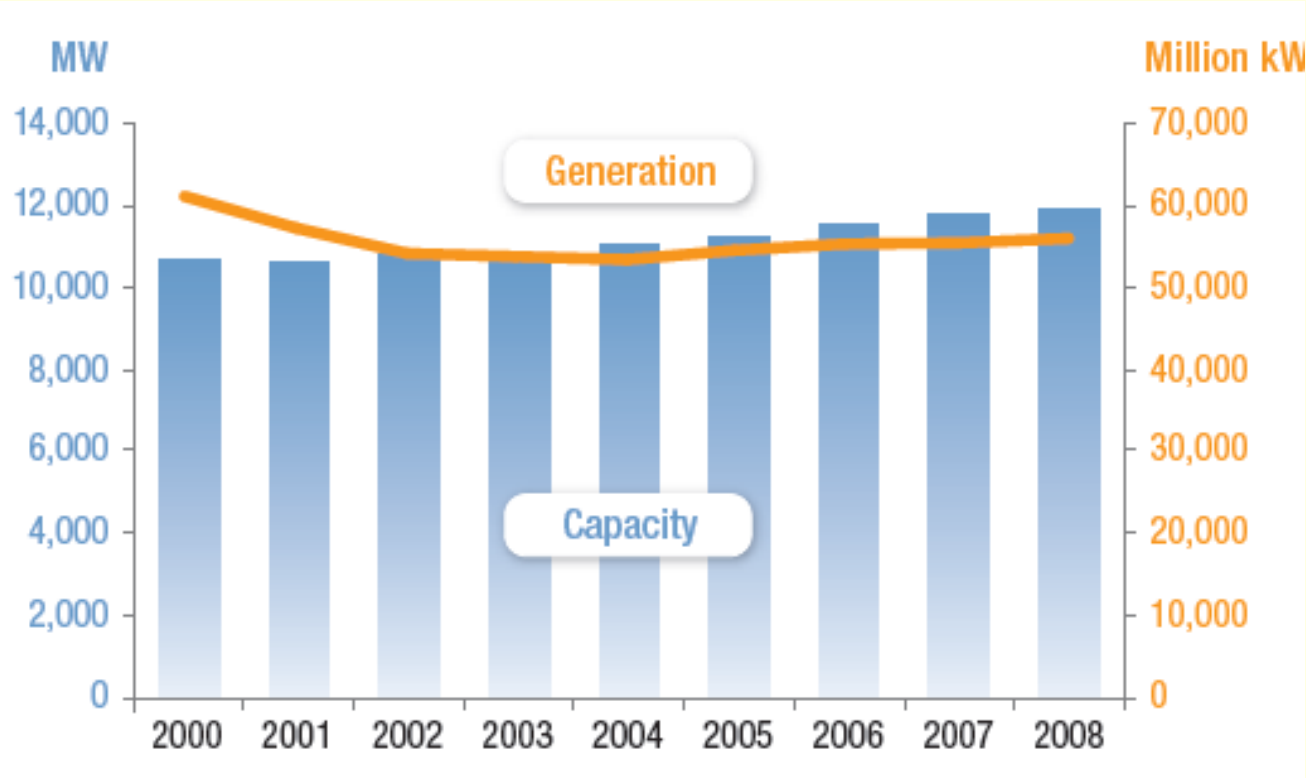


This study estimates the biomass resources currently available in the United States by county. It includes the following feedstock categories: crop residues (5 year average: 2003-2007), forest and primary mill residues (2007), secondary mill and urban wood waste (2002), methane emissions from landfills (2008), domestic wastewater treatment (2007), and animal manure (2002). For more information on the data development, please refer to <http://www.nrel.gov/docs/fy06osti/39181.pdf>. Although, the document contains the methodology for the development of an older assessment, the information is applicable to this assessment as well. The difference is only in the data's time period.

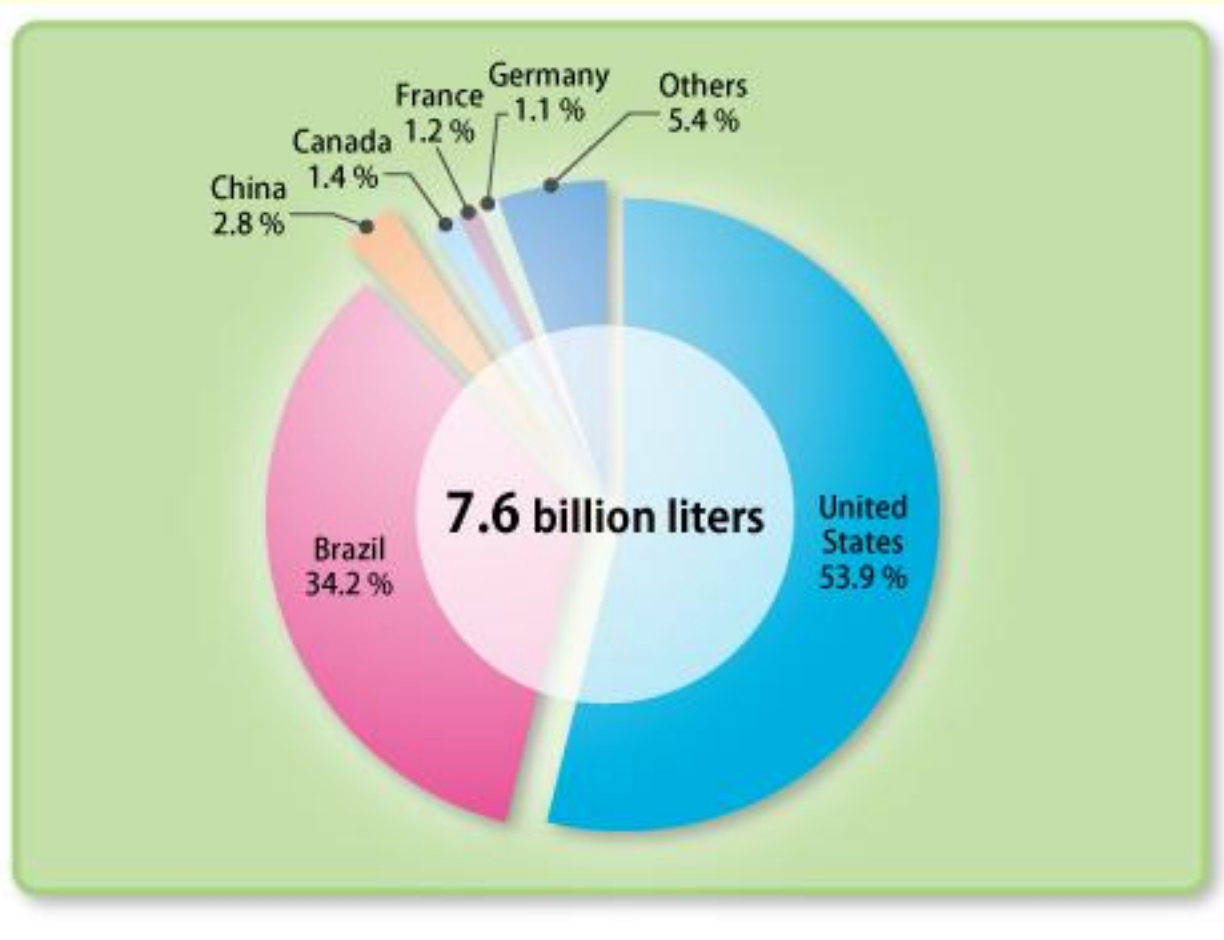


This map was produced by the  
National Renewable Energy Laboratory  
for the U.S. Department of Energy.

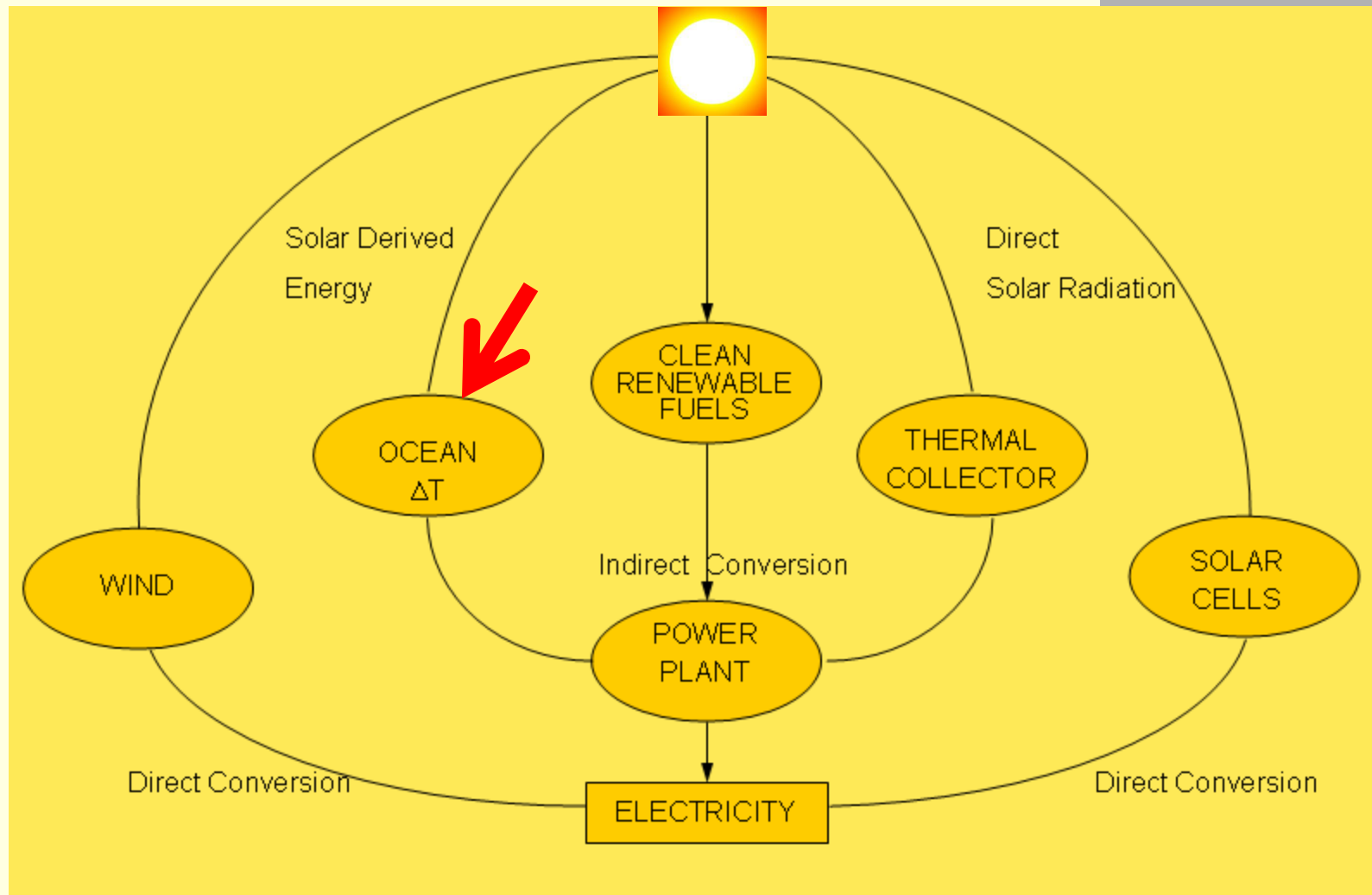
# US Bio-Power capacity



# Biomass – bioethanol production (2011)

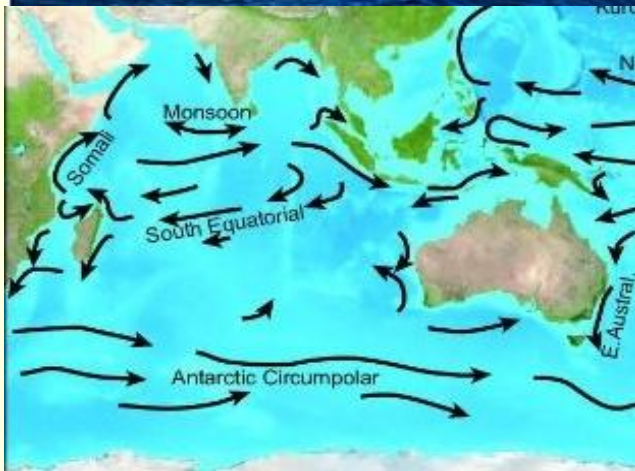


# Electricity production from renewables: Ocean power

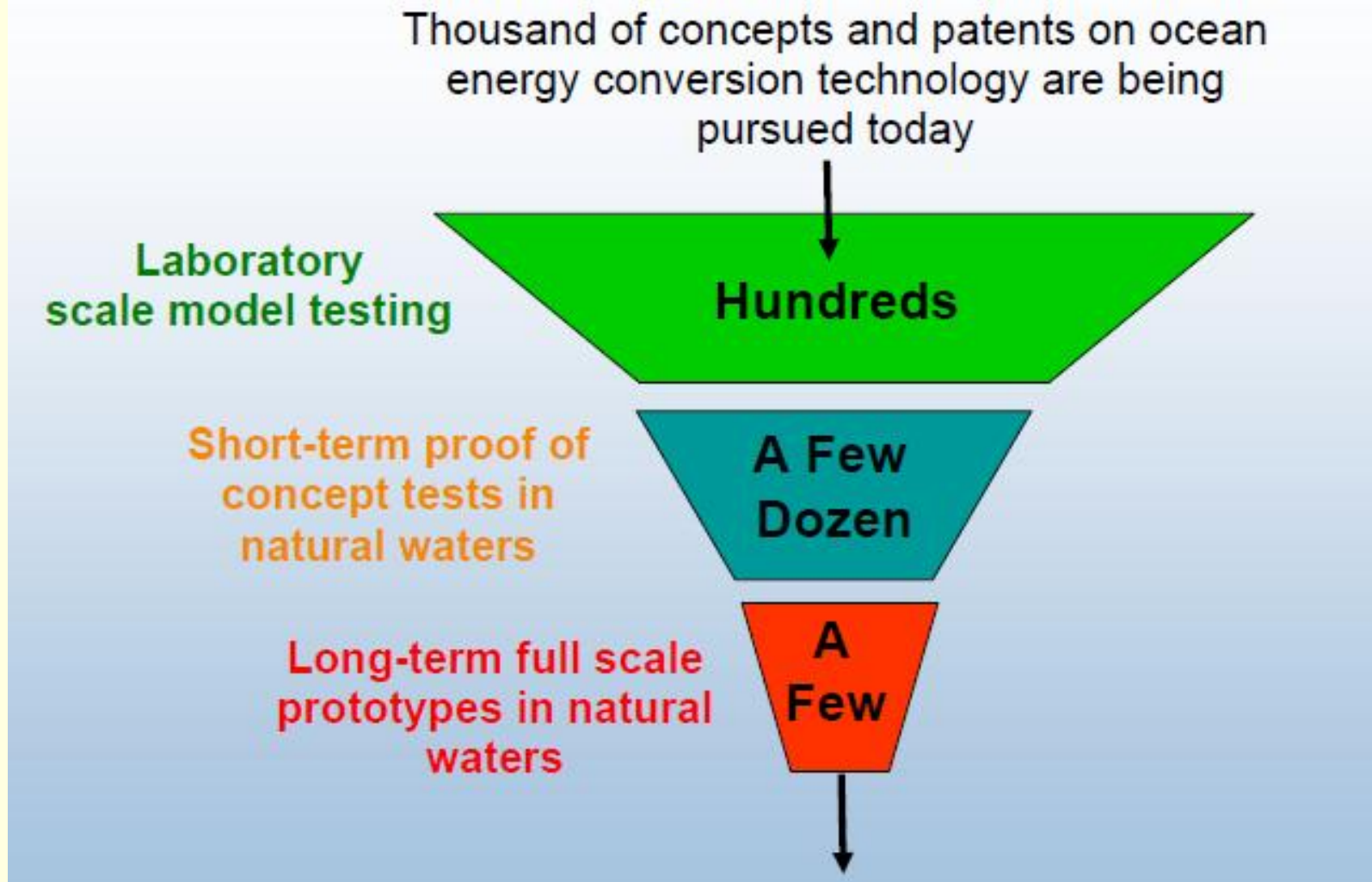


# Ocean Power

- Energy can be extracted from the power of the waves, from the tide, or from ocean currents



# Ocean power – technology development status



# Ocean Power - Waves

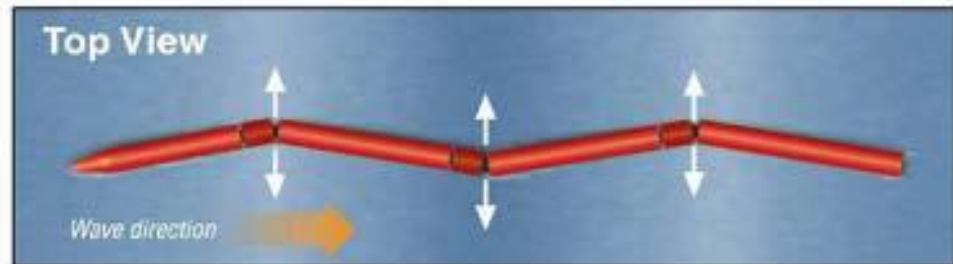
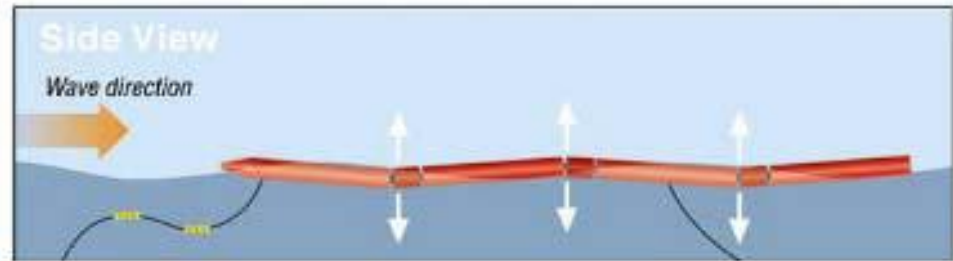
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- A variety of technologies have been proposed to capture the energy from waves. An example of this is the wave farm off the coast of Portugal that opened in 2008.



# Ocean Power - Waves

**Attenuators:** multi-segment floating structures oriented parallel to the direction of the waves. The differing heights of waves along the length of the device causes flexing where the segments connect. This motion is resisted by hydraulic rams which in turn drive electrical generators.

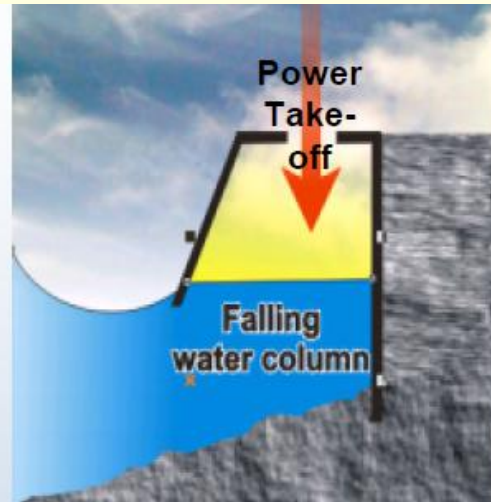
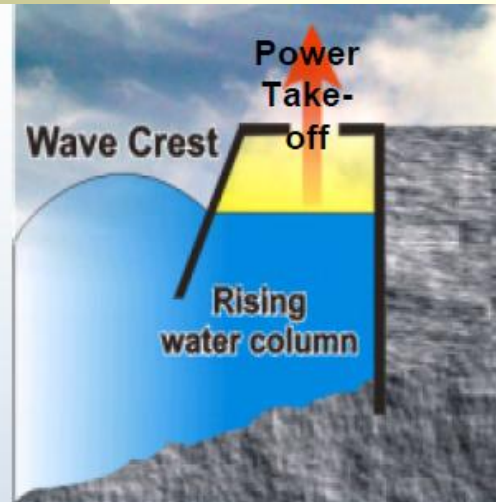


Source: Pelamis Wave Power



# Ocean Power - Waves

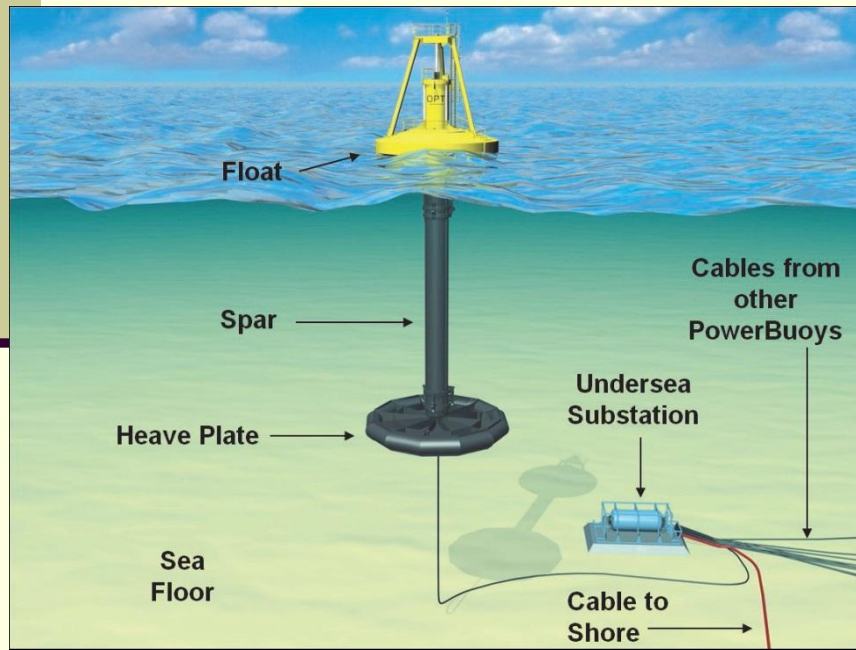
- **Oscillating water column** is a form of terminator in which water enters through a subsurface opening into a chamber with air trapped above it. The wave action causes the captured water column to move up and down like a piston to force the air through an opening connected to a turbine



Source: Oceanlinx, Australia

# Ocean Power - Waves

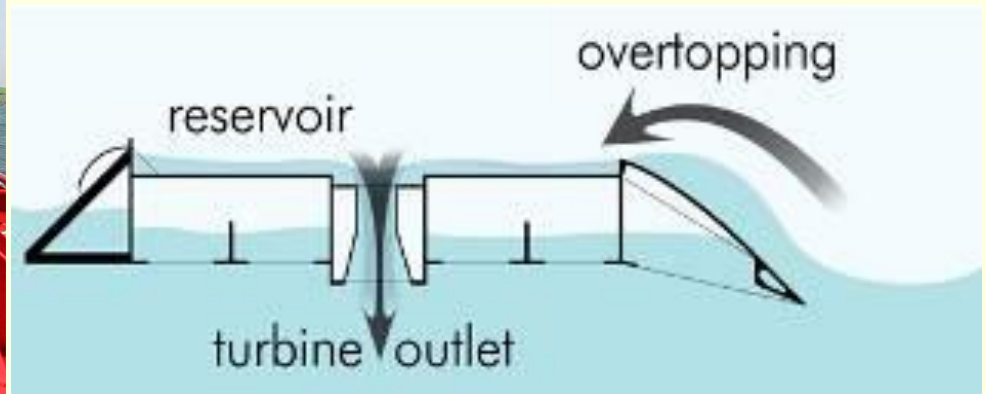
**A point absorber** is a floating structure with components that move relative to each other due to wave action (e.g., a floating buoy inside a fixed cylinder). The relative motion is used to drive electromechanical or hydraulic energy converters.



Source: Ocean Power Technologies

# Ocean Power - Waves

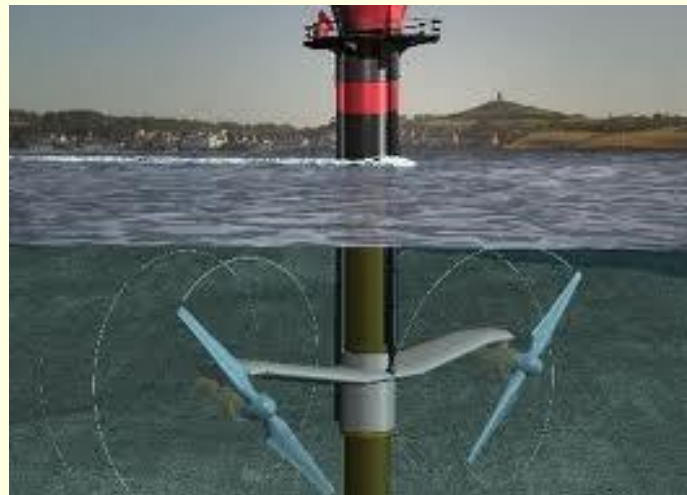
- **An overtopping device** has reservoirs that are filled by incoming waves to levels above the average surrounding ocean. Gravity causes it to fall back toward the ocean surface. The energy of the falling water is used to turn hydro turbines.



Source: Wave Dragon, Danmark

# Ocean Cower - Currents

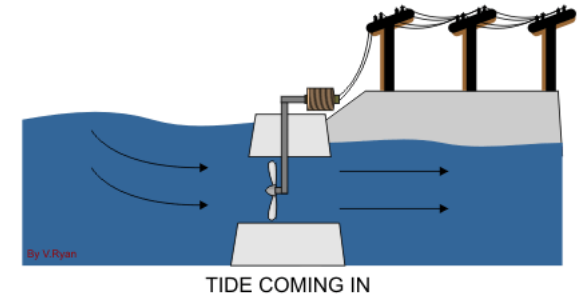
- **Ocean currents** flow in complex patterns affected by the wind, water salinity and temperature, topography of the ocean floor, and the earth's rotation.
- While ocean currents move slowly relative to typical wind speeds, they carry a great deal of energy because of the **density of water** (800 times denser than air).
- Many industrialized countries are pursuing ocean current energy. Technical challenges include prevention of marine growth buildup, and corrosion resistance.



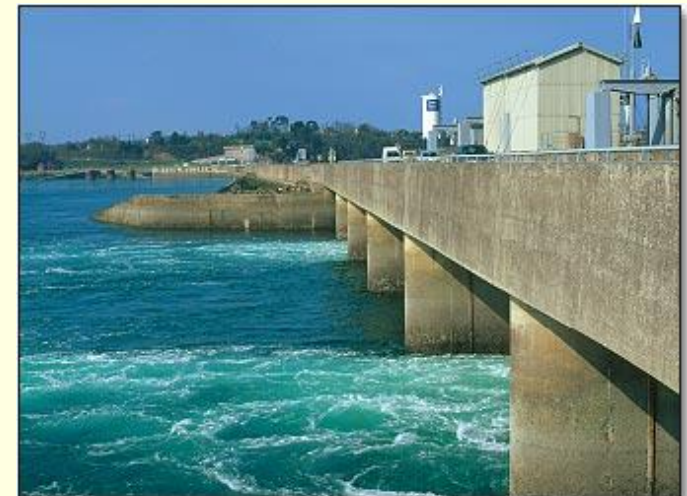
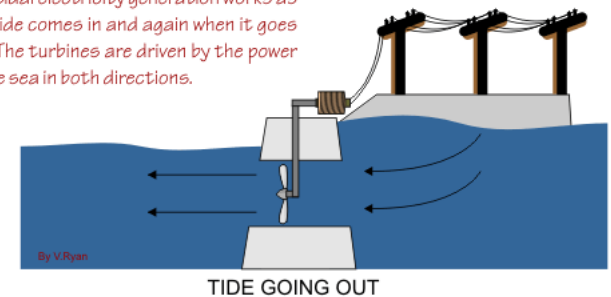
Ocean current power station in Northern Ireland (1.2 MW)

# Ocean power - Tide

- Twice a day enormous volumes of water rise and fall with the tides, and many coastal areas can take advantage of this free energy.
- The tides are the result of the gravitational attraction between the earth and the moon. The strength of the tide is greatly dependent on the earth-moon system.

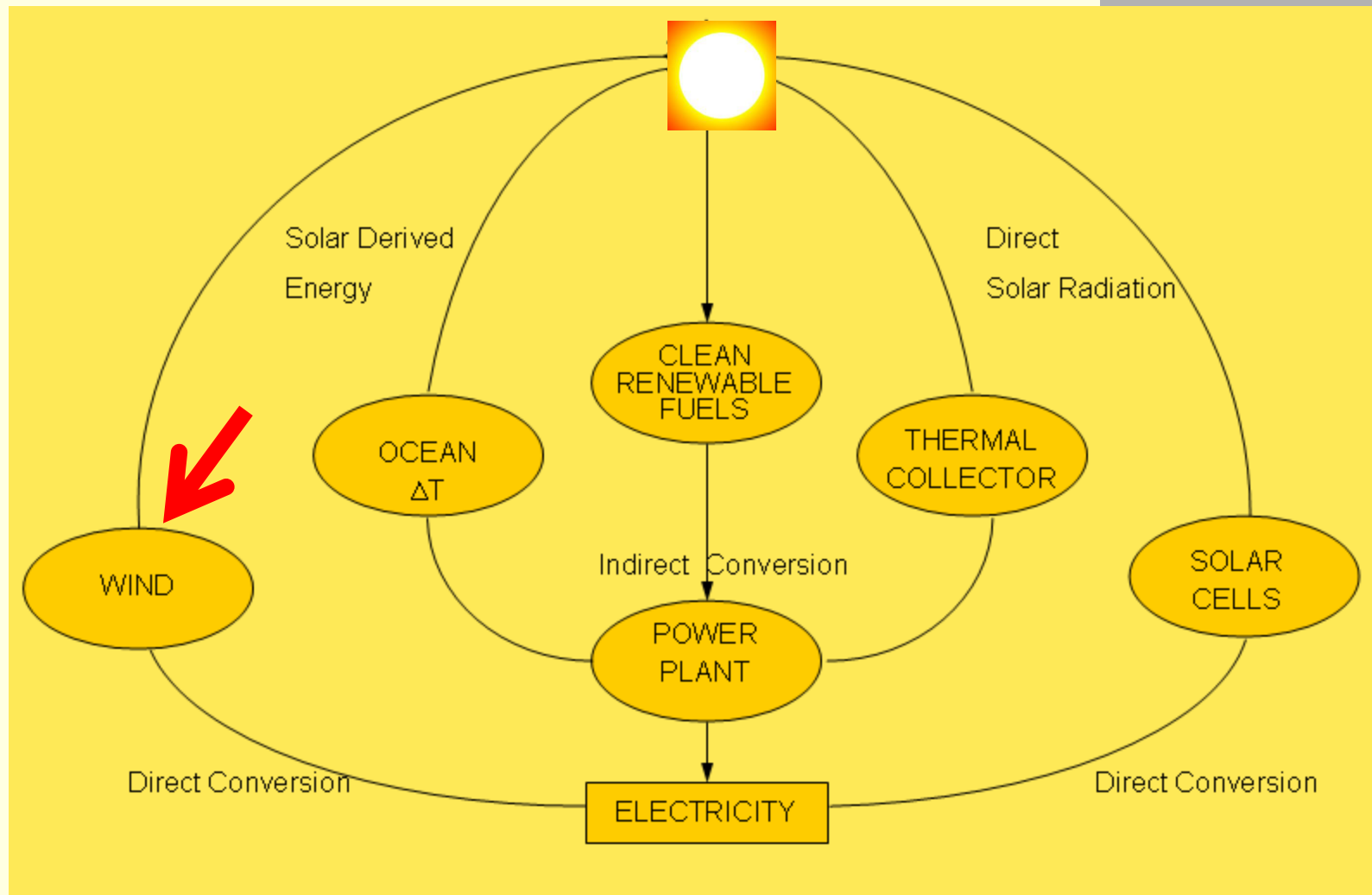


*This tidal electricity generation works as the tide comes in and again when it goes out. The turbines are driven by the power of the sea in both directions.*



Tidal power plant in Brittany, France (240 MW)














# Electricity production from renewables: Wind



# Wind Power ... inland and offshore

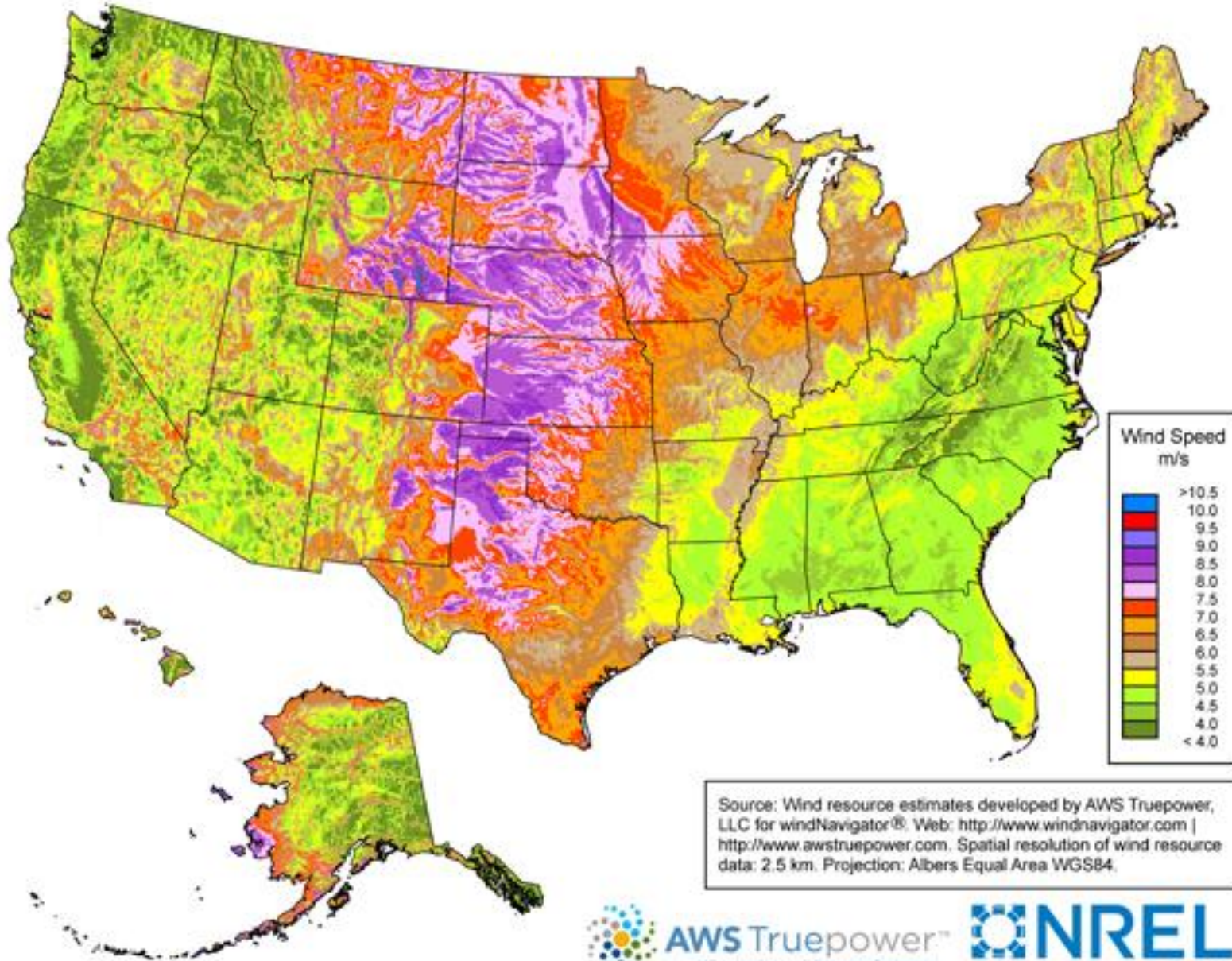


# Installed Wind Capacity by Country (MW)

#	Nation	2005	2006	2007	2008	2009	2010	2011
-	 European Union	40,722	48,122	56,614	65,255	74,919	84,278	93,957
1	 China	1,266	2,599	5,912	12,210	25,104	44,733	62,733
2	 United States	9,149	11,603	16,819	25,170	35,159	40,200	46,919
3	 Germany	18,428	20,622	22,247	23,903	25,777	27,214	29,060
4	 Spain	10,028	11,630	15,145	16,740	19,149	20,676	21,674
5	 India	4,430	6,270	7,850	9,587	10,925	13,064	16,084
6	 France	779	1,589	2,477	3,426	4,410	5,660	6,800
7	 Italy	1,718	2,123	2,726	3,537	4,850	5,797	6,747
8	 United Kingdom	1,353	1,963	2,389	3,288	4,070	5,203	6,540
9	 Canada	683	1,460	1,846	2,369	3,319	4,008	5,265
10	 Portugal	1,022	1,716	2,130	2,862	3,535	3,702	4,083
11	 Denmark	3,132	3,140	3,129	3,164	3,465	3,752	3,871
12	 Sweden	509	571	831	1,067	1,560	2,163	2,970



# US Wind Resource Map



# 2011 Wind Power Market Report

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- 32 percent of all new generating capacity additions were from wind, accounting for 6,800 MW of new generation.
- By the end of 2011, U.S. wind power capacity has grown to 50 GW.
- The country's cumulative installed wind energy capacity has increased more than 18-fold since 2000.
- Six states now meet more than 10 percent of their total electricity needs with wind power.
- 2013 may see a dramatic slowing of domestic wind energy deployment due in part to the possible expiration of federal renewable energy tax incentives, including the Production Tax Credit (PTC).

Source: <http://www1.eere.energy.gov/wind/resources.html>

# Largest wind turbine generator

- Manufacturer: Enercon
- Rated power: 6 MW,
- Rotor diameter: 126 m,
- Total height; 198 m.



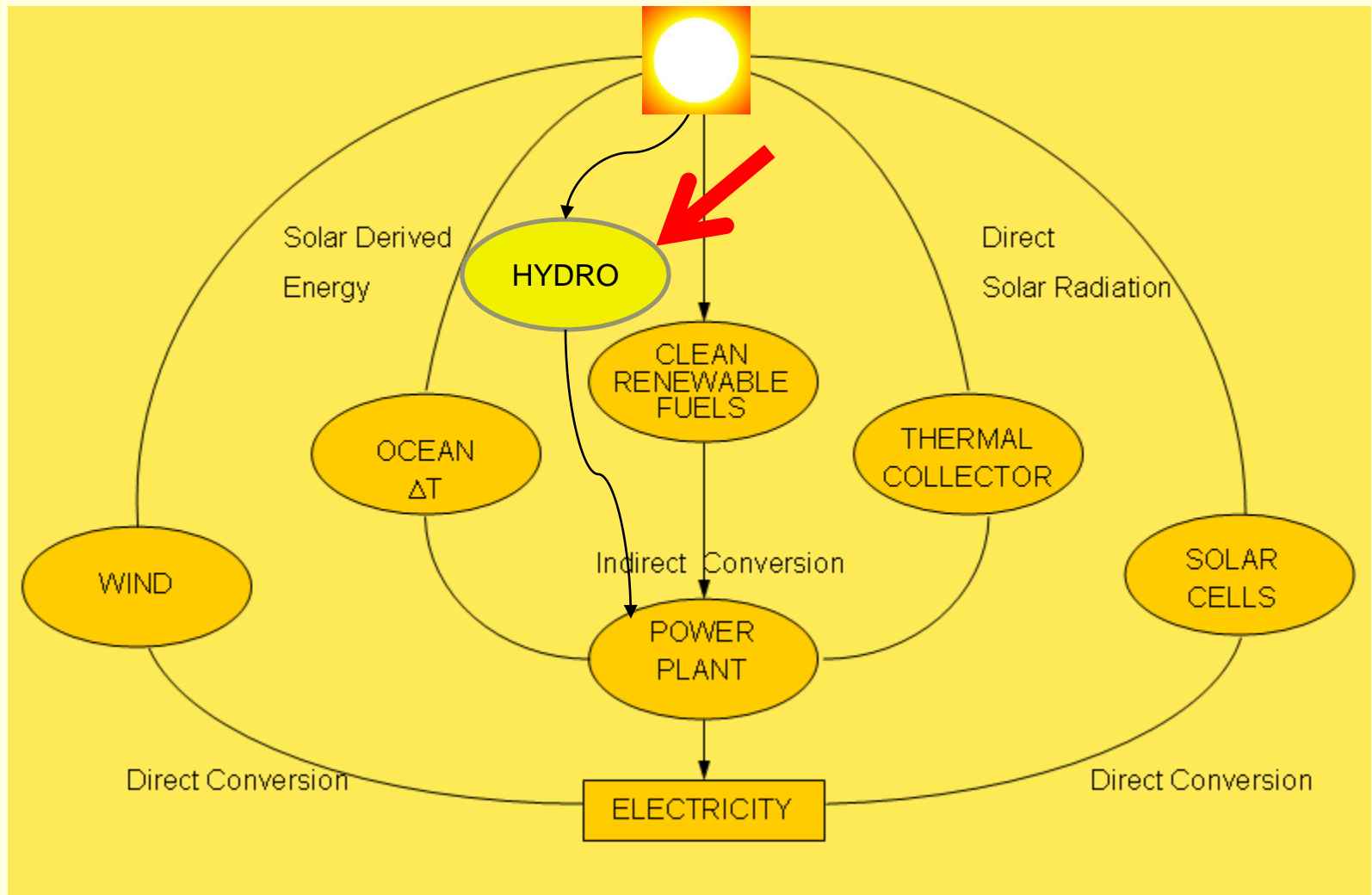
# Wind Power in Nevada:

## Spring Valley Wind (Pine County): 152 MW

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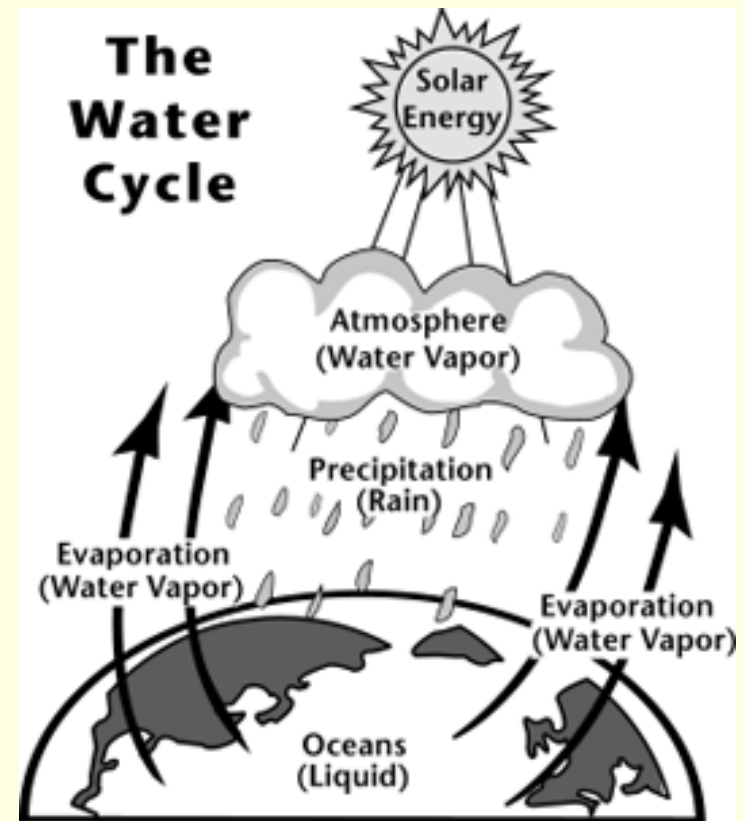


# Electricity production from renewables: hydro



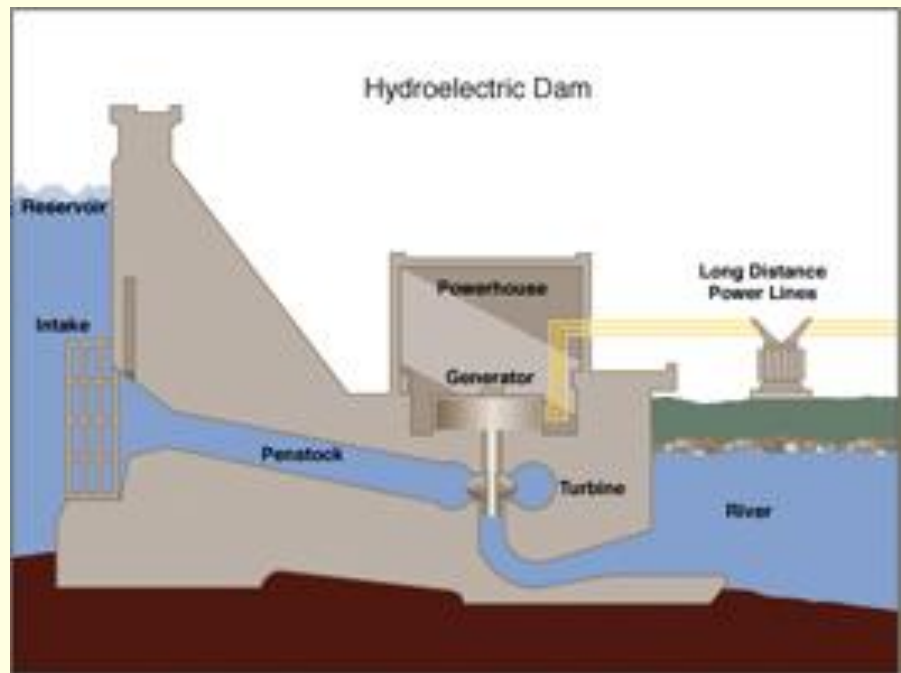
# Hydropower

- Hydropower relies on the water cycle. Herein:
  - Solar energy heats water on the surface, causing it to evaporate.
  - This water vapor condenses into clouds and falls back onto the surface as precipitation (rain, snow, etc.).
  - The water flows through rivers back into the oceans, where it can evaporate and begin the cycle over again



# Hydropower

- The amount of available energy in moving water is determined by its flow rate or fall.
  - Swiftly flowing water in a big river carries a great deal of energy in its flow.
  - Water descending rapidly from a very high point also has lots of energy in its flow.
- In either instance, the water flows through a pipe, or *penstock*, pushes against and turns blades in a turbine to spin a generator to produce electricity.



# Hydropower in the USA

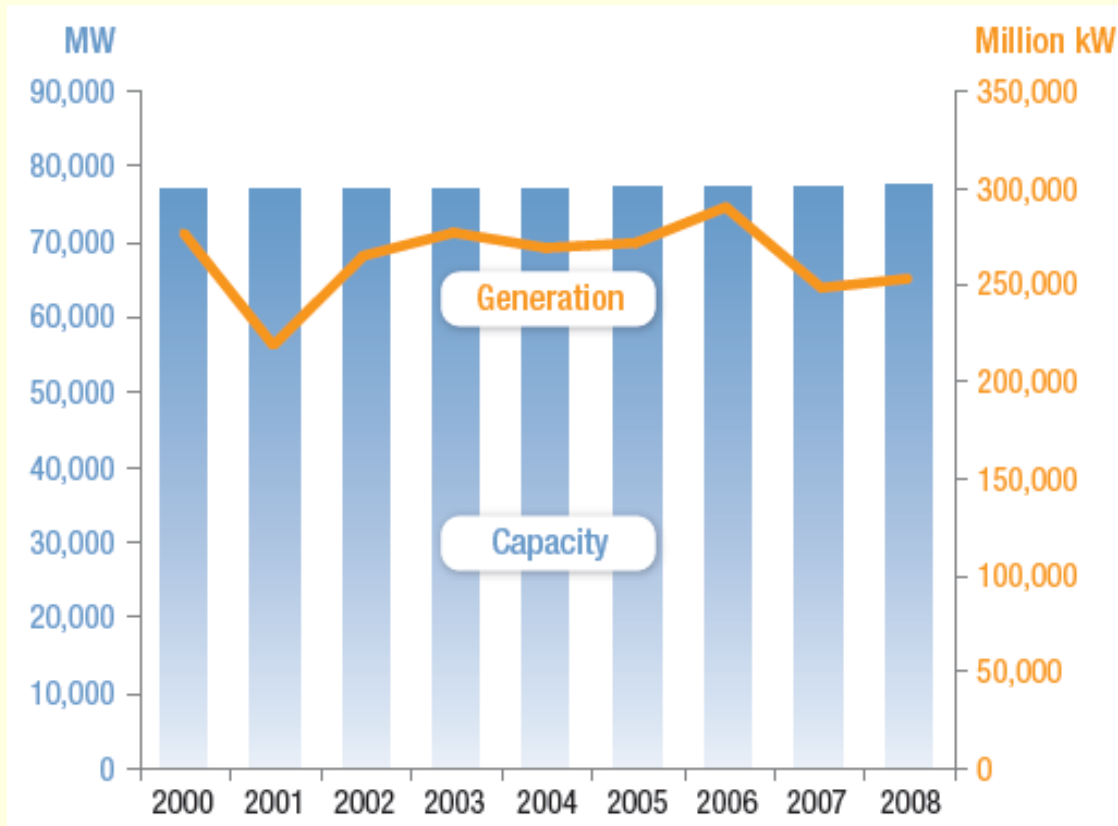
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- Hydropower is the renewable energy source that produces the most electricity in the United States. It accounted for 6% of total U.S. electricity generation and 63% of generation from renewables in 2011.
- Most hydropower is produced at large facilities built by the federal government.
  - Only a small percentage of all dams in the United States produce electricity.
  - Most dams were constructed solely to provide irrigation and flood control.



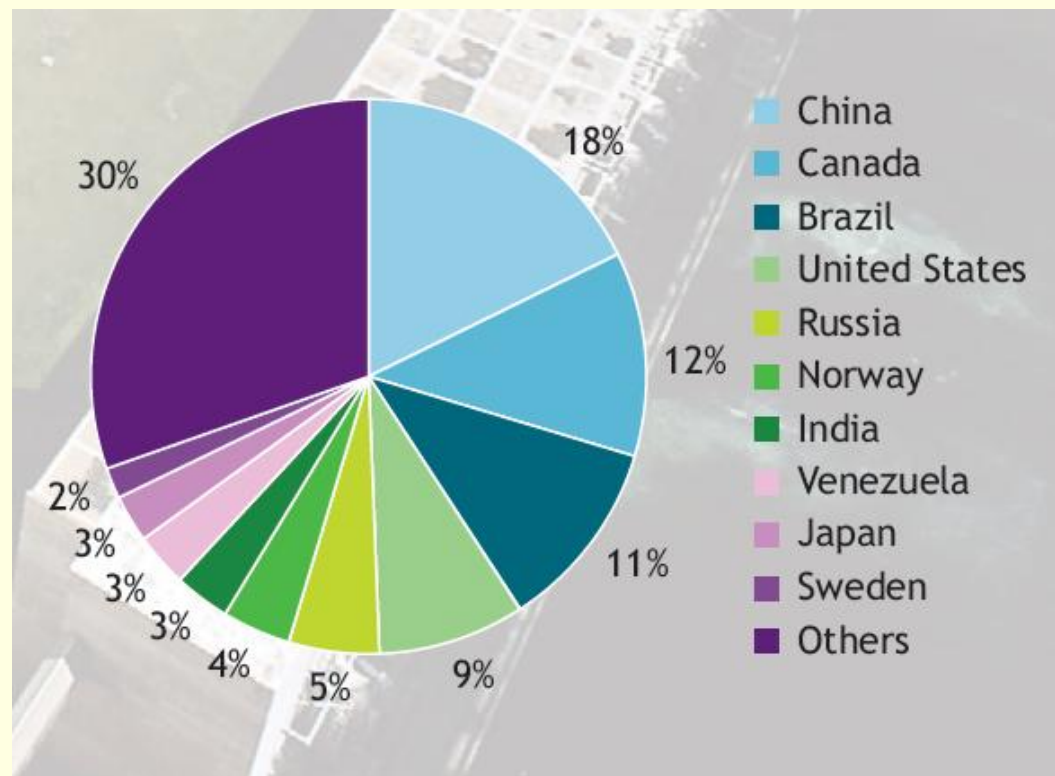
# US Hydropower Capacity

- 345 large plants (>30MW) with a total rating of 67 GW
- Nearly 900 small plants (1-30 MW) with total rating of 10 GW



# Hydropower in the world

- As of 2010, 16.3% of global electricity production is generated from hydropower.
- The Three Gorges Dam in China, has the world's largest generating capacity (22.5 GW), followed by the Itaipu Dam in Brazil (14 GW)



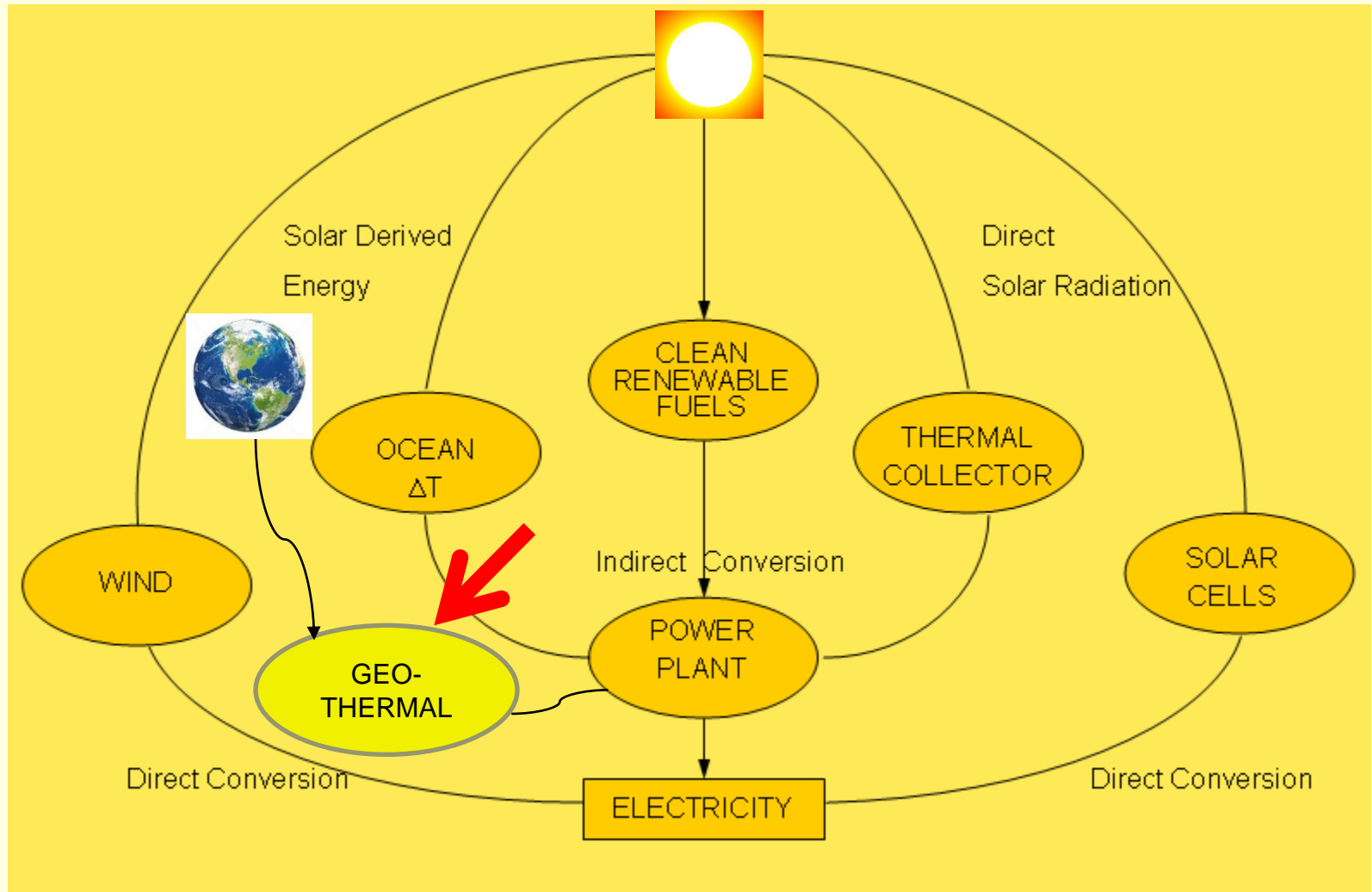
# Small Hydro Power Plants in Nevada:

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- **Fleish: 2.3 MW**
- **Hooper: 0.8 MW**
- **Truckee Carson Irrigation District: 4.0 MW**
- **Verdi: 2.2 MW**
- **Washoe: 2.2 MW**

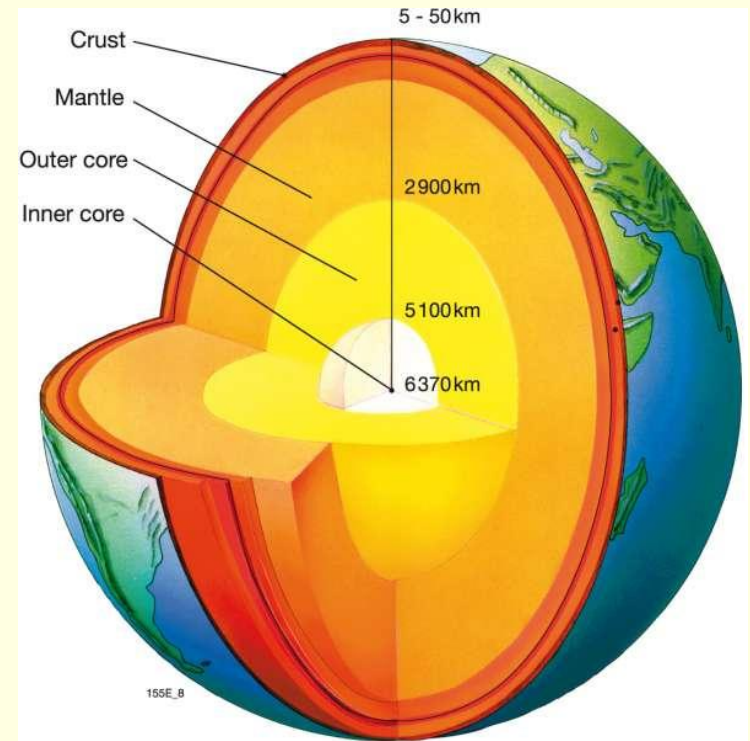


# Electricity production from renewables: geothermal



# Geothermal

- Geothermal energy is generated in the Earth's core. Temperatures hotter than the sun's surface are continuously produced inside the Earth by the slow decay of radioactive particles. The Earth has a number of different layers:
  - A solid inner core and an outer core made of magma (melted rock)
  - The mantle, made up of magma and rock, surrounds the core and is about 1,800 miles thick.
  - The crust is the outermost layer of the Earth, the land that forms the continents and ocean floors. The crust is 15 - 35 miles thick.



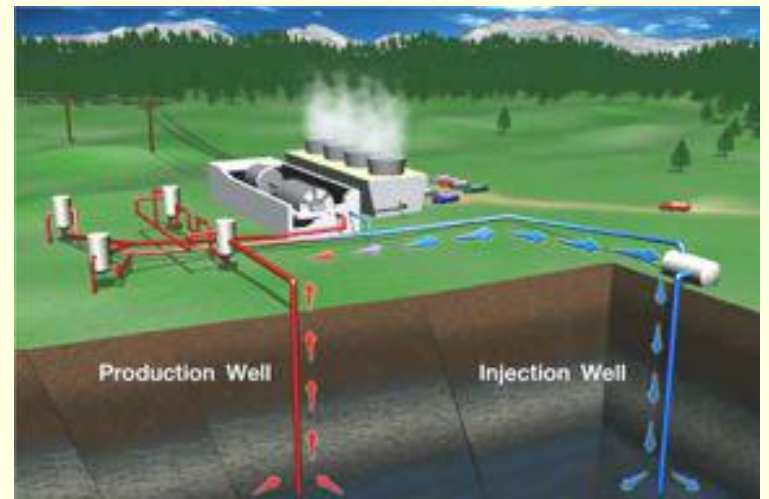
# Geothermal

- Naturally occurring large hydrothermal resources are called **geothermal reservoirs**. Most geothermal reservoirs are deep underground. But geothermal energy sometimes finds its way to the surface in the form of **volcanoes, hot springs** and **geysers**.
- In some cases, geothermal energy is used directly to heat city districts by digging wells and pumping the heated water or steam to the surface. For example, district heating system provides heat for 95% of the buildings in Reykjavik, Iceland.



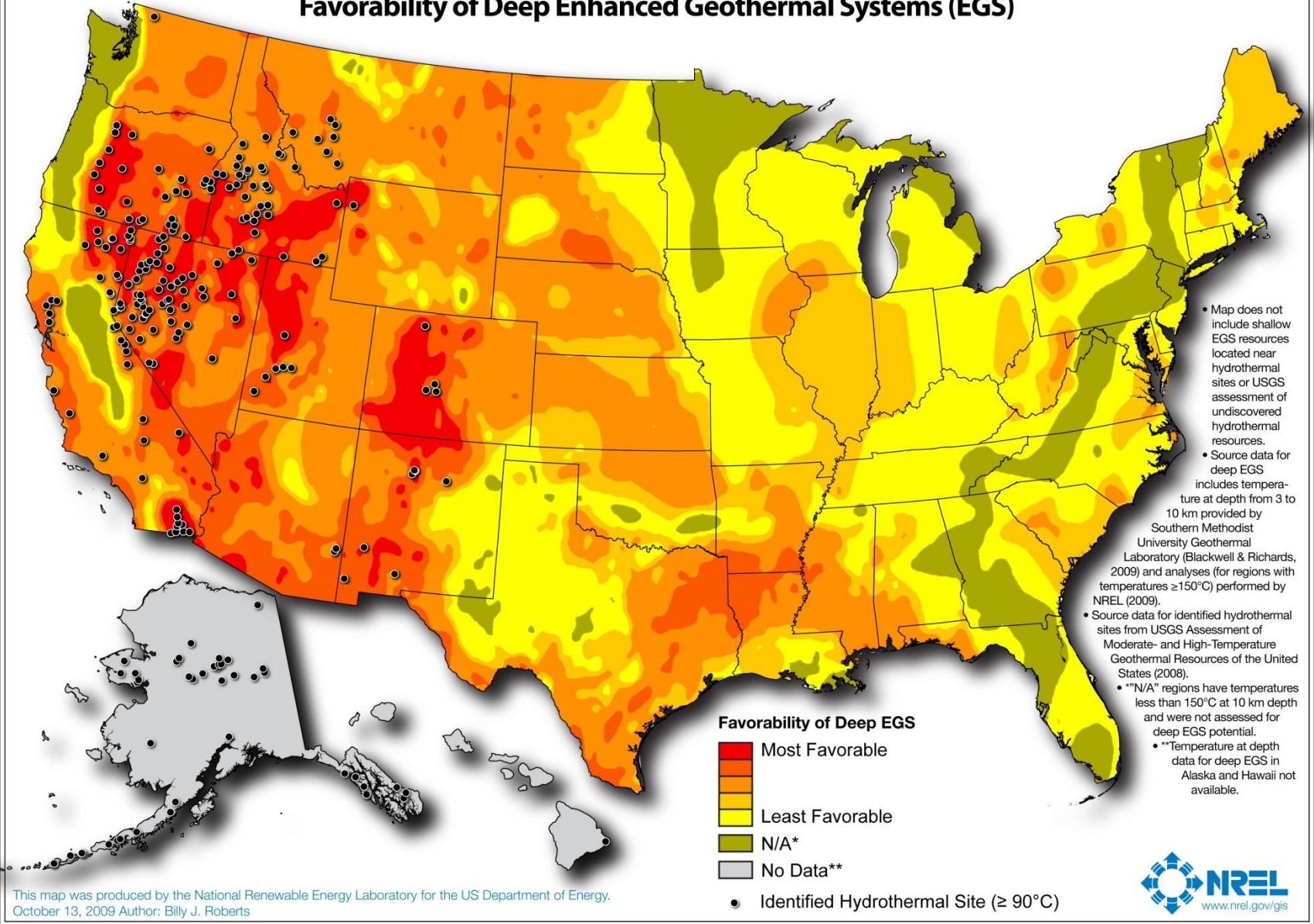
# Geothermal

- **Dry steam plants** use steam piped directly from a geothermal reservoir to turn the generator turbines. The first geothermal power plant was built in 1904 in Tuscany, Italy.
- **Flash steam plants** take high-pressure hot water from deep inside the Earth and convert it to steam to drive the generator turbines. When the steam cools, it condenses to water and is injected back into the ground to be used over and over again.



# Geothermal Resource of the United States

## Locations of Identified Hydrothermal Sites and Favorability of Deep Enhanced Geothermal Systems (EGS)



This map was produced by the National Renewable Energy Laboratory for the US Department of Energy.  
October 13, 2009 Author: Billy J. Roberts



# Top Counties with Geothermal Resources

Geothermal electricity production		Geothermal direct use	
Country	GWh/yr	Country	GWh/yr*
United States	16 603	China	20 932
Philippines	10 311	United States	15 710
Indonesia	9 600	Sweden	12 585
Mexico	7 047	Turkey	10 247
Italy	5 520	Japan	7 139
Iceland	4 597	Norway	7 000
New Zealand	4 055	Iceland	6 768
Japan	3 064	France	3 592
Kenya	1 430	Germany	3 546
El Salvador	1 422	Netherlands	2 972
Costa Rica	1 131	Italy	2 762
Turkey	490	Hungary	2 713
Papua New Guinea	450	New Zealand	2 654
Russia	441	Canada	2 465
Nicaragua	310	Finland	2 325

Source: OECD/IEA, 2010

# Geothermal in Nevada:

Current Capacity: 385 MW  
(+ 150 MW in construction or development stage).

## GEOHERMAL

- |   |   |  |
|---|---|--|
| <b>1</b> Beowawe Power<br>17.7 MW                     | <b>8</b> Galena 3<br>26.5 MW                              | <b>16</b> Soda Lake II<br>19.5 MW                                    |
| <b>2</b> Brady Geothermal Project<br>24.0 MW          | <b>9</b> Homestretch<br>2.1 MW                            | <b>17</b> Steamboat Hills<br>14.6 MW                                 |
| <b>3</b> Clayton Valley 1<br>● 53.5 MW                | <b>10</b> Jersey Valley Geothermal Project<br>22.5 MW     | <b>18</b> Steamboat IA<br>2.0 MW                                     |
| <b>4</b> Desert Peak Geothermal Project #2<br>25.0 MW | <b>11</b> McGinness Hills<br>48.0 MW                      | <b>19</b> Steamboat II<br>13.4 MW                                    |
| <b>5</b> Dixie Meadows<br>● 51.0 MW                   | <b>12</b> Richard Burdette Generation Facility<br>26.0 MW | <b>20</b> Steamboat III<br>13.4 MW                                   |
| <b>6</b> Faulkner 1<br>49.5 MW                        | <b>13</b> Salt Wells<br>23.6 MW                           | <b>21</b> Stillwater 2<br>47.2 MW<br>(Photovoltaic Addition 22.0 MW) |
| <b>7</b> Galena 2<br>13.0 MW                          | <b>14</b> San Emidio<br>11.8 MW                           | <b>22</b> Tuscarora (aka Hot Sulfur Springs 2)<br>32.0 MW            |
| <b>15</b> Soda Lake I<br>3.6 MW                       |   |  |

● In development or in construction



# End!

