

# Photovoltaic Systems Engineering

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Reference for this lecture:

International Energy related websites

Wikipedia

## Lecture 2

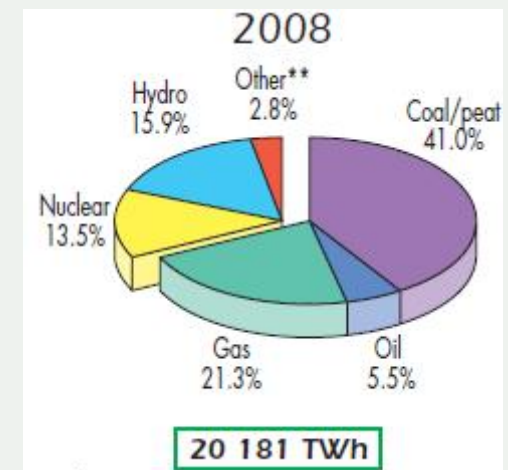
**Renewable energy** is energy which comes from natural resources such as sunlight, wind, rain, tides, and geothermal heat, which are renewable (naturally replenished).

About 16% of global final energy consumption comes from renewables,

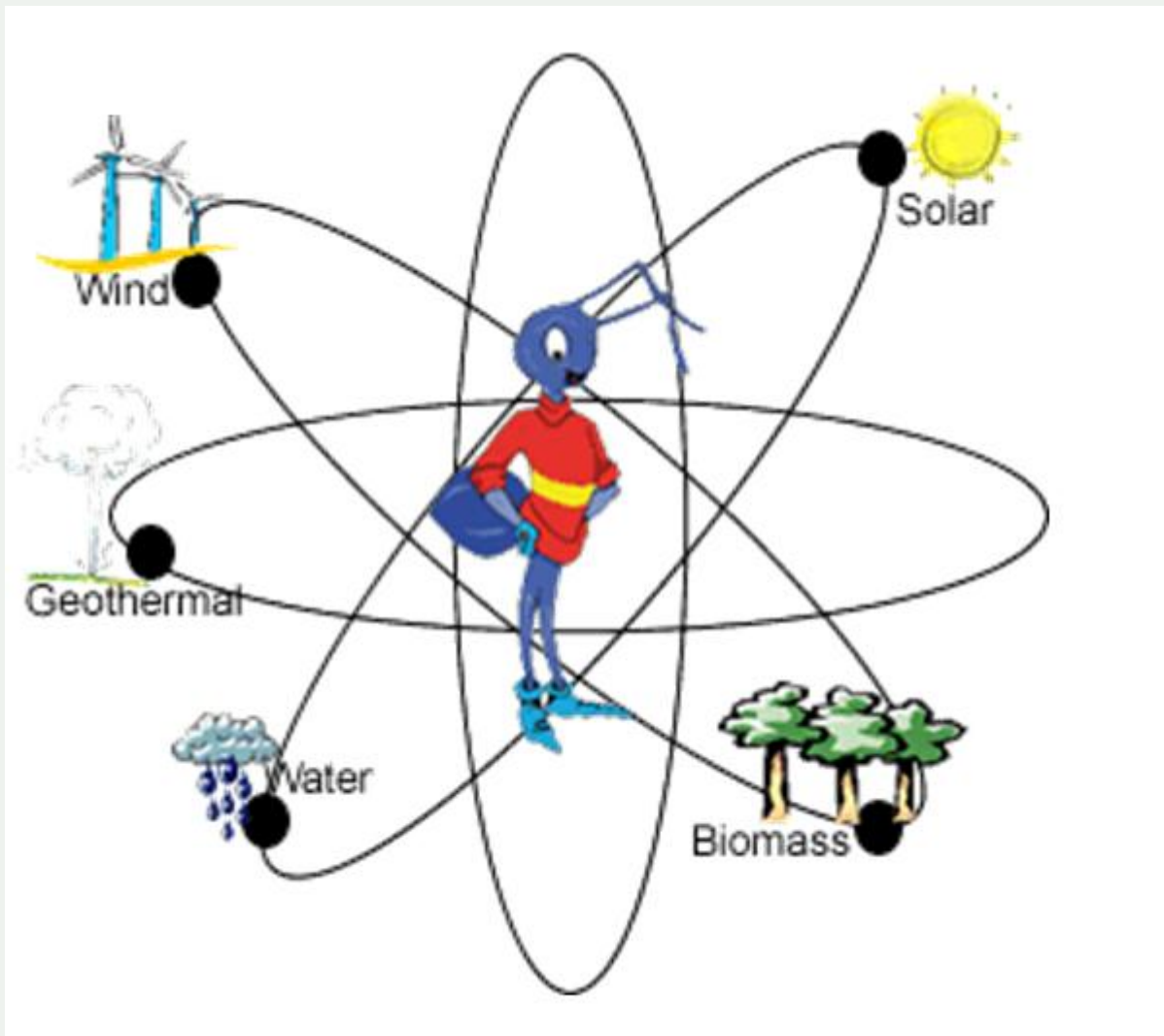
- 10%: traditional biomass, mainly used for heating,
- 3.4% : hydroelectricity
- Around 3%: small hydro, modern biomass, wind, solar, geothermal, and biofuels.

About 19% of global electricity coming from

- 16% global electricity coming from hydroelectricity
- 3% from new renewables.



# Renewable energy



## Biomass

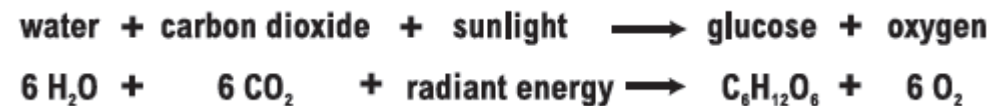


# Biomass

## What is Biomass?

Biomass is any organic matter such as wood, crops, seaweed, animal wastes, that can be used as an energy source. Biomass is probably our oldest source of energy after the sun. For thousands of years, people have burned wood to heat their homes and cook their food.

During a process called **photosynthesis**, sunlight gives plants the energy they need to convert water and carbon dioxide into oxygen and sugars.



These sugars, called **carbohydrates** ( $\text{C}_x(\text{H}_2\text{O})_y$ ), supply plants and the animals that eat plants with energy. Foods rich in carbohydrates are a good source of energy for the human body!

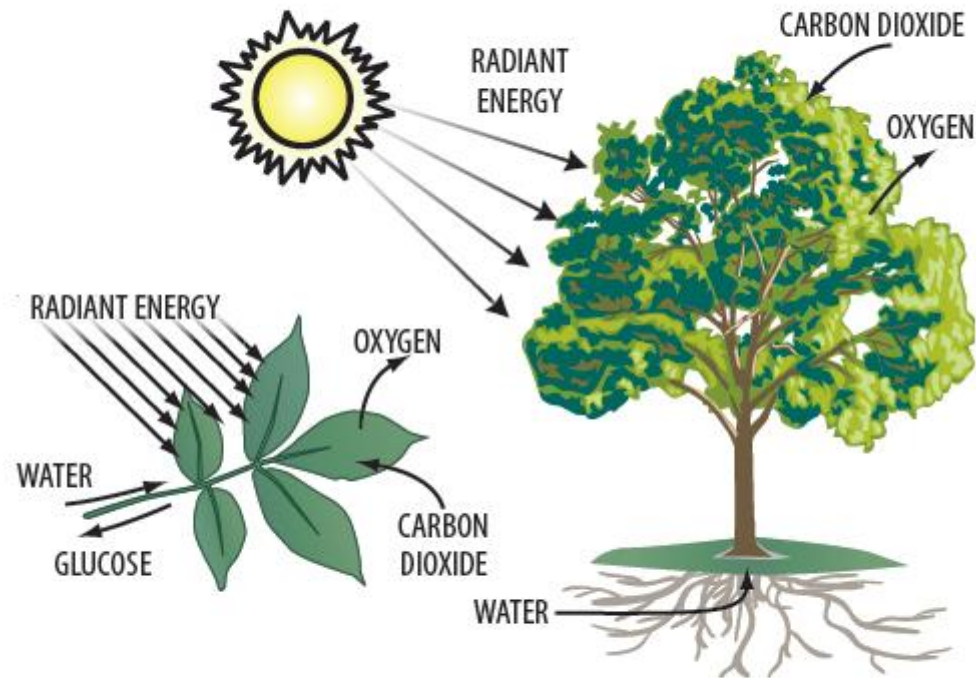


# Photosynthesis

**water + carbon dioxide + sunlight → glucose + oxygen**



In the process of photosynthesis, plants convert radiant energy from the sun into chemical energy in the form of glucose (or sugar).



**glucose + oxygen → water + carbon dioxide + energy**



# Biomass

## Types of Biomass

- ❖ **Wood and Agricultural Products**
- ❖ **Solid Waste**
- ❖ **Landfill Gas**

Bacteria and fungi are not picky eaters. A fungus on a rotting log is converting cellulose to sugars to feed itself. Although this process is slowed in a landfill, a substance called methane gas is still produced as the waste decays.

- ❖ **BioFuels**
  - **Ethanol**
  - **Biodiesel**
  - **Biogas**

# Biomass potential in Iran

## Iran and World Energy Facts and Figures

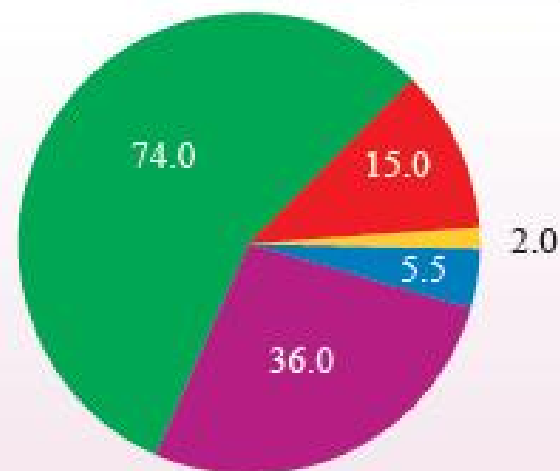
### Biomass Potential of Iran <sup>(1)</sup>

پتانسیل زیست توده در ایران <sup>(1)</sup>

(Mboe)

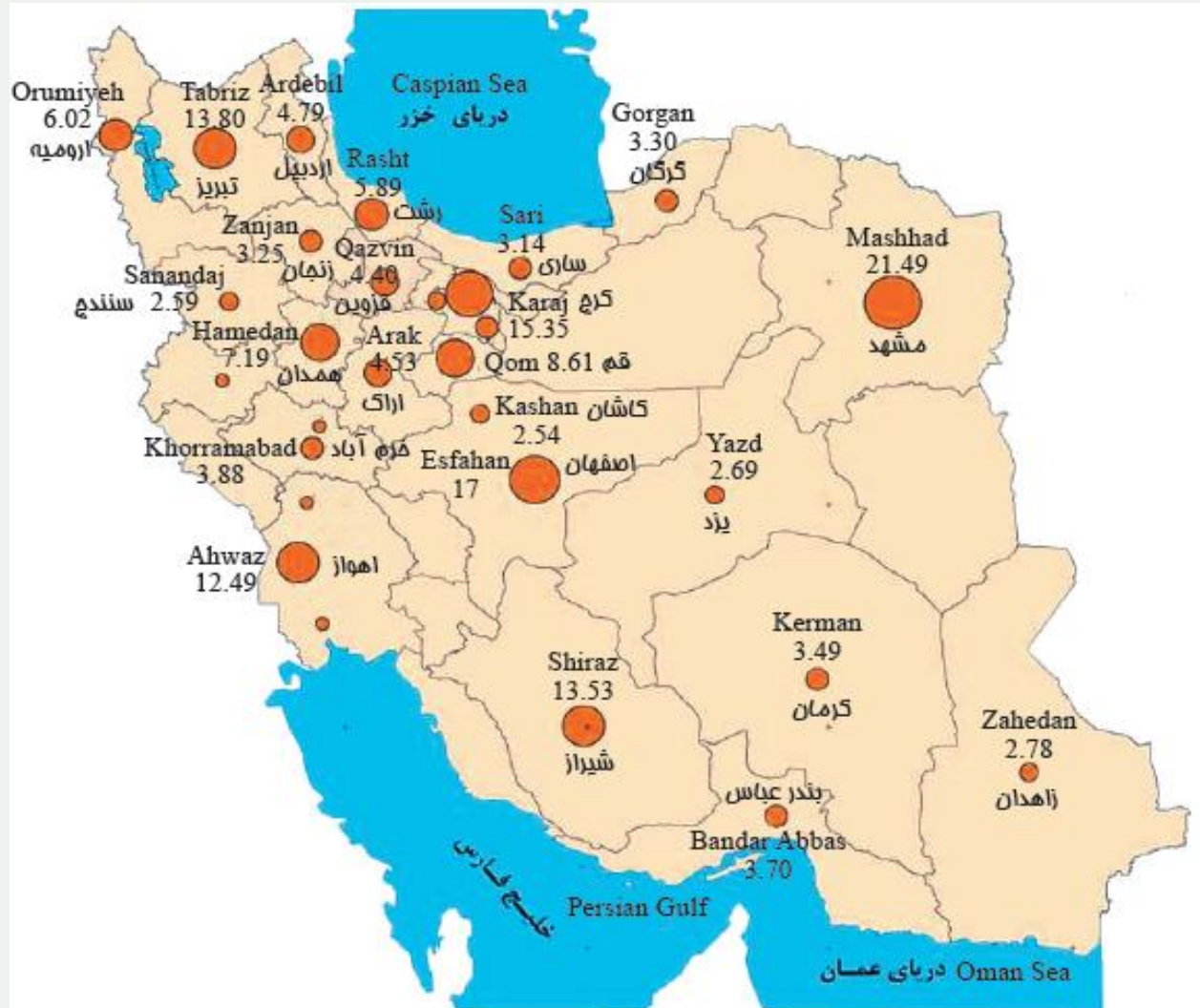
(میلیون بشکه معادل نفت خام)

- Vegetal Wastes ■ زایدات کشاورزی و جنگلی
- Animal Wastes ■ فضولات دامی
- Industrial Sewages ■ فاضلاب های صنعتی
- Municipal Sewages ■ فاضلاب های شهری
- Municipal Wastes ■ زباله های شهری



Iran around 200 Mtoe in 2008

# Maximum Actual Energy Potential from Urban Residuals





# Biomass

## BioFuels: Iran

### Biofuel

Name	Location	Capacity	Type	Notes
Shiraz Biogas Power Plant	Fars Province	1.1 MW	Biogas Power Plant	The plant uses organic waste as fuel for production of electricity
Mashhad Biogas Power Plant	Fars Province	0.65 MW	Biogas Power Plant	The plant uses organic waste as fuel for production of electricity

# Biomass

## BioFuels

### ➤ Ethanol

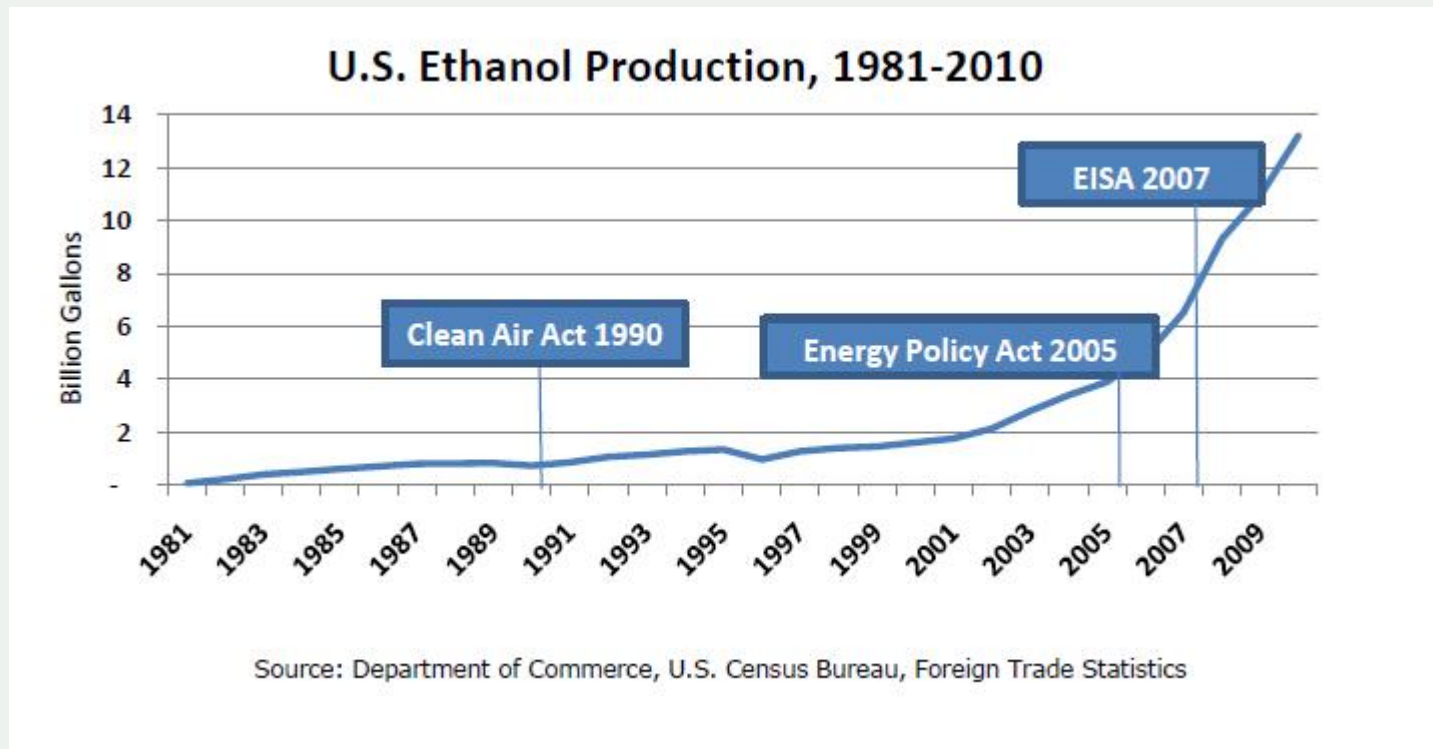
Ethanol is an alcohol fuel (ethyl alcohol) made by fermenting the sugars and starches found in plants and then distilling them. Any organic material containing cellulose, starch, or sugar can be made into ethanol.

New technologies are producing ethanol from cellulose in woody fibers from trees, grasses, and crop residues.

- ❑ Nearly all of the gasoline sold in the U.S. are E10.
- ❑ E85 is an alternative fuel.
- ❑ There are about seven million flexible fuel vehicles (FFV).
- ❑ 6% use E85.
- ❑ More than 2,000 E85 fueling stations in 46 states.
- ❑ **But unfortunately use of corn ethanol would result in little to no CO<sub>2</sub> reductions in the near future.**

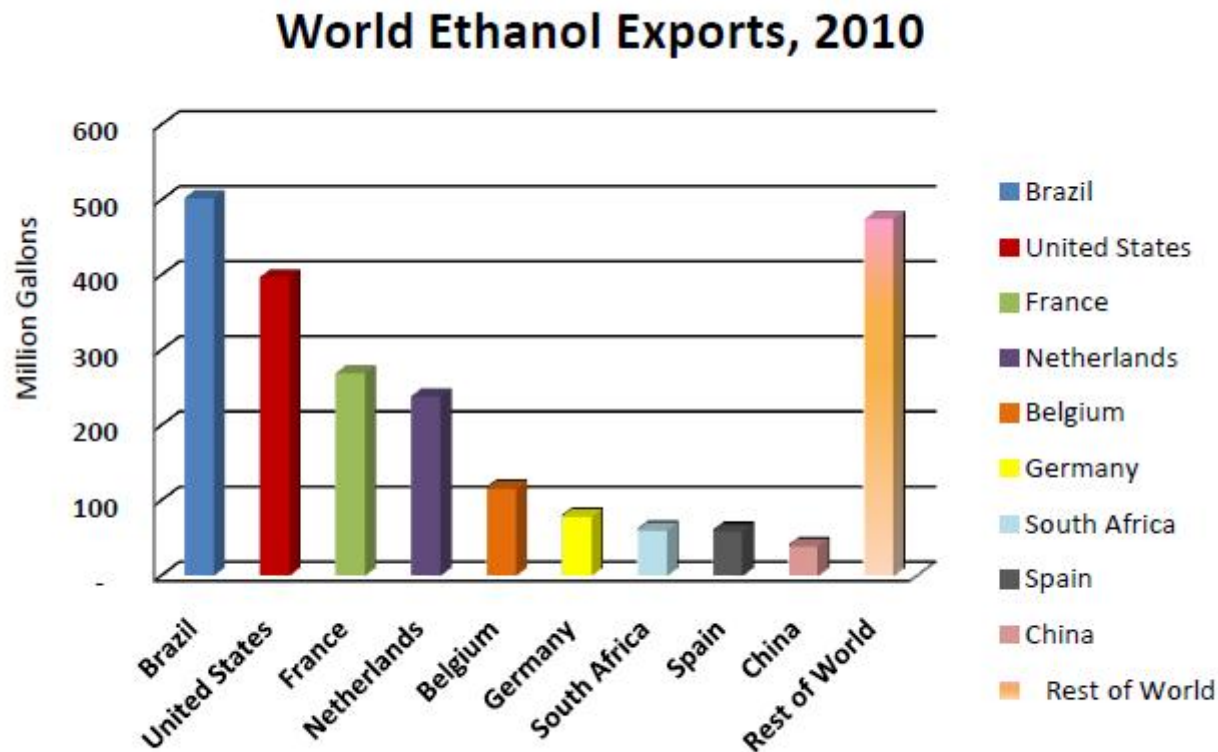
# Biomass

## BioFuels: U.S. Ethanol production in 2010



# Biomass

## BioFuels: World Ethanol Exports, 2010



Source: National Statistics Compiled by Global Trade Information Services (GTIS)



# Biomass

## BioFuels

### ➤ Biodiesel

Biodiesel is a fuel made by chemically reacting alcohol with vegetable oils, animal fats, or greases, such as recycled restaurant grease. Most biodiesel today is made from soybean oil.

Biodiesel is most often blended with petroleum diesel in ratios of two percent (B2), five percent (B5), or 20 percent (B20). It can also be used as neat (pure) biodiesel (B100).

**Compared to diesel, the production and use of soybean biodiesel would result in little to no CO<sub>2</sub> reductions in the near future.**

By comparison, the production of and use of biodiesel from recycled waste oils could reduce CO<sub>2</sub> emissions by over 80 percent compared to petroleum diesel.

# Biomass

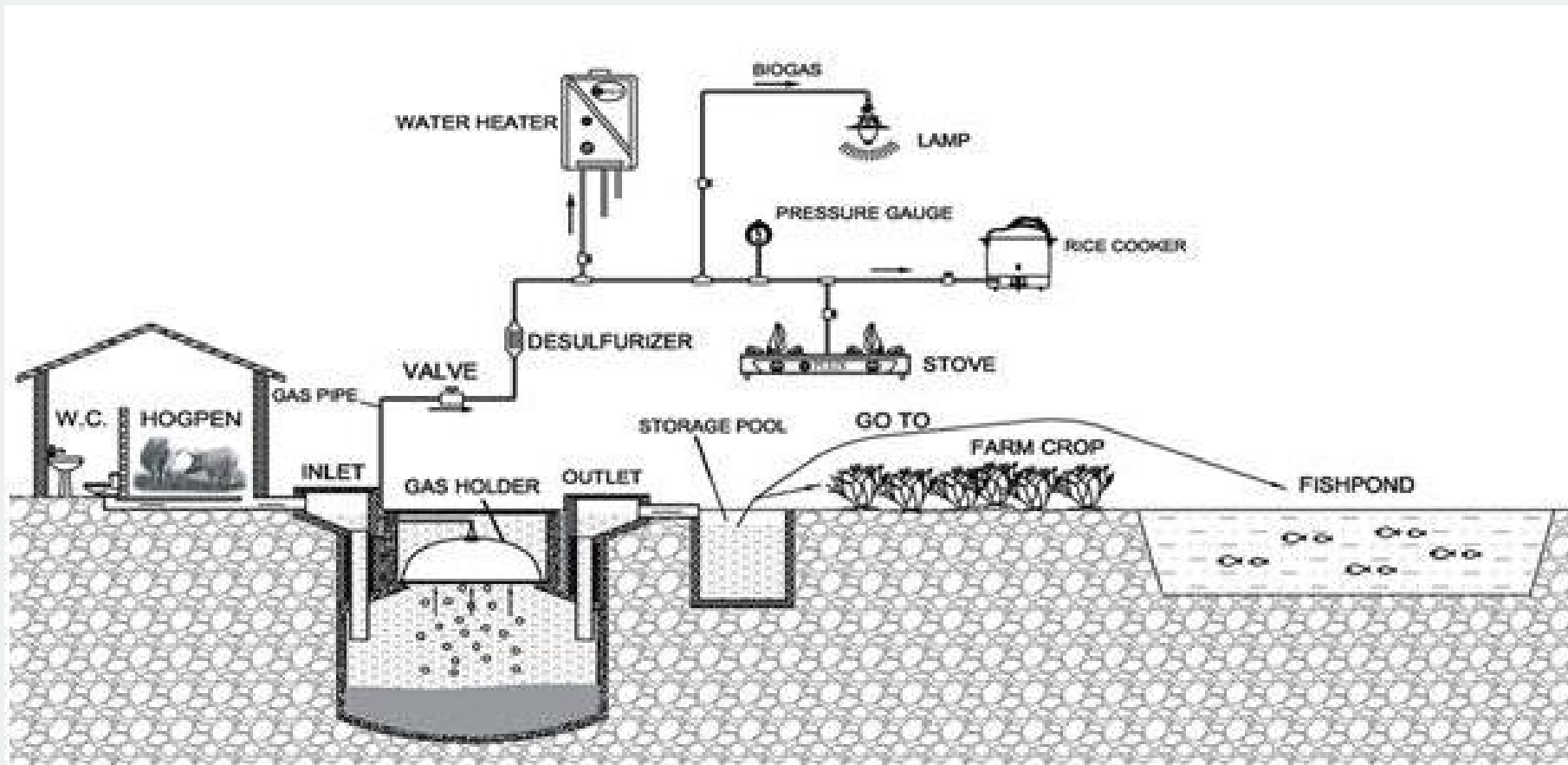
## BIODIESEL-POWERED GARBAGE TRUCK



Image courtesy of NREL

# Biomass

## Family size and medium size biogas systems



# Top Ten in Biomass

World top 10 producers (TW·h/year)

Country	Year	Biomass
United States	2009 <sup>[1]</sup>	54.3
Germany	2010 <sup>[8]</sup>	33.460
China	2009	3.0 <sup>[6]</sup>
Brazil	2009	21.354
Norway	2009	0.2 <sup>[7]</sup>
European Union <sup>[6]</sup>	2009	
Russia	2009	
Japan	2009	
Canada	2009	
India	2009	
Venezuela	2009	

Country	Year	Biomass (GWh)
United States	2009 <sup>[38]</sup>	54,300
Germany	2011	31,920
Brazil	2009	21,354
Sweden	2009	11,321
United Kingdom	2006 <sup>[35]</sup>	9,291 <sup>[37]</sup> (2007)
Italy	2010	9,281
Finland	2009	8,586
Canada	2009	7,582
Netherlands	2009 <sup>[25]</sup>	5,422
Poland	2009	4,976



# Advantages and Disadvantages of Biomass

## Advantages

It makes sense to use waste materials where we can.

The fuel tends to be cheap.

Less demand on the fossil fuels.

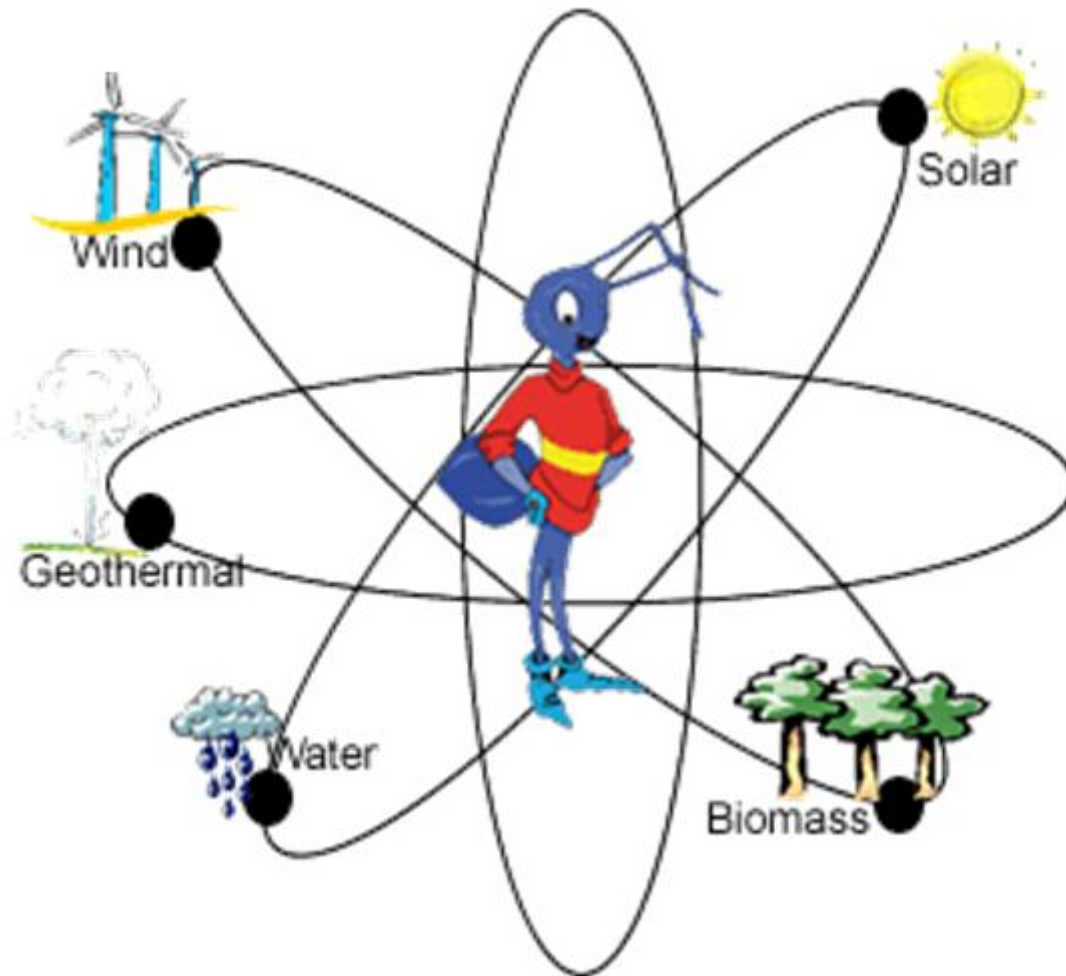
## Disadvantages

Collecting or growing the fuel in sufficient quantities can be difficult.

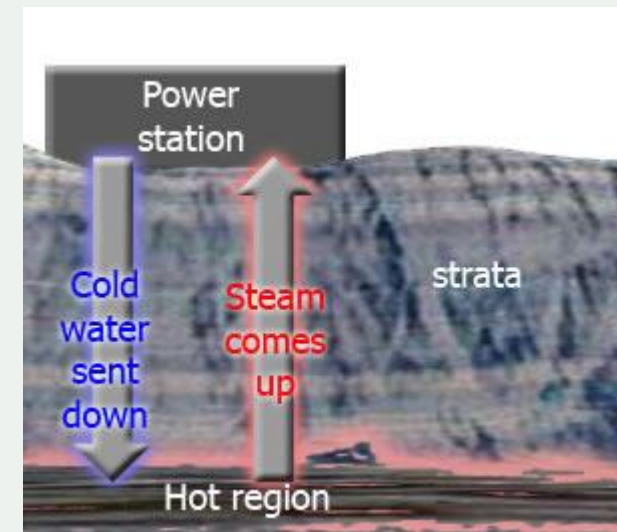
We burn the biofuel, so it makes greenhouse gases just like fossil fuels do.

Some waste materials are not available all year round.

# Renewable energy



## Geothermal



# Geothermal

## Geothermal Energy

- ❖ Direct use.
  - Balneology
  - Agriculture
  - Aquaculture
  - Residential and district heating
  
- ❖ Hydrothermal Power Systems.
  - Dry Steam Power Plants
  - Flash Steam Power Plants
  - Binary-Cycle Power Plants

# Geothermal

## Geothermal Energy

- ❖ Direct use.
  - Balneology
  - Agriculture
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  - Residential and district heating
  
- ❖ Hydrothermal Power Systems.
  - Dry Steam Power Plants
  - Flash Steam Power Plants
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## Geothermal: Direct heating

Native Americans using hot springs at what is now Calistoga, California.

Some tribes considered hot springs to be neutral territory where no wars were allowed.



# Geothermal: Direct heating

## Balneology





# Geothermal: Direct heating

## Agriculture



# Geothermal: Direct heating

## Aquaculture

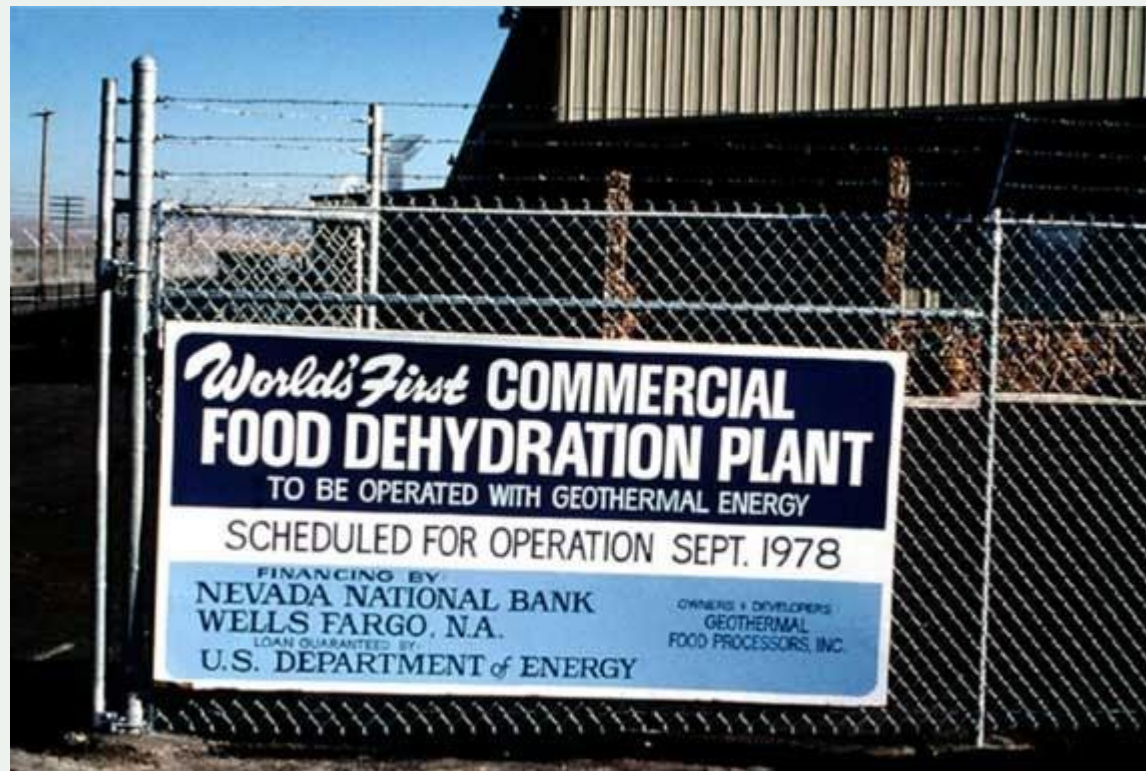
- Residential and district heating





# Geothermal: Direct heating

Residential and district heating (Industrial)



# Geothermal: Direct heating

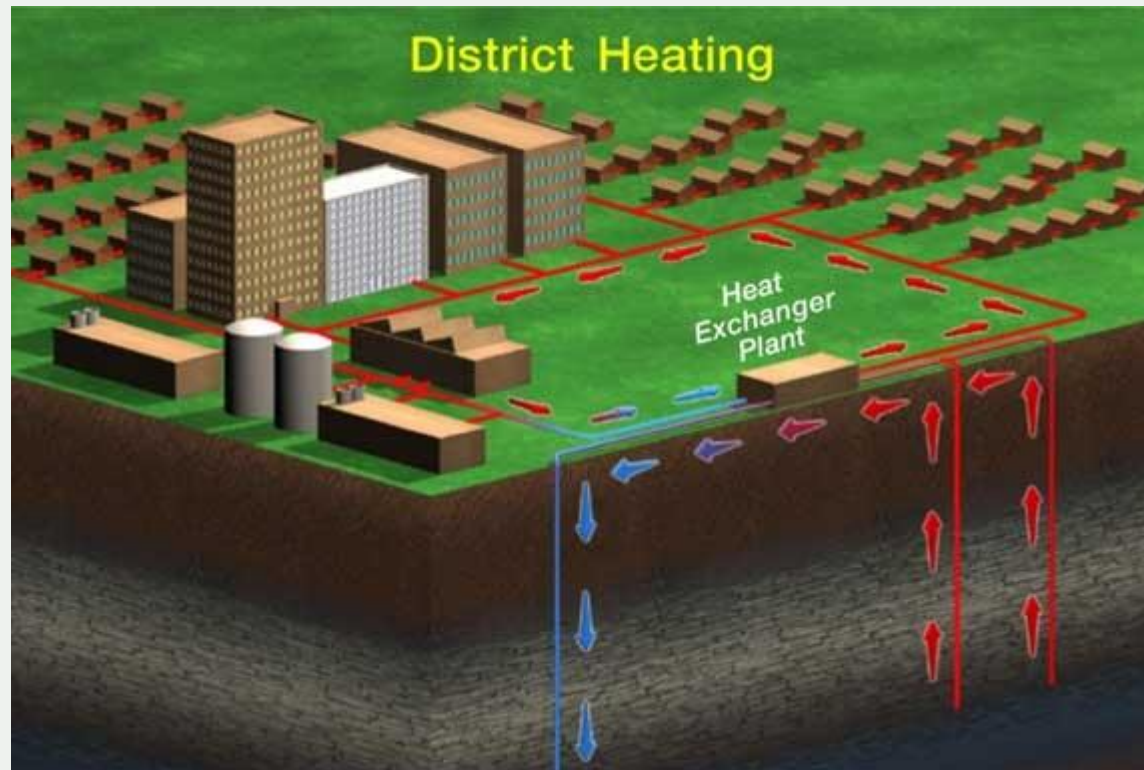
Residential and district heating





# Geothermal: Direct heating

## Residential and district heating



# Geothermal

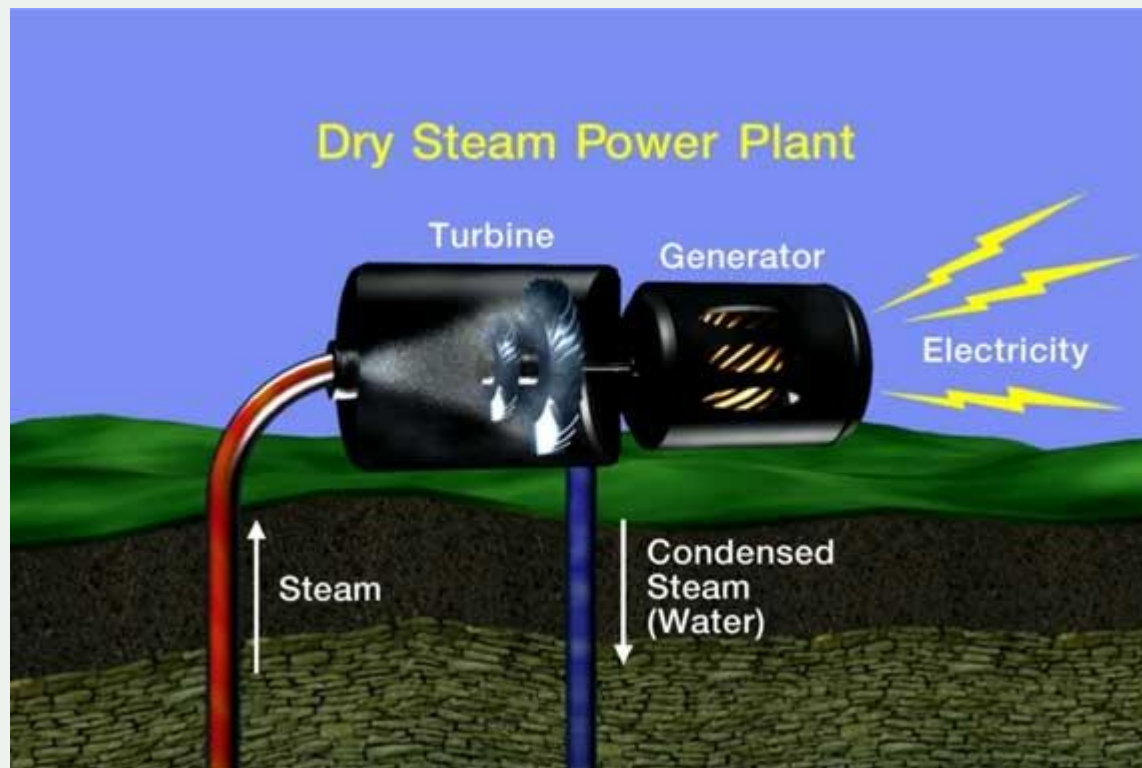
## Geothermal Energy

- ❖ Direct use.
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# Geothermal: Hydrothermal Power Systems

## Dry Steam Power Plants

The steam goes directly to a turbine, which drives a generator that produces electricity. It was first used at Lardarello in Italy in 1904, and is still very effective.





# Geothermal: Hydrothermal Power Systems

**The Geysers dry steam field, in northern California.**

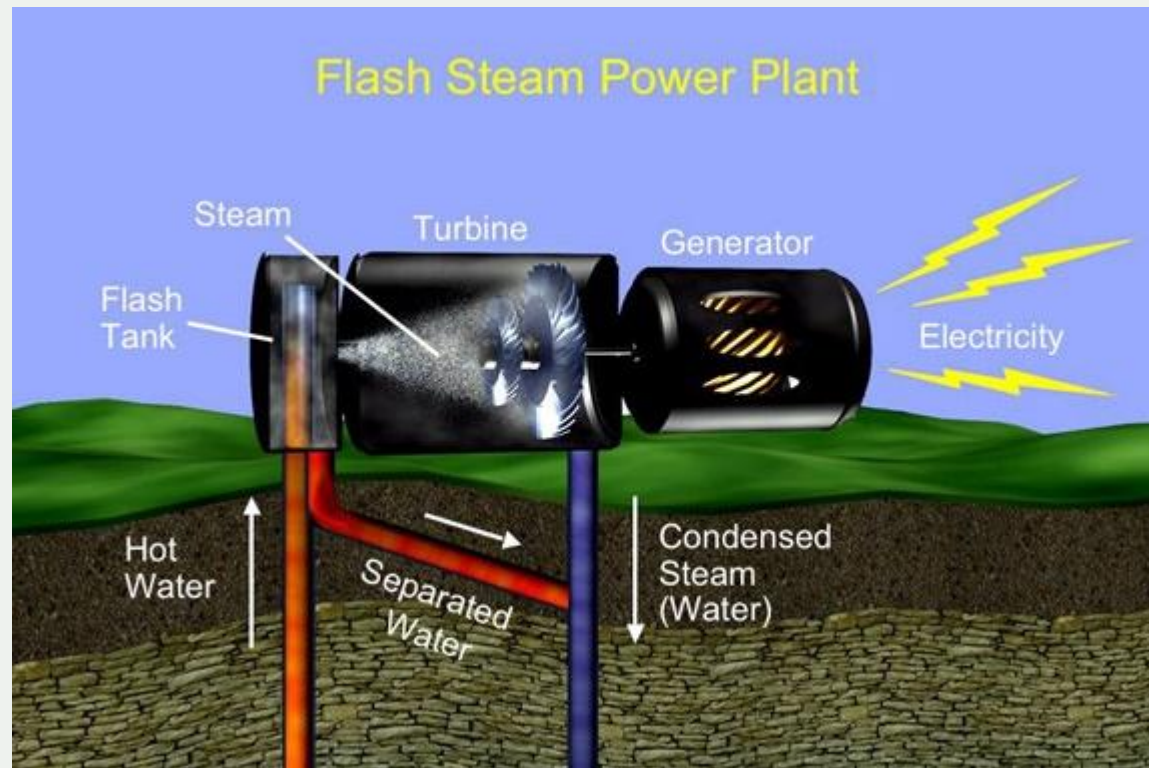
The first geothermal power plants in the U.S. were built in 1962 at



# Geothermal: Hydrothermal Power Systems

## Flash Steam Power Plants

Hydrothermal fluids above 360°F (182°C) can be used in flash plants to make electricity. Fluid is sprayed into a tank held at a much lower pressure than the fluid, causing some of the fluid to rapidly vaporize, or "flash."



# Geothermal: Hydrothermal Power Systems

**Flash technology was invented in New Zealand**

Flash steam plants are the most common, since most reservoirs are hot water reservoirs.

**Following flash steam plant is in East Mesa, California.**

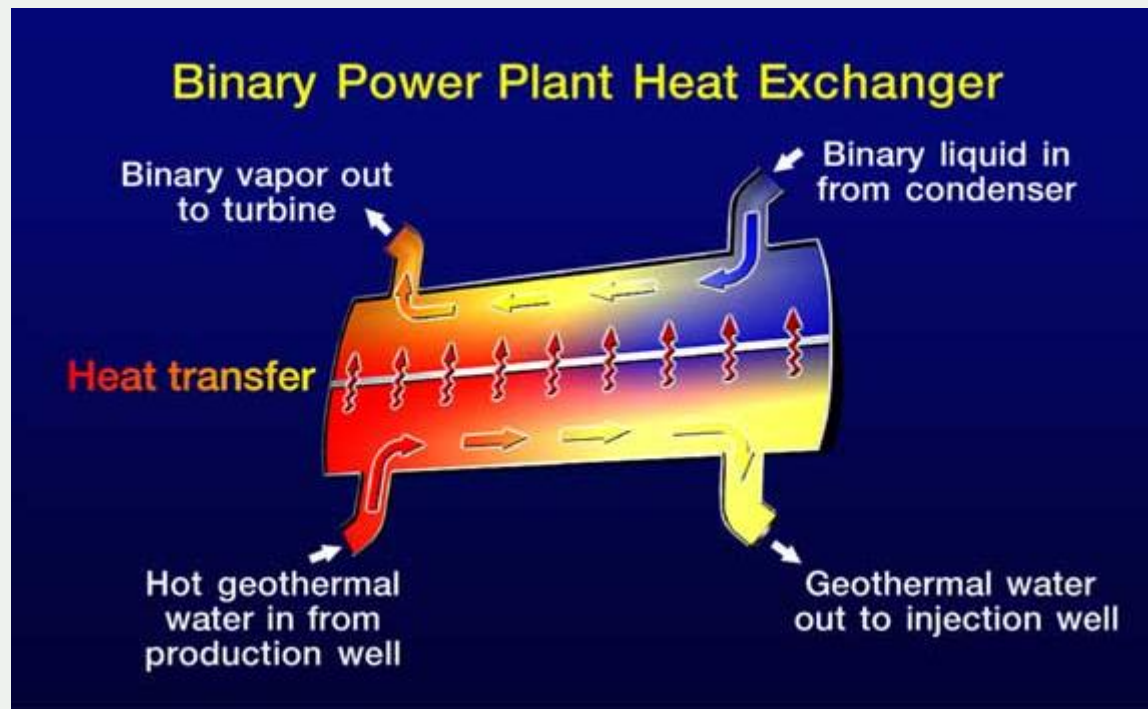




# Geothermal: Hydrothermal Power Systems

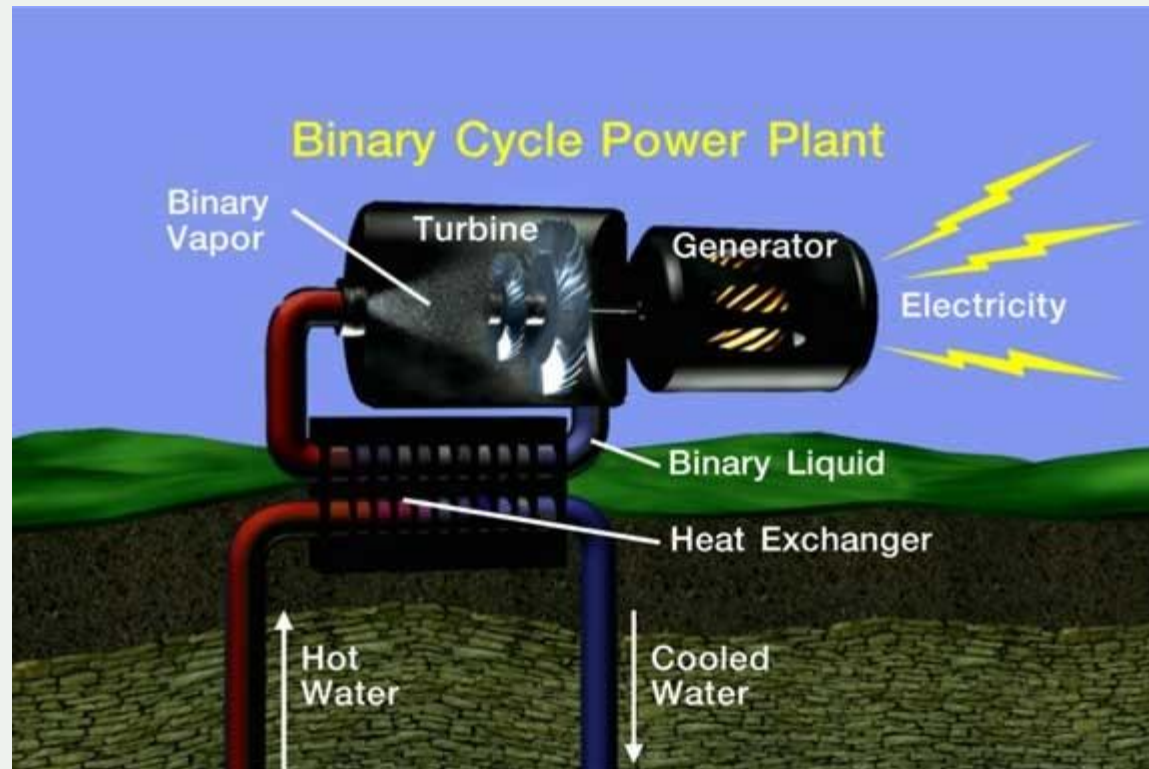
## Binary-Cycle Power Plants

Most geothermal areas contain moderate-temperature water (below 400°F or 204°C). Moderate-temperature water is by far the more common geothermal resource, and most geothermal power plants in the future will be binary-cycle plants.



# Geothermal: Hydrothermal Power Systems

## Binary-Cycle Power Plants





# Geothermal: Hydrothermal Power Systems

**Binary plant is at Soda Lake, Nevada.**

Binary technology allows the use of lower temperature reservoirs, thus increasing the number of reservoirs that can be used.



# Geothermal Power Plants



Geothermal Power Plants

## Geothermal in World

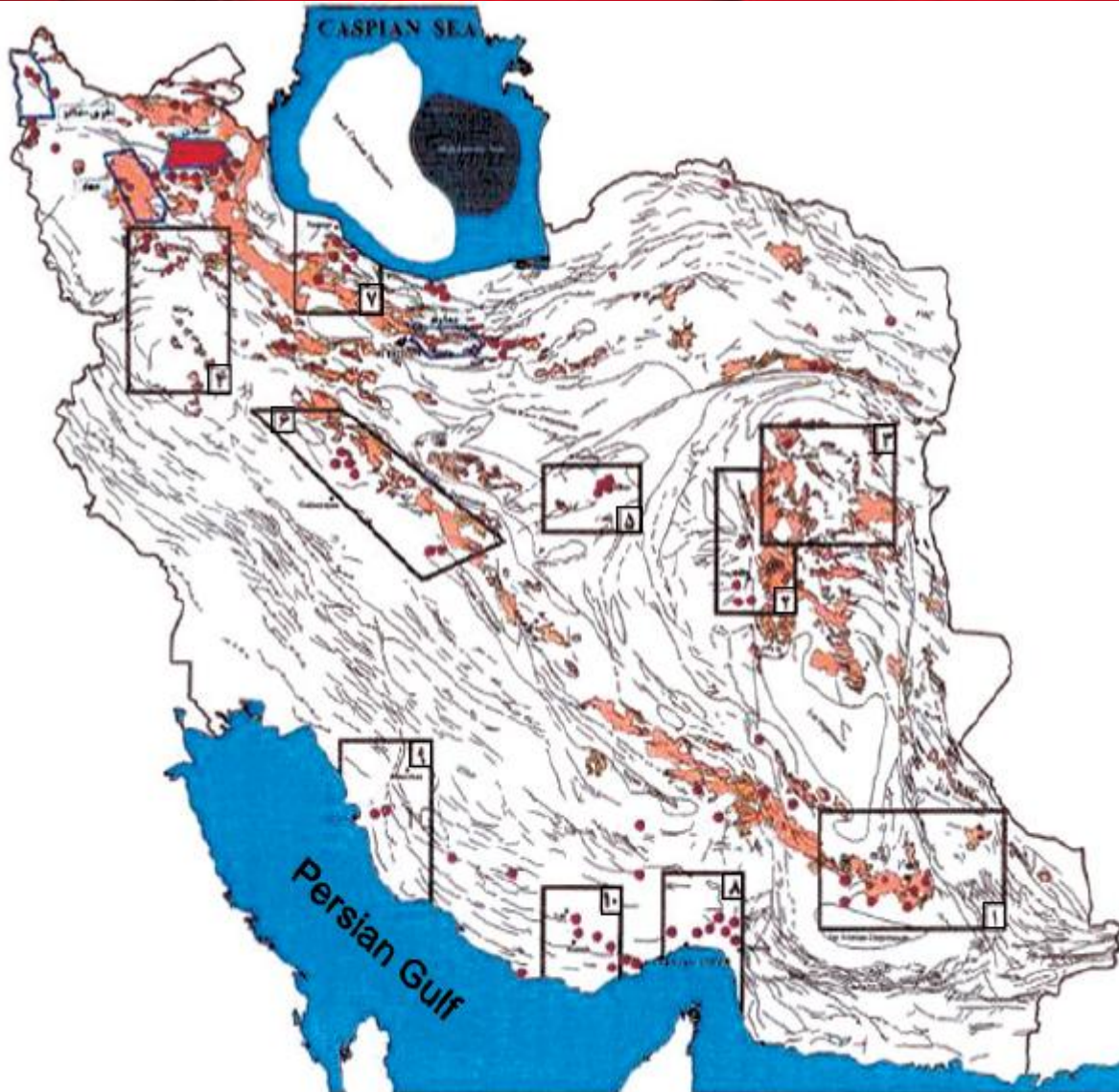
Installed Capacity, Electricity Generation  
and Direct Use of Geothermal Energy, 2007

ظرفیت نصب شده، تولید برق و استفاده  
مستقیم از انرژی زمین گرمایی - سال ۲۰۰۷

Regions	Installed Capacity ظرفیت نصب شده (MW)	Gross Electricity Generation تولید ناویژه برق (TWh)	Direct Use استفاده مستقیم (TJ)/Year	مناطق
North America	3174	24.2	634474	آمریکای شمالی
S. & Cent. America	●	2.9	103104	آمریکای مرکزی و جنوبی
Europe & Eurasia	1208	10.0	446018	اروپا و اورآسیا
Africa	●	1.0	36720	آفریقا
Asia Pacific	982	23.7	833043	آسیا و اقیانوسیه
<b>Total World</b>	●	<b>61.8</b>	<b>2053359</b>	<b>کل جهان</b>



# Geothermal Potential of Iran



- Neogene-quaternary igneous rocks
- Neogene-quaternary active volcanos
- Silent volcanos
- Major faults
- - - Minor faults
- · · Probably faults
- · · Major contrary faults
- · · Minor contrary faults
- Antic line axis
- Dents of central part
- Thermal spring in general
- Town
- Suggested areas for geothermal potential (SUNA)
- Suggested areas (Enel)
- Hottest known geothermal regions

**Areas suggestion by SUNA:**

- 1- Taftan-Bazman
- 2- Naibandand
- 3- Ferdows-Tabas
- 4- Takab
- 5- Khur-Biabanak
- 6- Esfahan-Mahalat
- 7- Ramsar
- 8- Bandar Abbas - Minab
- 9- Bushehr - Kazeroun
- 10- Lar - Bastak

**Areas suggestion by Enel:**

- 1- Sabalan
- 2- Khoy - Makou
- 3- Damavand
- 4- Sahand

# Geothermal in Iran

## Geothermal

Name	Location	Capacity	Type	Notes
Meshkinshahr Geothermal Power Plant	Ardabil Province	250 MW	Geothermal Power Plant	It is Iran's first geothermal electricity generation station



## Top Ten in Geothermal

Measurements are in TW·h/year (terawatt-hours per year)

Rank ↕	Country	Year ↕	Geothermal <sup>[6]</sup>
2	 United States	2011	17.0
	 <i>European Union</i> <sup>[7]</sup>	2010	5.6
9	 Japan	2011	2.89
5	 Russia	2010	0.47
7	 Germany	2011	0.03
1	 China	2011	
10	 Spain	2011	
6	 India	2011	
4	 Canada	2011	
3	 Brazil	2011	
8	 Norway	2011	

Country	Year ↕	Geothermal (GWh) <sup>[6]</sup>
 United States	2009 <sup>[38]</sup>	15,200
 Philippines	2009	10,187
 Indonesia	2008	7,882
 New Zealand	2011	5,770
 Italy	2010	5,358
 Iceland	2009	4,553
 Japan	2007	3,027
 El Salvador	2008	1,443
 Kenya	2008	1,120
 Costa Rica	2008	1,075

# Advantages and Disadvantages of Geothermal

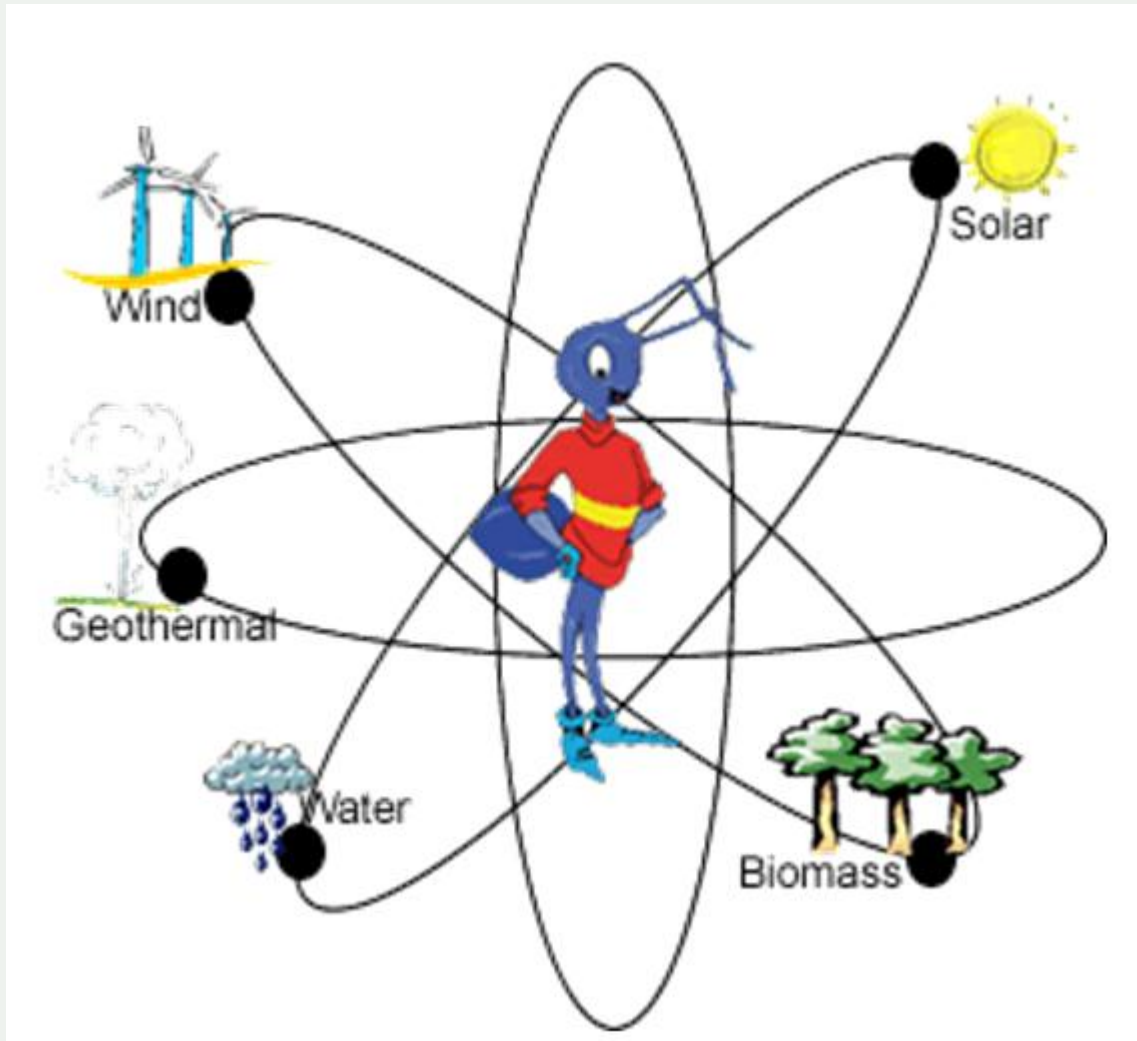
## Advantages

Does not produce any pollution, and no contribute to the greenhouse effect.  
The power stations do not take up much room, so there is not much impact on the environment.  
No fuel is needed.  
Once you've built a geothermal power station, the energy is almost free.

## Disadvantages

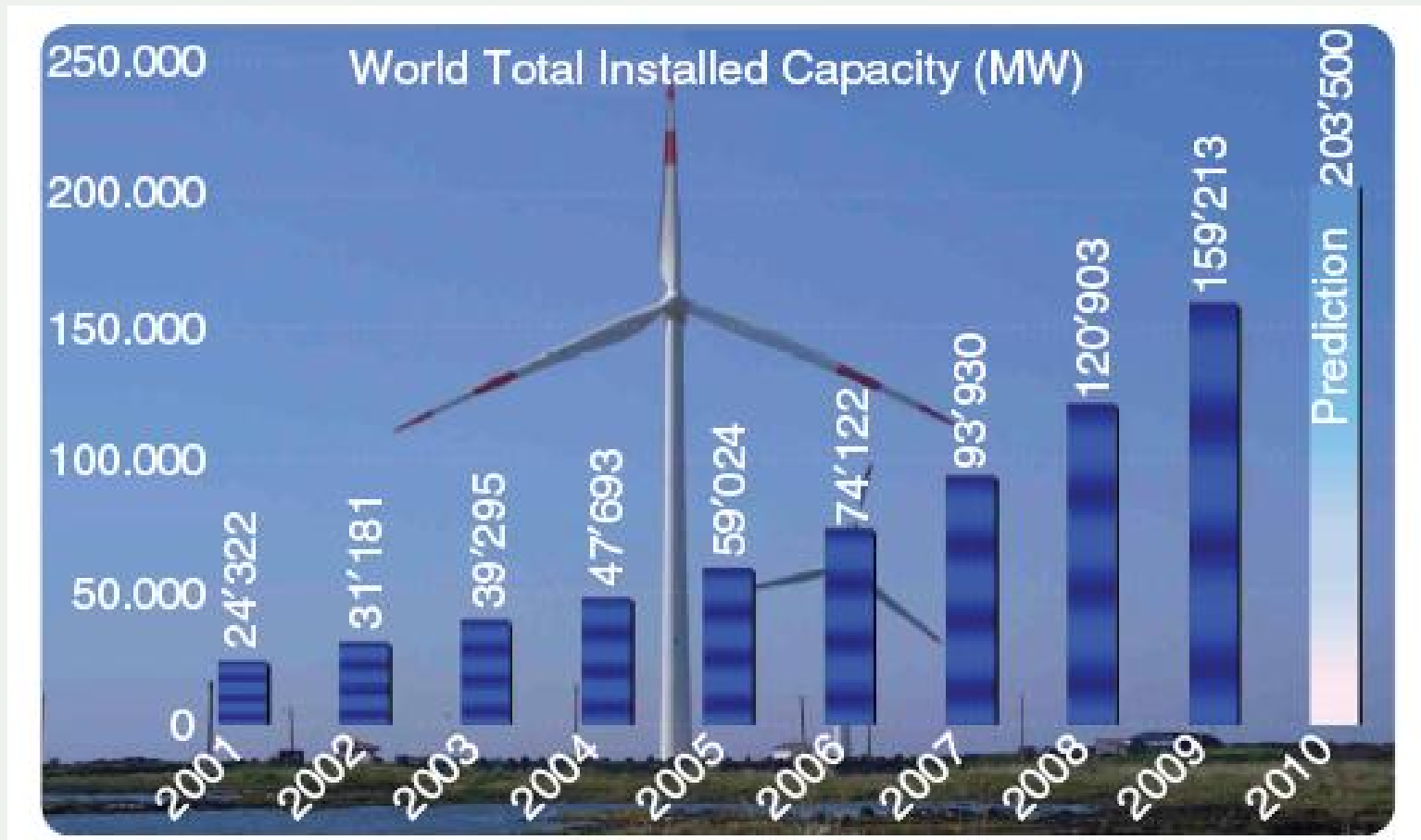
Not many places where you can build a geothermal power station.  
You need hot rocks of a suitable type, at a depth where we can drill down to them.  
Sometimes a geothermal site may "run out of steam", perhaps for decades.  
Hazardous gases and minerals may come up from underground, and can be difficult to safely dispose of.

# Renewable Energy(Wind)



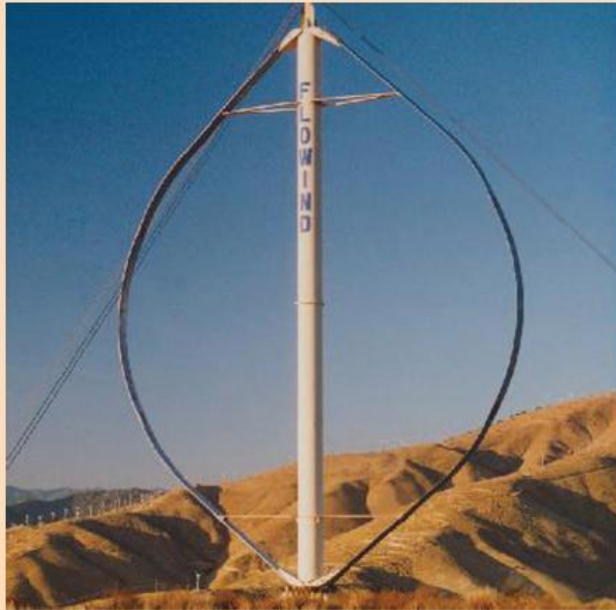
The Babylonians and Chinese were using wind power to pump water for irrigating crops 4,000 years ago, and sailing boats were around long before that.

# Installed wind energy capacity worldwide





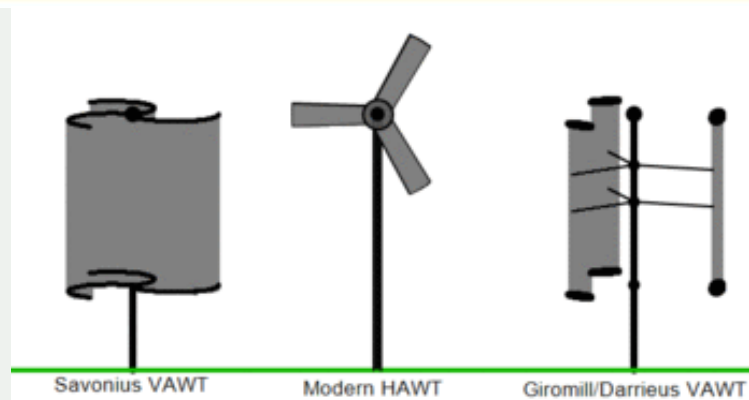
Vertical-axis and horizontal-axis wind turbines.



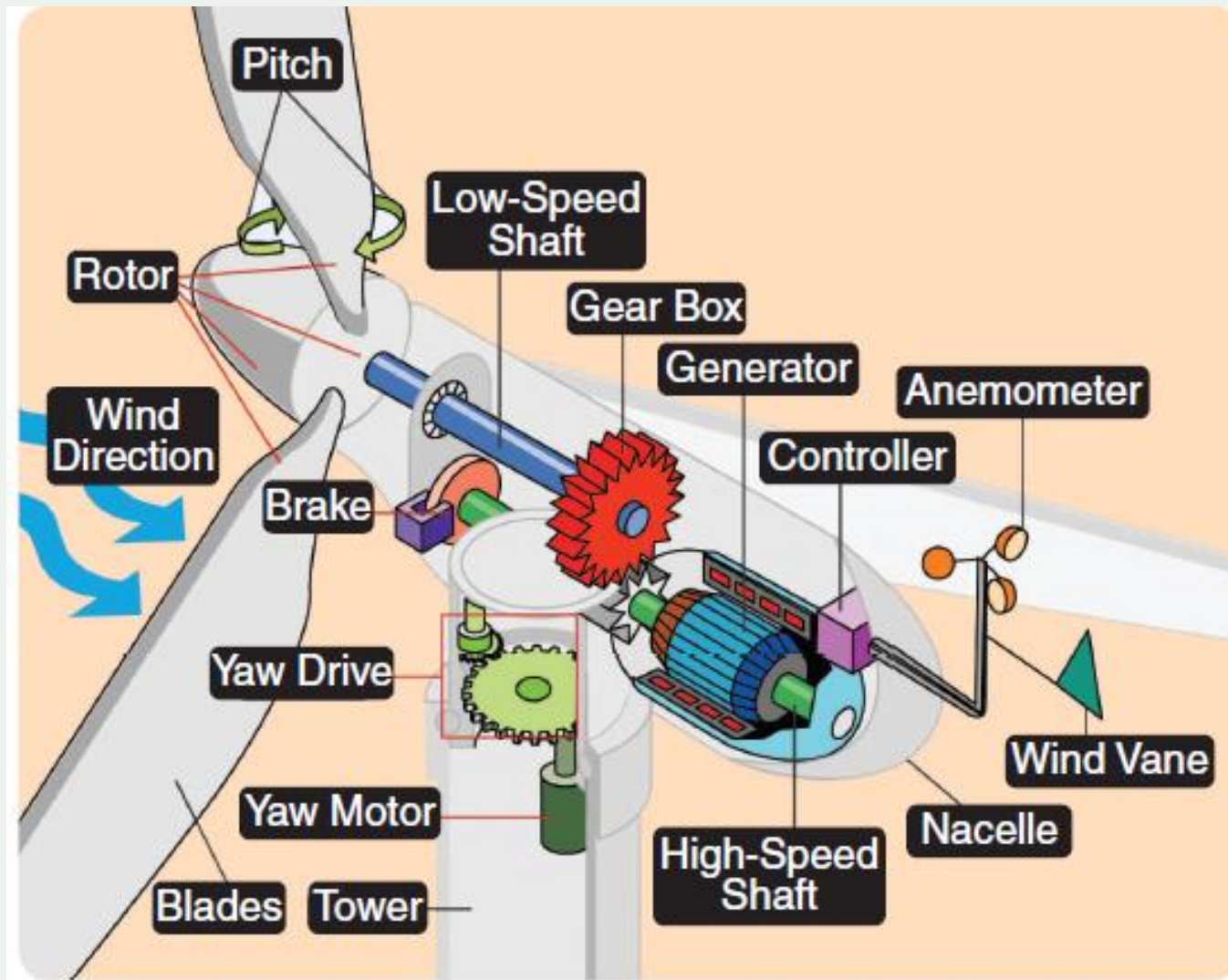
(a)



(b)

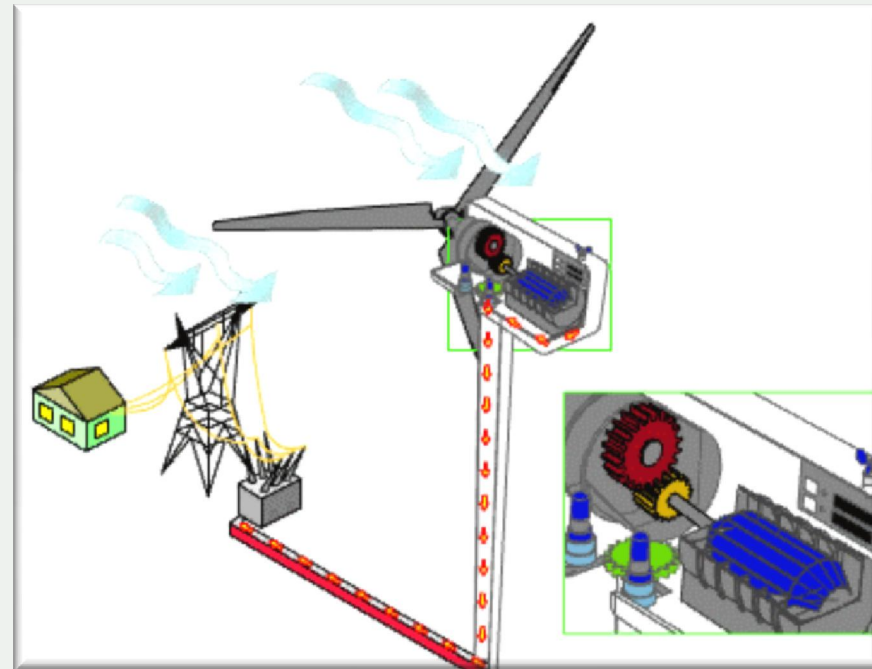


# horizontal-axis wind turbines components



# Wind Turbine

- ❖ The wind first encounters the rotor on this upwind horizontal-axis turbine, causing it to spin. The low-speed shaft transfers energy to the gearbox, which steps up in speed and spins the high-speed shaft. The high-speed shaft causes the generator to spin, producing electricity.
- ❖ the yaw-actuation mechanism, which is used to turn the nacelle so that the rotor faces into the wind

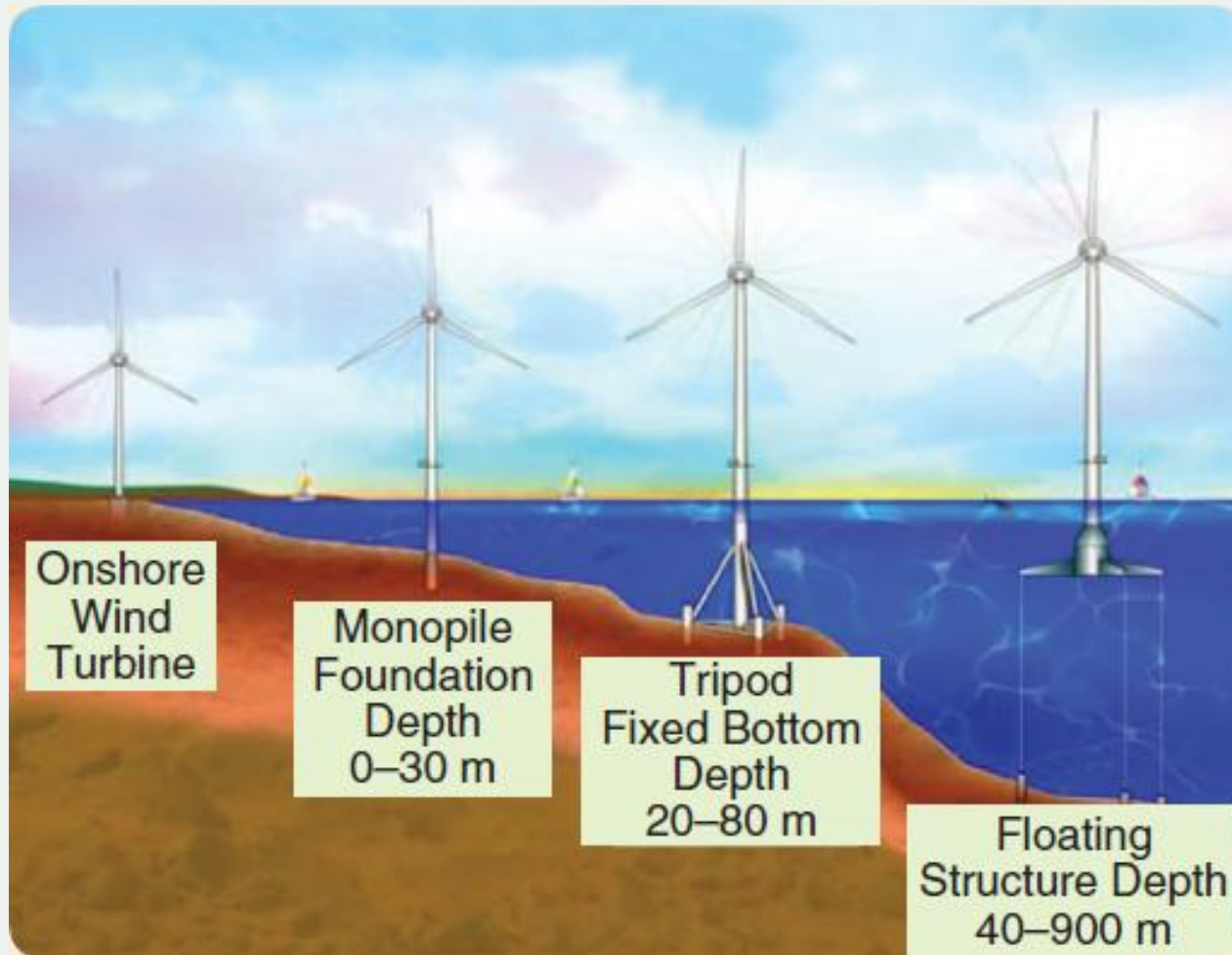




# Wind Farms



# Offshore Wind Turbines



## Top Ten in Wind Energy

Measurements are in TW·h/year (terawatt-hours per year)

Rank ↕	Country	Year ↕	Wind Power <sup>[3]</sup>
	 European Union <sup>[7]</sup>	2010	149.1
2	 United States	2011	119.7
1	 China	2011	73.2
7	 Germany	2011	46.5
10	 Spain	2011	42.4
6	 India	2011	26
4	 Canada	2011	19.7
9	 Japan	2011	4.35
3	 Brazil	2011	2.71
8	 Norway	2011	1.29
5	 Russia	2010	0.004

Country	Year ↕	Wind (GWh) <sup>[9]</sup> ▼
 United States	2009 <sup>[38]</sup>	70,800
 Germany	2011	46,500
 Spain	2010 <sup>[33]</sup>	42,976
 China	2009	25,000
 India	2009	15,300
 Portugal	2010 <sup>[30]</sup>	9,024
 Italy	2010	8,449
 Denmark	2009	6,721
 Australia	2011	6,432
 Turkey <sup>[citation needed]</sup>	2010	5,832



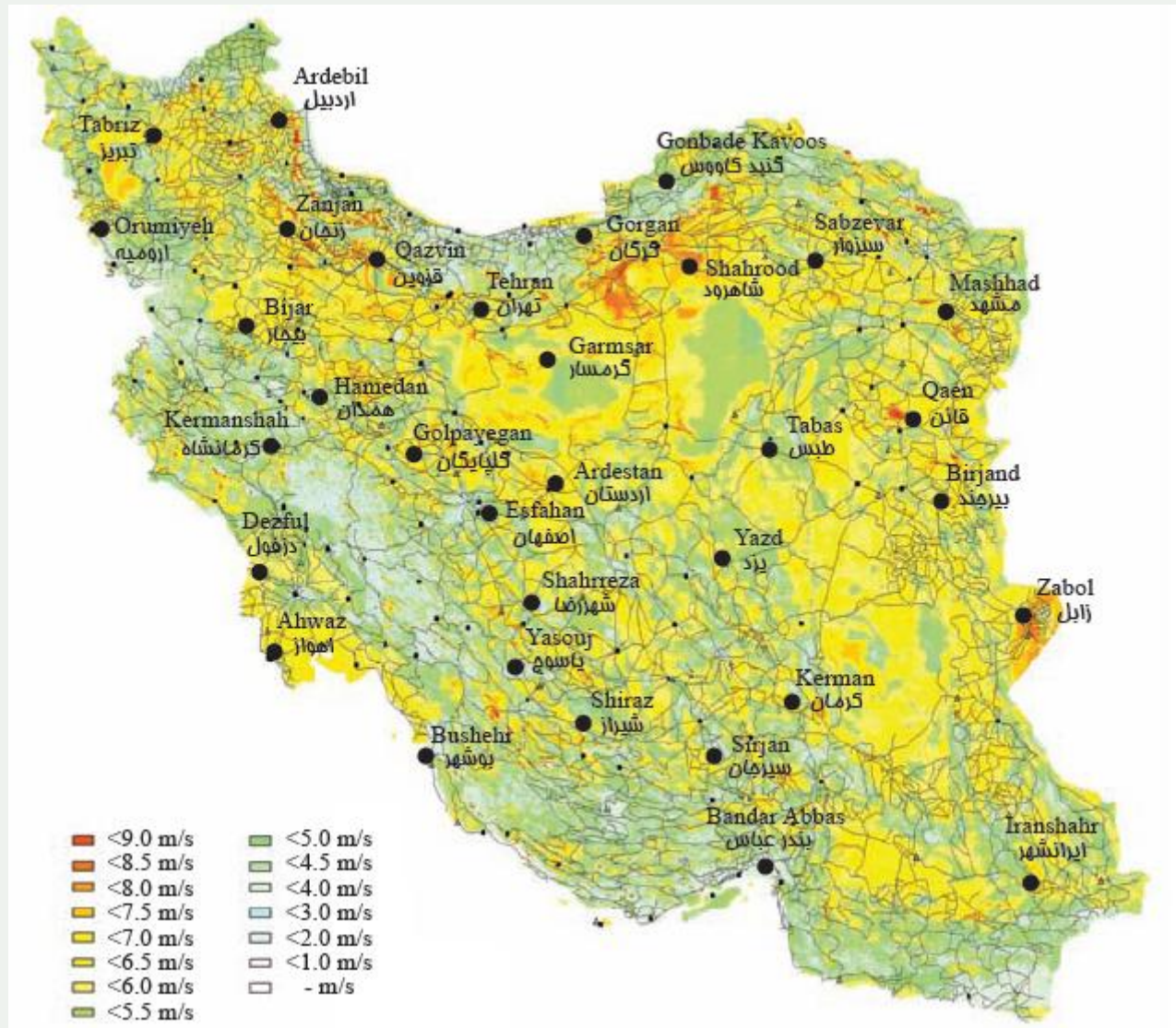
# Iran Wind Power

## Wind

*See also: Wind power in Iran*

Name	Location	Capacity	Type	Operational	Notes
Binalood wind farm	Razavi Khorasan Province	28.2 MW	Onshore wind farm	2008	The wind farm uses 43 units of 660 kW-h; Currently being upgraded to 93 turbine units with a total capacity of 61.2 MWh
Manjil and Rudbar Wind Farm	Gilan Province	100.8 MW	Onshore wind farm	1994	The wind farm uses 171 units of 300-660 kW-h turbines; It was the first wind farm in Iran
Jarandaq wind farm	Qazvin Province	60 MW			Being studied.

# Map of Iran Wind Potential at 80m Above the Ground Level



# Advantages and disadvantages of wind energy

## Advantages

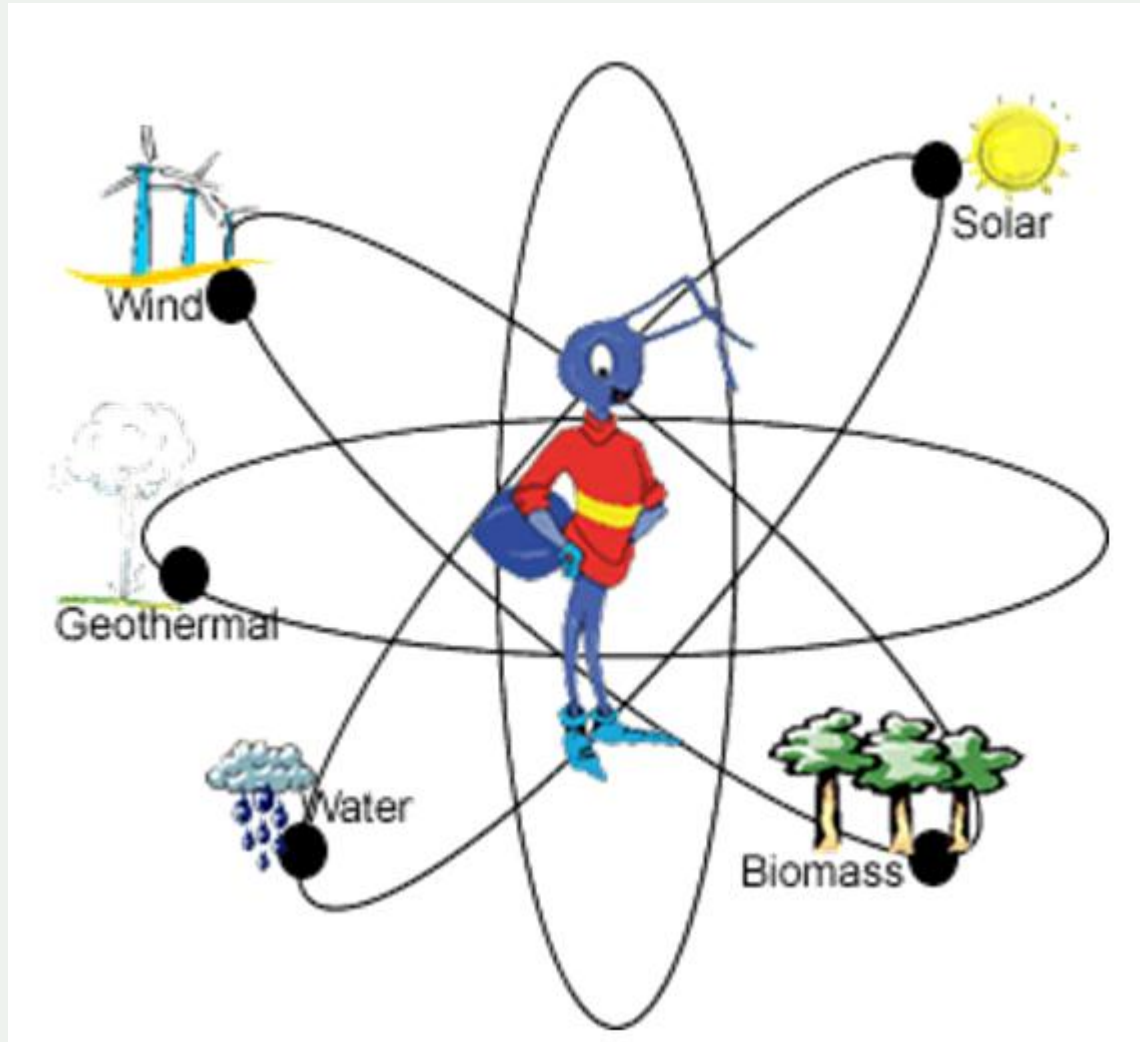
- Wind is free, wind farms need no fuel.
- Produces no waste or greenhouse gases.
- The land beneath can usually still be used for farming.
- Wind farms can be tourist attractions.
- A good method of supplying energy to remote areas.

## Disadvantages

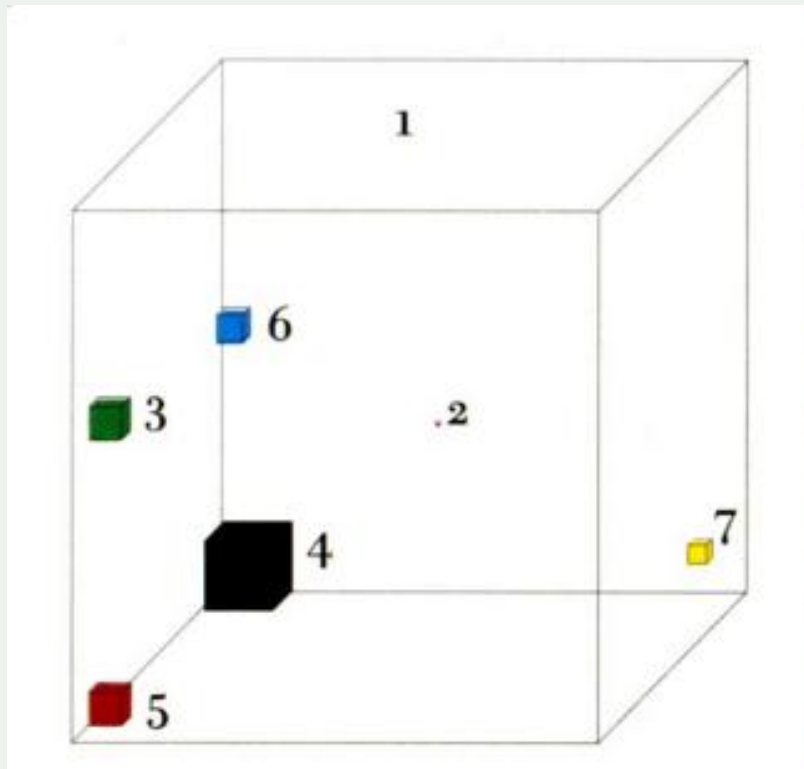
- The wind is not always predictable - some days have no wind.
- Suitable areas for wind farms are often near the coast, where land is expensive.
- Some people feel that covering the landscape with these towers is unsightly.
- Can kill birds - migrating flocks tend to like strong winds.
- Can affect television reception if you live nearby.
- Can be noisy.



# Renewable(Solar Energy)



# Amount of Solar Energy



- 1. Amount of Solar energy falling on Earth in one year.
- 2. Present solar energy use.
- 3. Natural gas reserves.
- 4. Coal reserves of coal.
- 5. Oil reserves.
- 6. Uranium reserves.
- 7. World energy consumption in one year.

## Different Types of Solar Energy

### Solar energy technologies:

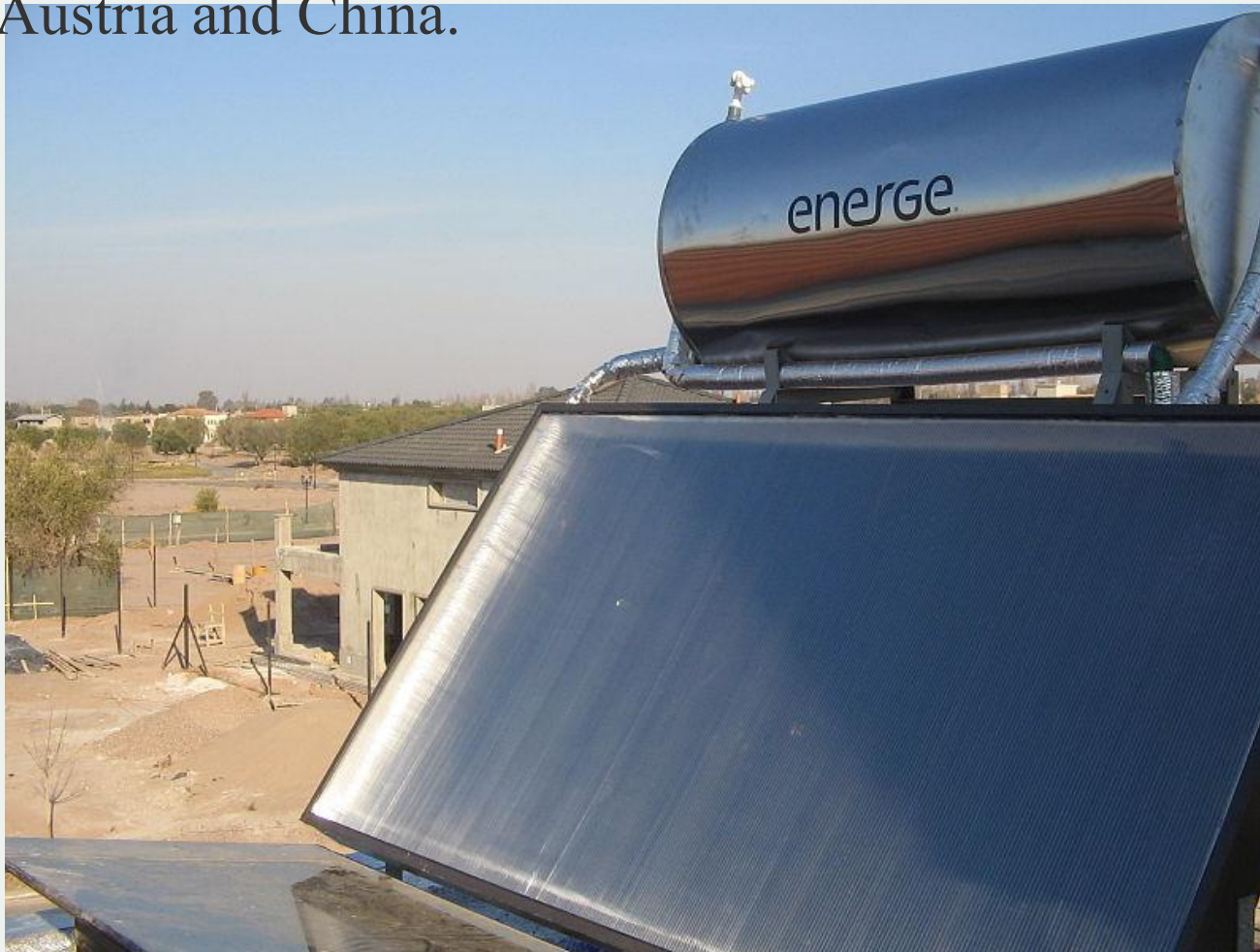
- Solar heating,
- Solar photovoltaic,
- Solar thermal electricity
- Solar architect



# Solar Heating

**Solar water heating (SWH) or solar hot water (SHW)**

SWH has been widely used in Greece, Turkey, Israel, Australia, Japan, Austria and China.





# Solar Photovoltaic





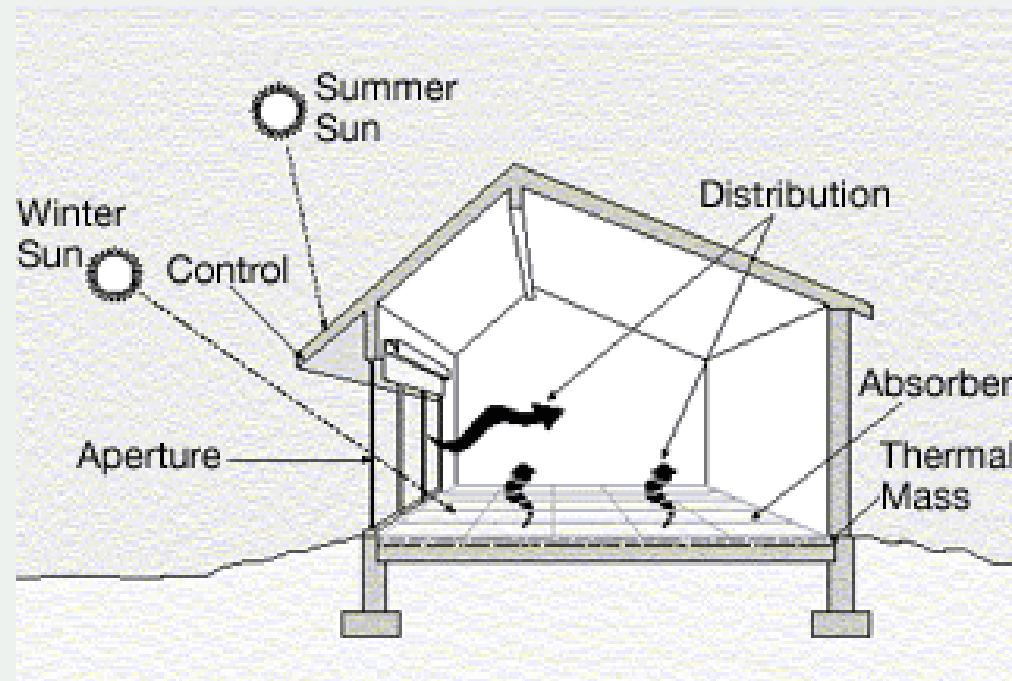
## Solar Thermal Electricity

**Solar thermal energy (STE)** is a technology for harnessing solar energy for thermal energy (heat). Solar thermal collectors are classified by the United States Energy Information Administration as low-, medium-, or high-temperature collectors. Low-temperature collectors are flat plates generally used to heat swimming pools. Medium-temperature collectors are also usually flat plates but are used for heating water or air for residential and commercial use. High-temperature collectors concentrate sunlight using mirrors or lenses and are generally used for electric power production. STE is different from and much more efficient than photovoltaics, which converts solar energy directly into electricity.



# Solar Architect

In **passive solar building design**, windows, walls, and floors are made to collect, store, and distribute solar energy in the form of heat in the winter and reject solar heat in the summer. This is called passive solar design or climatic design because, unlike active solar heating systems, it doesn't involve the use of mechanical and electrical devices.



## Top Ten in Solar

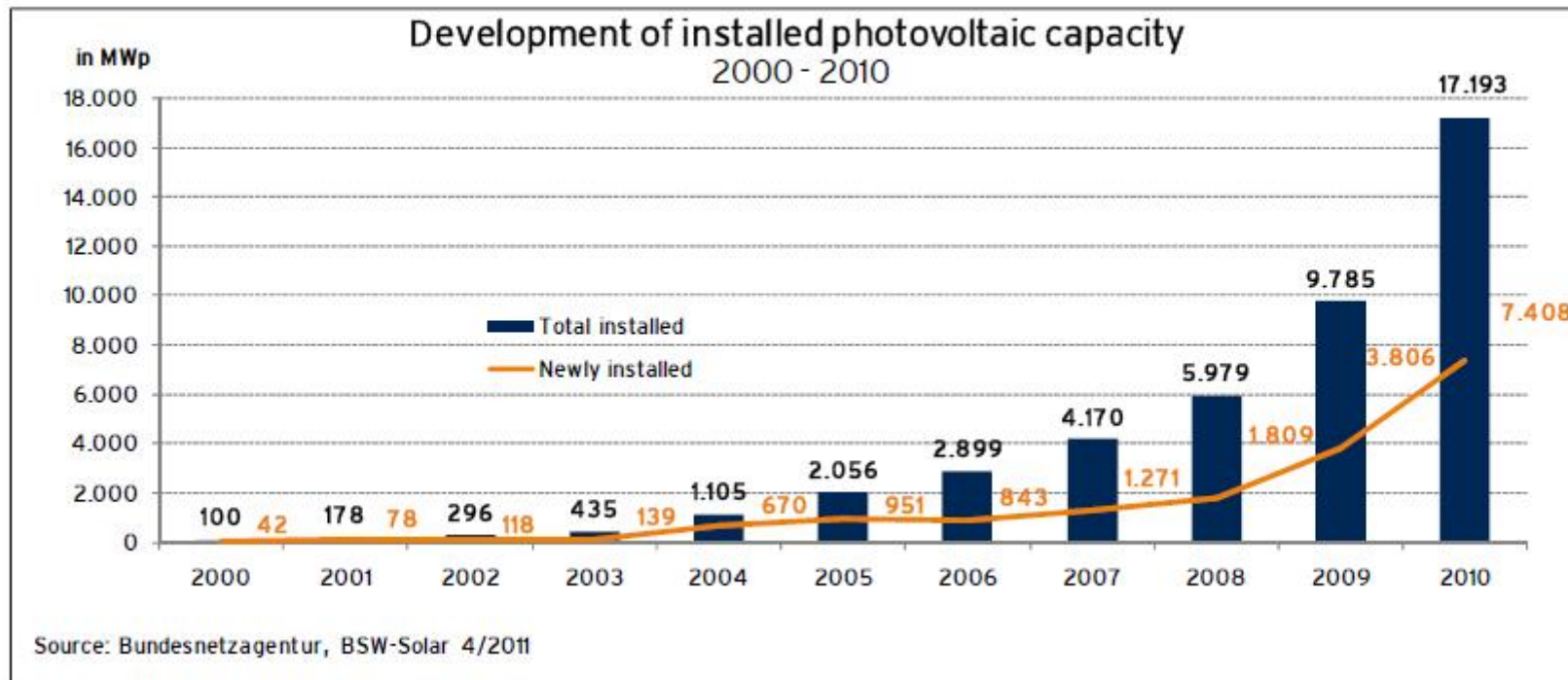
Measurements are in TW-h/year (terawatt-hours per year)

Rank	Country	Year	Solar <sup>[5]</sup>
	 European Union <sup>[7]</sup>	2010	23.1
7	 Germany	2011	19.0
10	 Spain	2011	7.28
9	 Japan	2011	3.80
1	 China	2011	3
2	 United States	2011	1.81
6	 India	2011	1
4	 Canada	2011	0.43
8	 Norway	2011	0.02
3	 Brazil	2011	0.0002
5	 Russia	2010	0

Country	Year	Solar (GWh) <sup>[10]</sup>
 South Korea	2009	945
 Mexico <sup>[citation needed]</sup>	2011	9
 United States	2009 <sup>[38]</sup>	808
 United Kingdom	2006 <sup>[35]</sup>	8
 Spain	2010 <sup>[33]</sup>	7,276
 Australia	2011	684.4
 Canada	2009	63
 Czech Republic	2010	615.7
 Finland	2009	6
 Ireland	2007	5 (2001)

# German Installed Capacity

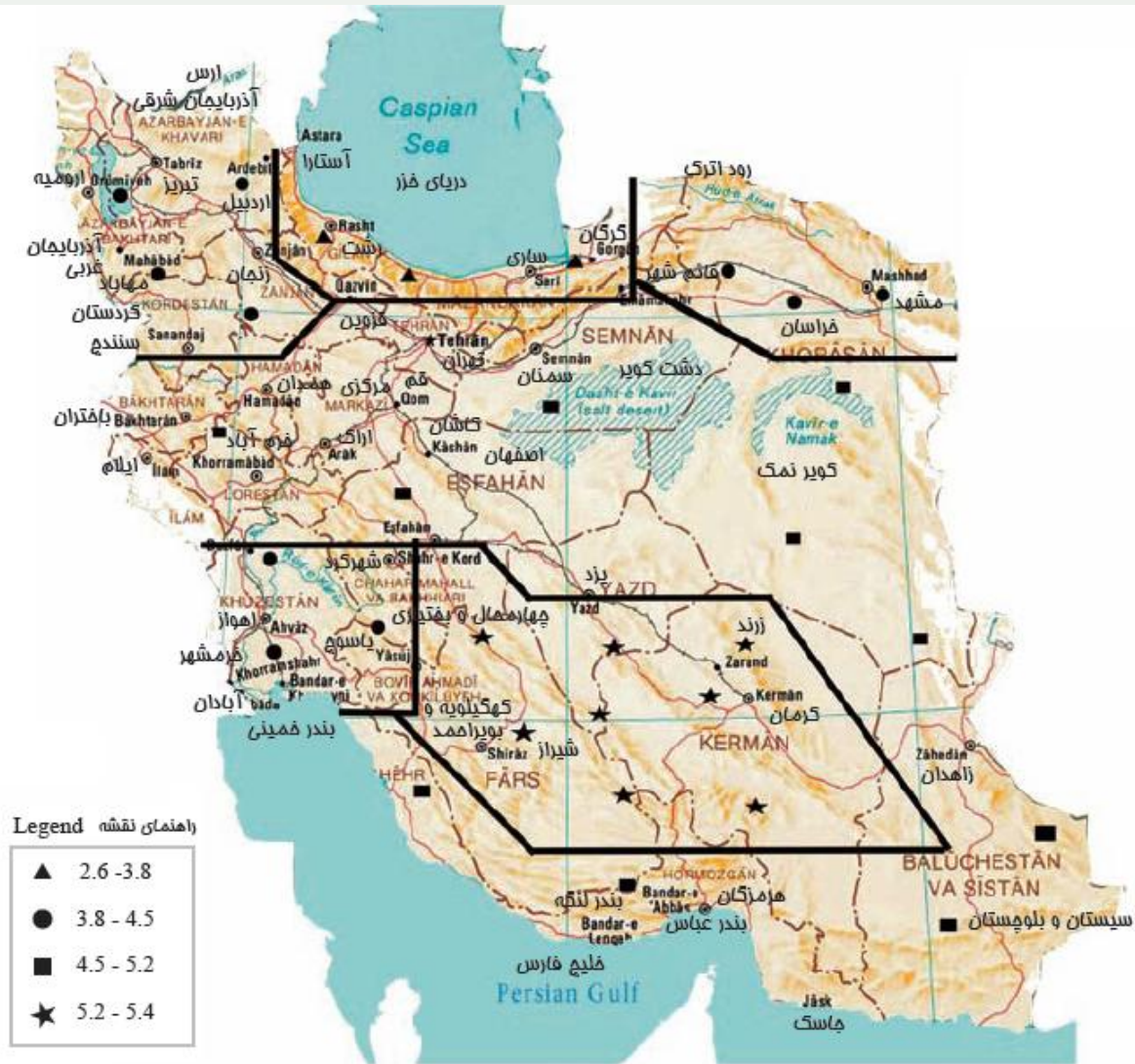
## 1) Solar power on the path to becoming a key pillar of sustainable energy supply in Germany



3% of total electricity in 2011 and some market analysts expect this could reach 25 percent by 2050.



# Iran Solar Radiation Potential



# Iran Solar Plants

## Solar

With about 300 clear sunny days a year and an average of 2,200 kilowatt-hour solar radiation per square meter, Iran has a great potential to tap solar energy.

Name	Location	Capacity	Type	Notes
Yazd solar thermal power plant	Yazd	467 MW	Integrated Solar Combined Cycle	Yazd solar thermal power plant is the world's first integrated solar combined cycle power station using natural gas and solar energy. It is the largest solar power plant in the Middle East and the eighth largest in the world.
Shiraz solar power plant	Shiraz	250 kW	Concentrating solar power	Shiraz solar power plant is Iran's first Solar power station; Currently being upgraded to 500 kW-h

# Advantages and Disadvantages of Solar Energy

## Advantages

Solar energy is free - it needs no fuel and produces no waste or pollution.

In sunny countries, solar power can be used where there is no easy way to get electricity to a remote place.

- Handy for low-power uses such as solar powered garden lights and battery chargers, or for helping your home energy bills.

## Disadvantages

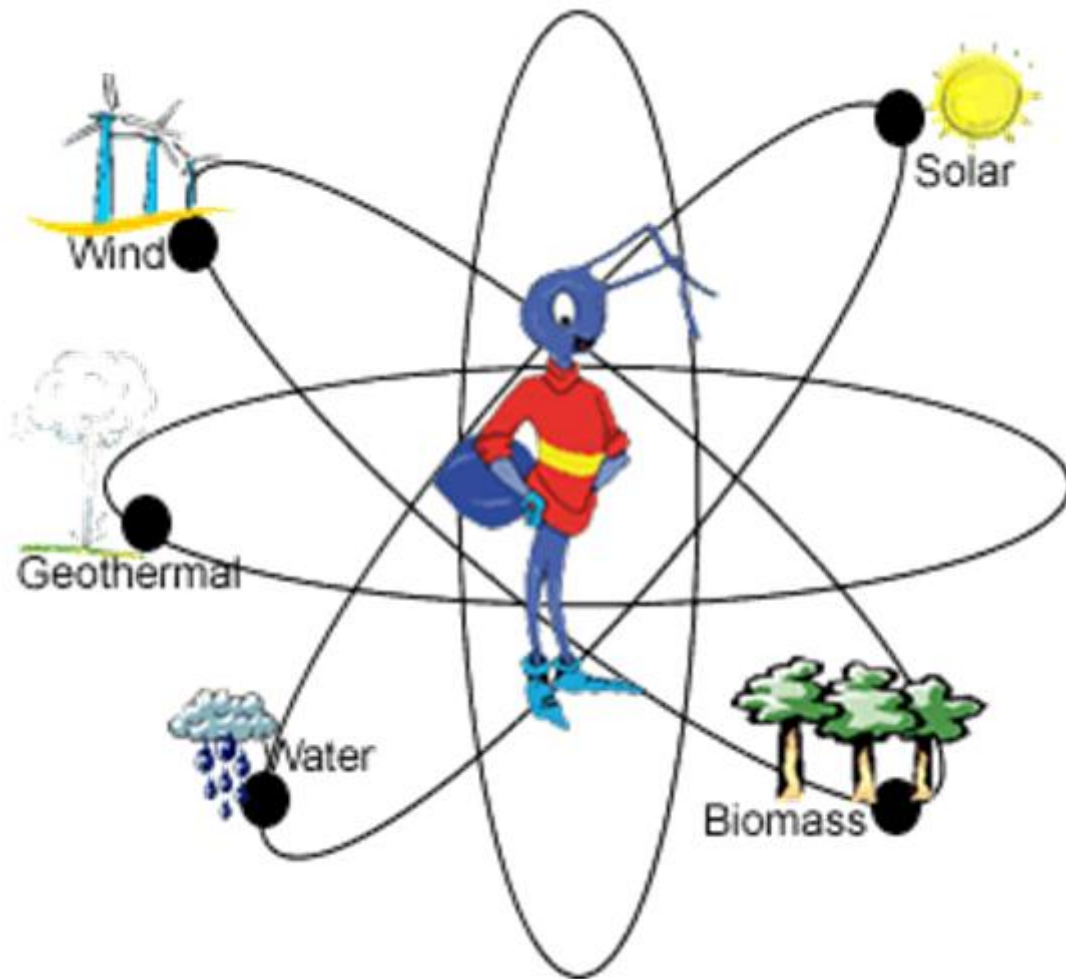
Doesn't work at night.

Very expensive to build solar power stations, although the cost is coming down as technology improves.

Can be unreliable unless you're in a very sunny climate.



# Renewable Energy



## Water



# Top Ten in Hydro Electricity

Measurements are in TW·h/year (terawatt-hours per year)

Rank ↕	Country	Hydroelectricity
1	 China	687.1
3	 Brazil	424.3
	 <i>European Union</i> <sup>[7]</sup>	397.7
4	 Canada	372.6
2	 United States	325.1
5	 Russia	163.3
6	 India	131
8	 Norway	119.6
9	 Japan	82.5
10	 Spain	30.3
7	 Germany	18.2

Country	Year ↕	Hydro (GWh) <sup>[8]</sup> ▼
 China	2009	548,955
 Brazil	2009	387,078
 Canada	2009	363,241
 United States	2009 <sup>[38]</sup>	272,100
 Russia	2009 <sup>[14]</sup>	162,270
 Norway	2009	126,077
 India	2009	104,439
 Japan	2007	86,350
 Venezuela	2009	85,839
 France	2008	68,841

## Advantages and disadvantages of Hydro Electricity

### Advantages

Once the dam is built, the energy is virtually free.

No waste or pollution produced.

Much more reliable than wind, solar or wave power.

Water can be stored above the dam ready to cope with peaks in demand.

Hydro-electric power stations can increase to full power very quickly, unlike other power stations.

Electricity can be generated constantly.

### Disadvantages

The dams are very expensive to build. However, many dams are ....

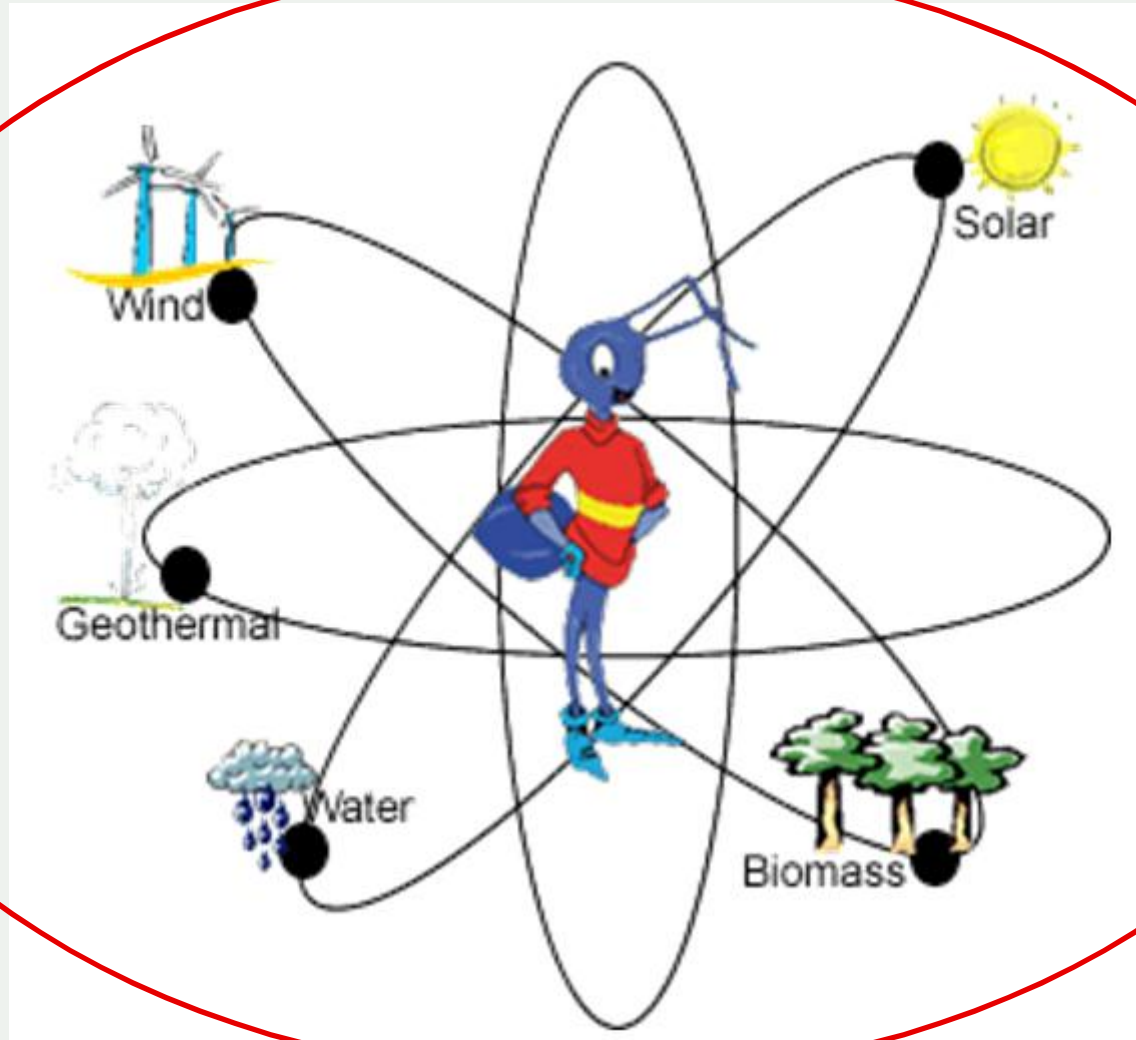
Building a large dam will flood a very large area upstream, causing ...

Finding a suitable site can be difficult - the impact on residents and the environment may be unacceptable.

Water quality and quantity downstream can be affected, which can have an impact on plant life.



# Renewable Energy



# Top Ten in Renewable Energy












World top 10 renewable electricity producers (TW·h/year)

Rank	Country	Year	Total <sup>[1]</sup>	Hydroelectricity	Wind Power	Biomass	Solar <sup>[3]</sup>	Geothermal <sup>[4]</sup>
-	 European Union	2009	587.2					
1	 China	2009	576.9	549.0	40.2	3.0 <sup>[6]</sup>	0.140 <sup>[5]</sup>	
2	 United States	2009	424.3	272.1	70.8	54.3	0.808	15.2
3	 Brazil	2009	409.8	387.1	1.374	21.354		
4	 Canada	2009	374.5	363.2	2.5		0.017	
5	 Russia	2009	165.1	163.2	0.007			0.48
6	 Norway	2009	126.2	125.0	0.977	0.2 <sup>[7]</sup>		
7	 India	2009	121.8	104.4	14.7			
8	 Germany	2010	101.7	19.694	36.500	33.460	12.000	0.027
9	 Japan	2009	98.9	75.2	1.754		0.002	3.027
10	 Venezuela	2009	85.8	85.8				

# Top Ten in Renewable Energy

## World top 10 renewable electricity producers

Measurements are in TW·h/year (terawatt-hours per year), equal to 1 billion Kilowatt-hours per year.

Rank	Country	Year	Total <sup>[1]</sup>	Hydroelectricity	Wind Power <sup>[3]</sup>	Biomass and Waste	Solar <sup>[5]</sup>	Geothermal <sup>[6]</sup>
1	 China	2011	797.4	687.1	73.2	34	3	
	 <i>European Union</i> <sup>[7]</sup>	2010	699.3	397.7	149.1	123.3	23.1	5.6
2	 United States	2011	520.1	325.1	119.7	56.7	1.81	17.0
3	 Brazil	2011	459.2	424.3	2.71	32.2	0.0002	
4	 Canada	2011	399.1	372.6	19.7	6.4	0.43	
5	 Russia	2010	166.6	163.3	0.004	2.8	0	0.47
6	 India	2011	162	131	26	4	1	
7	 Germany	2011	127.3	18.2	46.5	43.6	19.0	0.03
8	 Norway	2011	121.4	119.6	1.29	0.48	0.02	
9	 Japan	2011	116.4	82.5	4.35	23.1	3.80	2.89
10	 Spain	2011	87.0	30.3	42.4	9.12	7.28	