RENWABLE ENERGY RESEARCH
A CRITICAL INVESTMET FOR THE ARAB REGION

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The World currently relies heavily on Fossil fuel (coal, oil and Natural gas)

Fossil fuel is:

- **Non-renewable (finite resources).**
- **Becoming too expensive.**
- **Have a high impact on environment.**

Renewable energies resources are:

- **Clean.**
- **Non-depleted.**
- **Have very small impact on environment**

Characteristics and Benefits of RE Resources

- **RE resources are sustainable sources of energy.** Renewable technologies are designed to run on a virtually inexhaustible or replenish able supply of natural fuels. The primary long term benefits of renewable technologies is that once a renewable energy project has been constructed and fully operated, it become a permanent and low cost component of the national energy system.

- **RE resources promote energy diversification**. Development of a diverse portfolio of generation assess reduces a country dependence on any one particular form of technology or fuel.

- **RE resources have the lowest environmental impact?** Renewable energy technologies have a very small impact on environment compared to fossil fuel. The discharge of unwanted or unhealthy substance in air, ground and water commonly associated with other forms of energy use can be reduced significantly by using renewable energies.

- **RE resources have values beyond they generate**. Renewable energy systems are modular, flexible and can be installed anywhere and in any size. Investment in locally available renewable energy generates more jobs, greater earnings and higher output. The renewable energy industry provides a wide range of employment opportunities, from high technology manufacturing of PV components to maintenance jobs at solar thermal or wind systems.

Types of Renewable Energy resources

- **Solar Energy**
- **Wind Energy**
- **Biomass Energy**
- **Hydrogen Energy & Fuel Cell**
- **Hydropower Energy**
- **Ocean Energy**
- **Geothermal Energy**

Solar Energy

- Intensity of solar radiation along the earth orbit is 1.368 kW/ m2.
  The average earth radius ? 6366 Km.
  Therefore the Amount of insolation intercepted by the earth
  ? 174000 x 1012 Watt
  ? 174000 tera Watt
  ? 17000 times the world installed power generation capacity.

- The sun's heat and light provide an abundant source of energy that can be harnessed in many ways. There are a variety of technologies that have been developed to take advantage of solar energy. These include:

  - **Solar hot water heating systems.**
  - **Solar process heat and space heating & cooling.**
  - **Photovoltaic systems.**
  - **Concentrating solar power systems.**

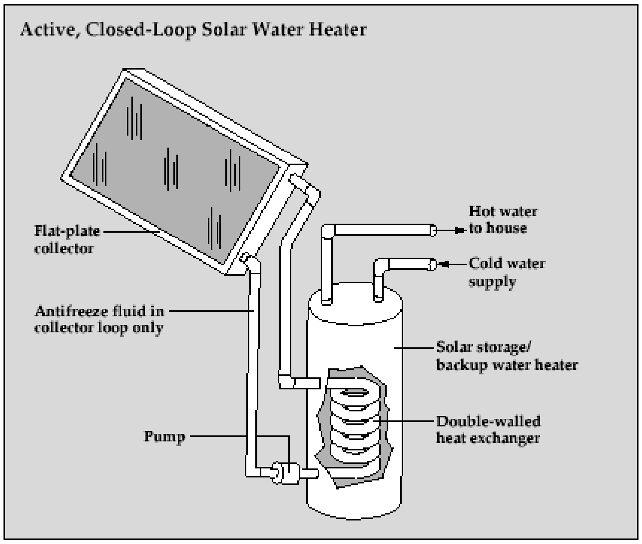
Solar Water Heating

- **Solar water heating is a very cost effective way to produce hot water in any climate, and the fuel they use is free (sun shine).**
- **Solar water heating systems include solar collectors and storage tanks, and they are two types**:
  - **Active systems (have a circulating pump and control).**
  - **Passive systems which works on natural convection.**

Active solar heating systems

They are two types;

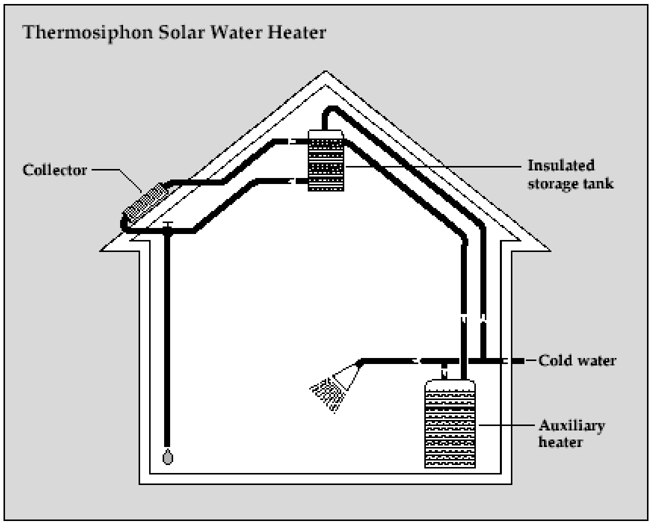
- **Pump circulates household water through the collectors and into the home (open loop),**
- **Pump circulates the heat transfer fluid through the collectors and a heat exchanger (closed loop). This heats the water that flows into the home.**



An active, closed-loop system heats a heat-transfer fluid (such as water or antifreeze) in the collector and uses a heat exchanger to transfer the heat to the household water.

Thermosyphon systems

- **Water flows through the system when warm water rises as cooler water sinks.**
- **The collector must be installed below the storage tank so that warm water will rise into the tank.**

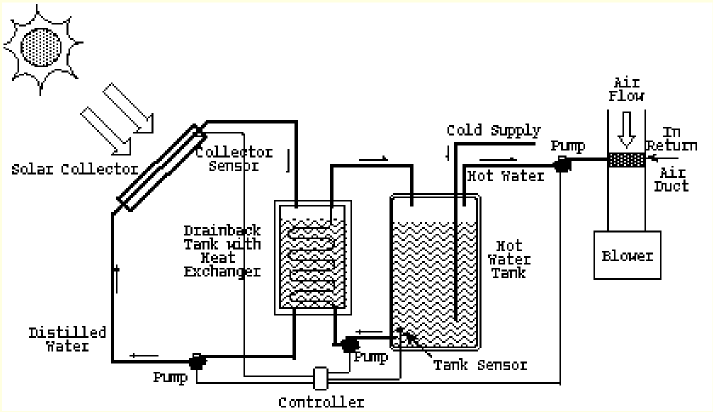


A thermosiphon solar water heater uses natural convection to circulate water through the collectors. Cold water flows from the bottom of the insulated storage tank to the bottom of the collector, and then returns to the storage tank when warmed.

Solar water heater (Thermosyphon system)

Solar Space Heating Systems

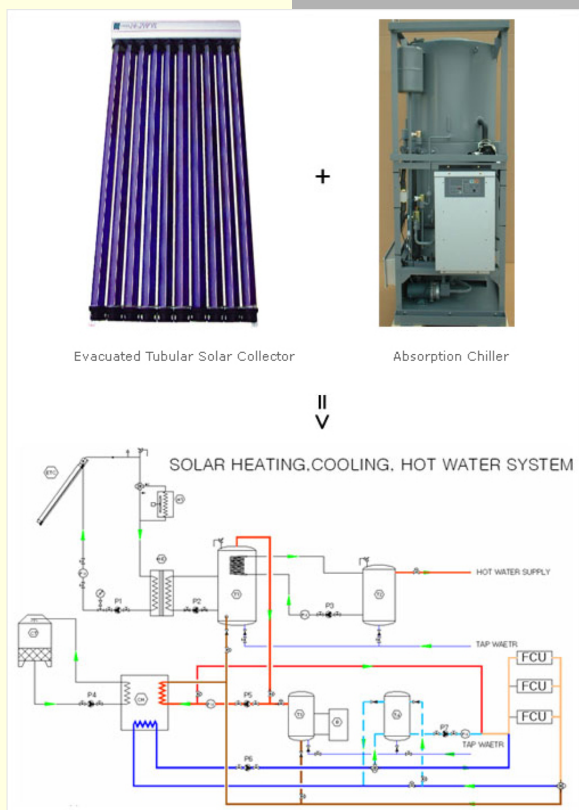
- There are two basic types of active solar heating systems based on the type of fluid that is heated in the solar energy collectors.
- Liquid-based systems which heat water in a liquid collector.
- Air-based systems which heat air in an air collector.



Solar space cooling

A solar thermal cooling system consists of:

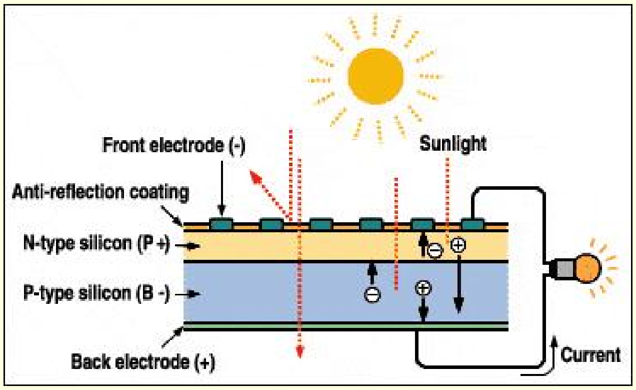
-Solar collectors.
-Storage tank.
-Control unit, pipes and pumps.
-Thermally driven chiller.



Solar power production

Photovoltaic systems

- **Photovoltaic (PV) (photo=light, voltaic=electricity) is a semiconductor-based technology which converts light energy directly into an electric current that can either be used immediately or stored, such as in a battery, for later use.**

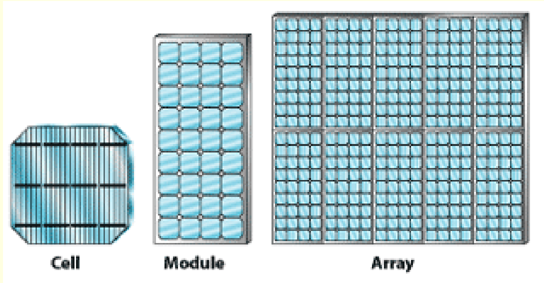


Solar cell

- **PV cell consist of two or more thin layers of semi conducting material most commonly silicon. A silicon cell is a wafer of P-type silicon doped with a small amount of impurity (usually boron) and a thin layer of N-type silicon dopes with a small amount of impurity (usually phosphorous).**
- **When the cell exposed to the light, electrical charges are generated and this can be connected a way by metal contacts as direct current.**

Solar panel (Module)
- Consist of solar cells connected in series and parallel.

Solar Array
- Consist of different solar panels connected in series and parallel.



Types of Solar Cells
The performance of a solar or photovoltaic (PV) cell is measured in terms of its efficiency at converting sunlight into electricity. There are a variety of solar cell materials available, which vary in conversion efficiency.

Mono crystalline silicon
- Manufactured by saw- cut from a single cylindrical crystal of silicon.
- Most efficient (around 15%) and most expensive.

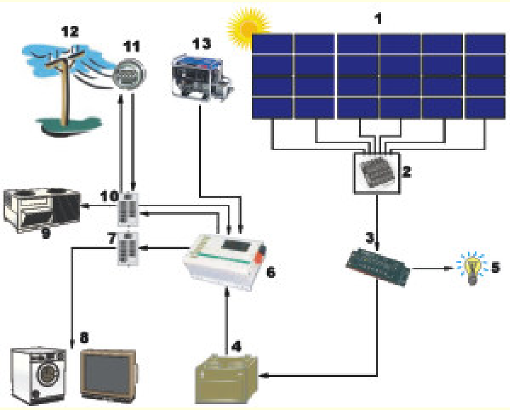
Poly crystalline silicon
- Manufactured by cut from an ingot of melted and re-crystallized silicon.
- Less efficient and cheaper than mono-crystalline.

Amorphous silicon
- Manufactured as a thin film of deposit silicon on substrates.
- less efficient than crystalline silicon and cheaper.

Other Thin Films
They have higher efficiency than amorphous silicon cell and can be produced cheaper.

- Cadmium telluride (CdTe).
- Copper Indian Deselenide (CIS)
- Gallium Arsenide (GaAs).

Complete battery backup system configuration with options



1 - Solar array

2 - Fused array combiner and/or ground fault protection.

3 - Solar regulator

4 - System storage battery

5 - DC load equipment

6 - DC/AC inverter

7 - AC load equipment load panel

8 - AC load equipment operating from solar system

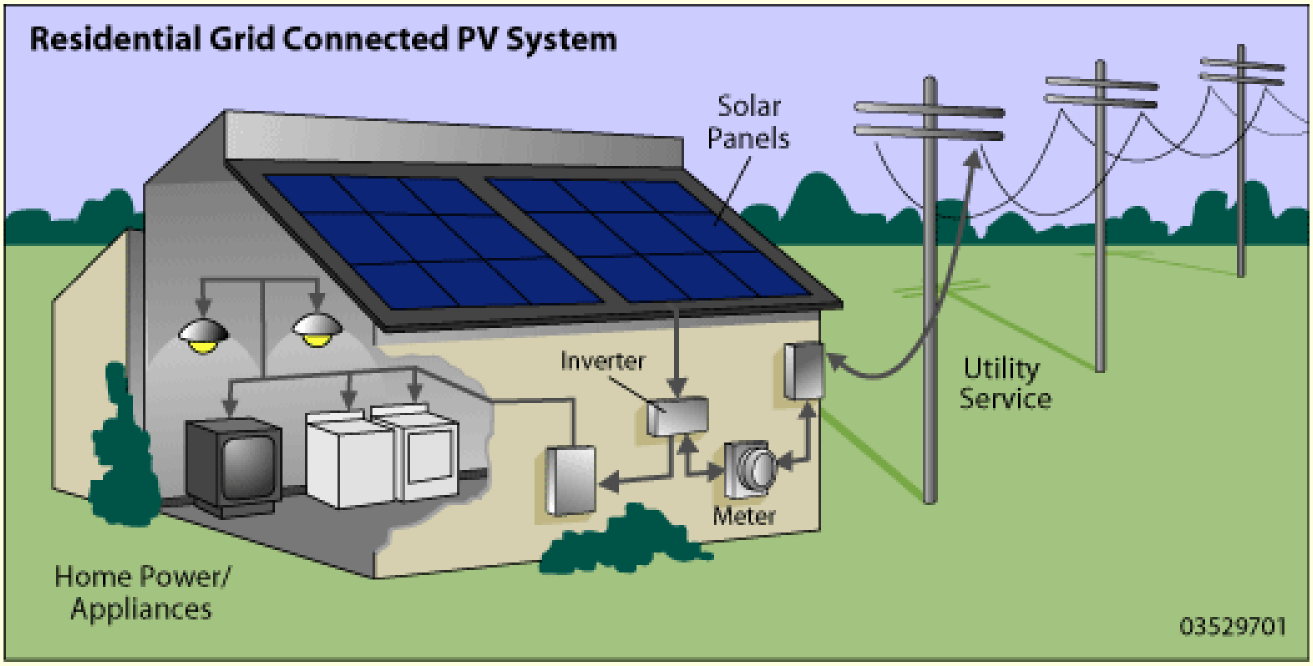
9 - AC load equipment operating from utility

10 - AC utility panel

11 - Utility meter

12 - Utility power

13 - Backup generator


Residential Grid Connected PV System
Solar Panels
Inverter
Utility Service
Meter
Home Power/ Appliances
03529701

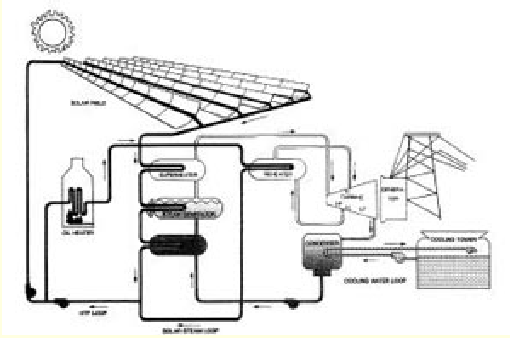
Solar thermal power

Technology works by converting sun energy to heat, which is usually used to produce steam for driving a turbine and a generator. This technology is more efficient (15%) than PV (around 10%) and less expensive when the system is very large in MW.

Three types of systems

Parabolic trough

- The system works by concentrating the sun rays through long rectangular, curved (U-shaped) mirrors, focusing the sunlight on a pipe that runs down the center of the trough.
- The temperature of the fluid flow inside the pipe (usually oil) could reach 400°C



Central receiver system

- It uses a large number of mirrors and heliostats that track the sun and reflect sunlight to the top of a tower, where the receiver sits.
- The system operates at temperatures between 500°C and 1500°.

Parabolic Dish System

- Mirror dish that reflects and concentrate sunlight to a receiver which absorbs the heat and transfer it to fluid within the engine.
- Engines types are: Rankine engine, Brigton engine and stirling engine.
- Striling engine is the most efficient one (30%).

Comparison between different power production technologies

Technology	Area/Power Km^2/MW	Efficiency %	Installation cost $/kW	Electricity cost Cent/kWh
PV system	0.12	10% (5-15%)	6000-8000 11000-14000	50-75
Solar thermal system	0.08	15% (10-20%)	2800-3500	12-17
Gas turbine cycle	0.04	38%	450-650	3-4

Wind Energy

- Wind turbines capture the kinetic energy in the wind using propeller-like blades mounted on a shaft. When the wind makes the blades turn, the shaft spins a generator to produce electricity.
- Small wind turbines can be used to pump water or provide power to a home, for example.
- Larger turbines can be used to a power an entire community or to provide power to the electricity grid.
- Wind-generated electricity is the least expensive form of renewable power, and is becoming one of the cheapest forms of electricity — from any source. In some locations, the cost of electricity from wind is comparable to that from conventional fossil-fueled power plants.

Biomass Energy

- Biomass is any organic material derived from plants or animals — essentially all energy originally captured by photosynthesis.
- Domestic biomass resources include agricultural and forestry residues, municipal solid wastes, industrial wastes, and terrestrial and aquatic "energy crops" grown solely for energy purposes.

Biomass power

- Biomass power is electricity produced from plant materials and animal products.
- Biomass power technologies convert renewable biomass fuels into electricity (and heat) using modern boilers, gasifiers, turbines, generators, and fuel cells.
- Biomass fuels include residues from the wood and paper products industries, residues from food production and processing, trees and grasses grown specifically as energy crops, and gaseous fuels produced from solid biomass, animal wastes, and landfills.

Wood chips made from energy crops, such as hybrid willows (upper), provide raw material for a new gasifier at the McNeil Generating Station (lower). 50-MW wood-fired power plant located in Vermont.

Direct Combustion and Co-firing

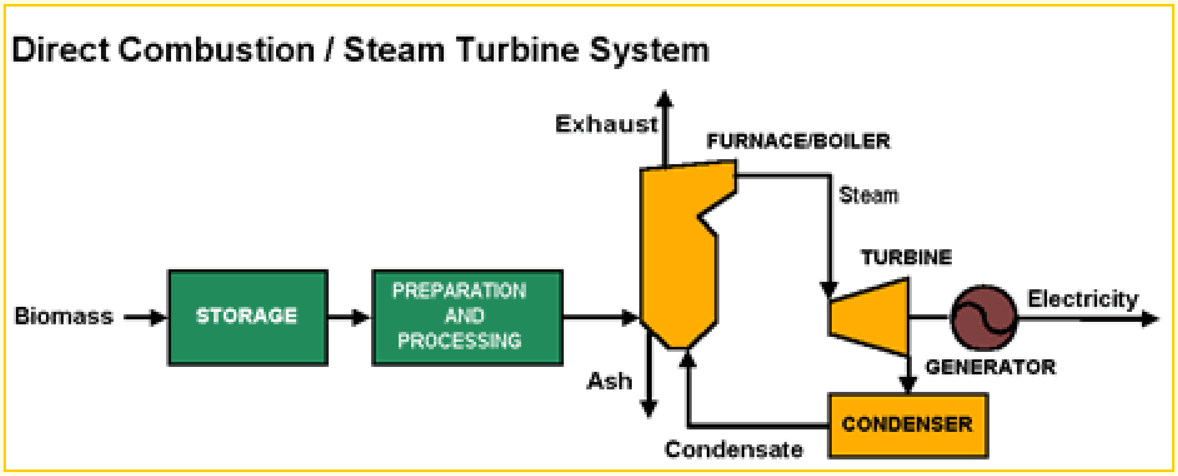


Diagram : In a direct combustion system, processed biomass is the boiler fuel that produces steam to operate a steam turbine and generator to make electricity.

Gasification

- Solid biomass can be converted into a fuel gas in a gasifier such as the one shown in Diagram .
- In this method, sand (at about 1,500°F) surrounds the biomass and creates a very hot, oxygen-starved environment.
- These conditions break apart wood or other biomass and create an energy-rich, flammable gas.
- The biogas can be cofired with wood (or other fuel) in a steam boiler or used to operate a standard gas turbine.

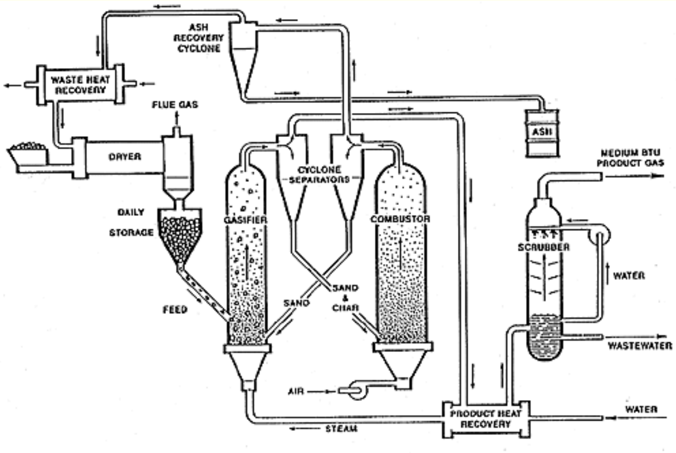


FIGURE 1. BATTELLE'S BIOMASS GASIFICATION SYSTEM

Diagram: one method of transforming biomass particles into biogas fuel.

Anaerobic Digestion

- Biogas can also be produced by digesting food or animal wastes in the absence of oxygen, as shown below.

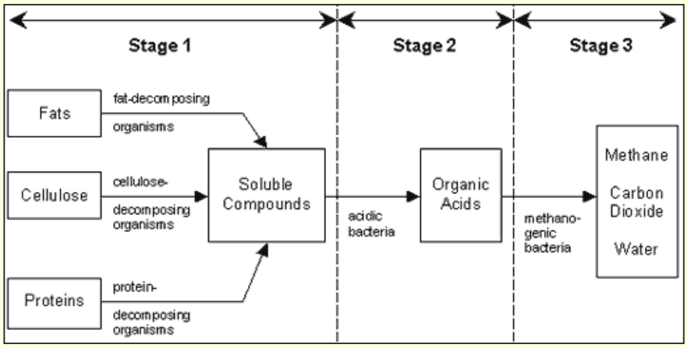


Diagram: Anaerobic digestion, which takes place in three stages inside an airtight container, produces biogas. Different kinds of micro-organisms are responsible for the processes that characterize each stage.

Landfill gas

Landfills also produce a methane-rich biogas from the decay of wastes containing biomass. However, landfill gas must be cleaned to remove harmful and corrosive chemicals before it can be used to generate electricity.

Using Biomass Fuel Gases

- Fuel gases made from biomass can be used to generate electricity in a gas turbine, as shown.

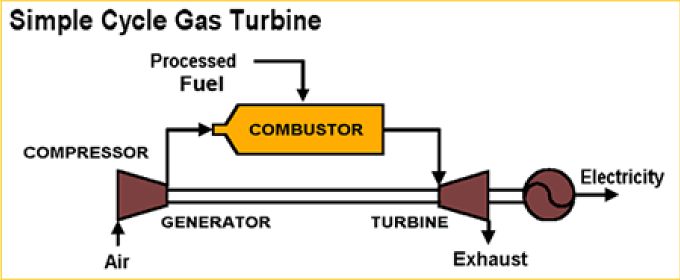


Diagram: In a simple-cycle gas turbine, both pressurized fuel gas and hot combustion product gases operate a gas turbine and generator, producing electricity.

Biomass Energy - Biofuels

- "Biofuel" is liquid fuels, such as ethanol and biodiesel used for transportation and electricity production.
- Unlike gasoline and diesel, biofuels contain oxygen. Adding biofuels to petroleum products allows the fuel to combust more completely, reducing air pollution.
- The market for biofuels is growing. Existing production methods typically use relatively high-priced common crops — oil-rich seeds such as soybeans; sugarcane, corn, and other cereals — as feedstocks. All of these crops have other uses, driving up their cost.

Ethanol

- Ethanol is the most widely used biofuel today. In 2003, more than 2.8 billion gallons were added to gasoline in the United States to improve vehicle performance and reduce air pollution.
  starch crops are converted into sugars, the sugars are fermented into ethanol, and then the ethanol is distilled into its final form. Ethanol is used to increase octane ratings and improve the emissions quality of gasoline.

Ethanol production plant in Nebraska.

Renewable Diesel Fuels

- There are a variety of fuels that can be used in diesel engines and that are made from renewable resources such as vegetable oils, animal fats, or other types of biomass such as grasses and trees.
- These renewable diesel fuels can be used in place of, or blended with, petroleum diesel.

Hydrogen Energy & Fuel Cell

Hydrogen can be found in many organic compounds, as well as water. It's the most abundant element on the Earth. But it doesn't occur naturally as a gas. It's always combined with other elements, such as with oxygen to make water. Once separated from another element, hydrogen can be burned as a fuel or converted into electricity.

Hydrogen can be produced from:

Solar Thermal Water Splitting

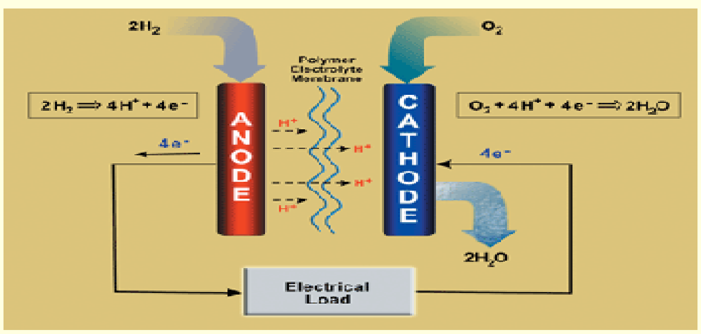
- **Concentrated solar energy can also be used to generate temperatures of several hundred to over 2,000 degrees at which thermo chemical reaction cycles can be used to produce hydrogen. Such high-temperature, high-flux solar driven thermo chemical processes offer a novel approach for the environmentally benign production of hydrogen.**

Renewable Electrolysis

- **Renewable energy sources such as photovoltaic, wind, biomass, hydro, and geothermal can provide clean and sustainable electricity to produce hydrogen through the electrolysis—splitting with an electric current—of water and to use that hydrogen in a fuel cell to produce electricity during times of low power production or peak demand, or to use the hydrogen in fuel cell vehicles.**

Fuel Cell

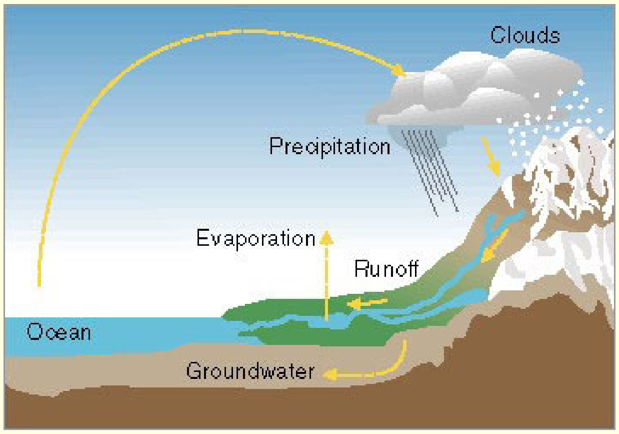
- fuel cell is an electrochemical energy conversion device. It produces electricity from external supplies of fuel (on the anode side) and oxidant (on the side). These react in the presence of an electrolyte. Generally, the reactants flow in and reaction products flow out while the electrolyte remains in the cell. Fuel cells cacathode n operate virtually continuously as long as the necessary flows are maintained.
- Fuel cells differ from batteries in that they consume reactants, which must be replenished, while batteries store electrical energy chemically in a closed system. Additionally, while the electrodes within a battery react and change as a battery is charged or discharged, a fuel cell's electrodes are catalytic and relatively stable.



Two electrodes; one positively charged and one negatively charged & a substance that conduct electricity (electrolyte) sandwiched between them.

Hydropower Energy

- Water constantly moves through a vast global cycle, evaporating from lakes and oceans, forming clouds, precipitating as rain or snow, then flowing back down to the ocean. The energy of this water cycle, which is driven by the sun, can be tapped to produce electricity.



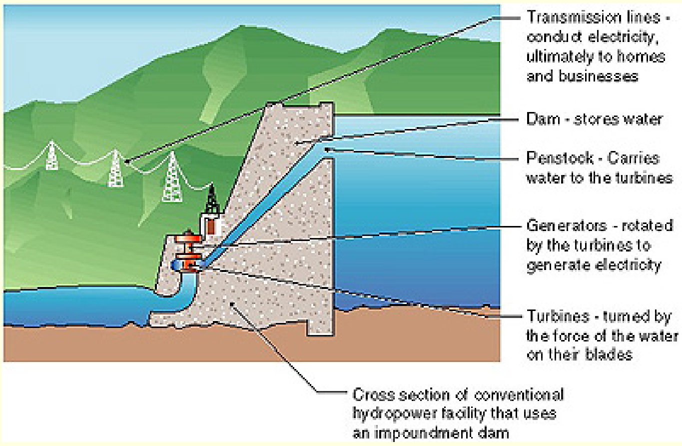
There are three types of hydropower facilities:

- Impoundment(usually large).
- Diversion(usually small).
- Pumped storage.

- Some hydropower plants use dams and some do not.
- Hydropower plants range in size from small systems for a home or a village to large plants producing electricity for utilities.

Impoundment (Large) power plant

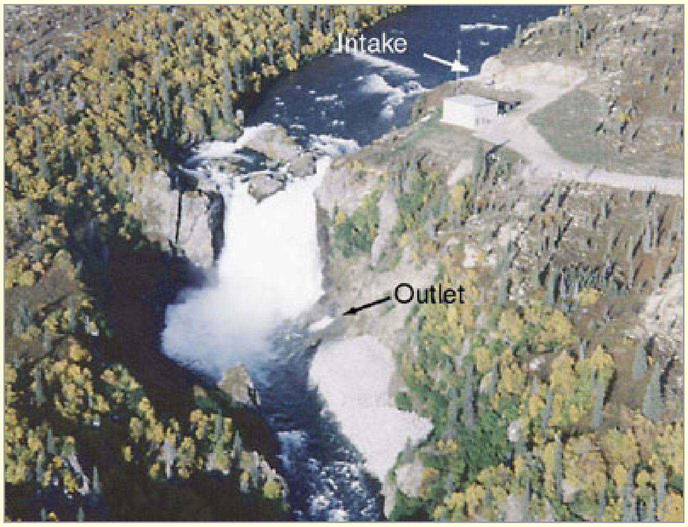
- It is typically a large hydropower system, uses a dam to store river water in a reservoir. Water released from the reservoir flows through a turbine, spinning it, which in turn activates a generator to produce electricity. The water may be released either to meet changing electricity needs or to maintain a constant reservoir level.



An impoundment hydropower plant dams water in a reservoir.

Small power plants

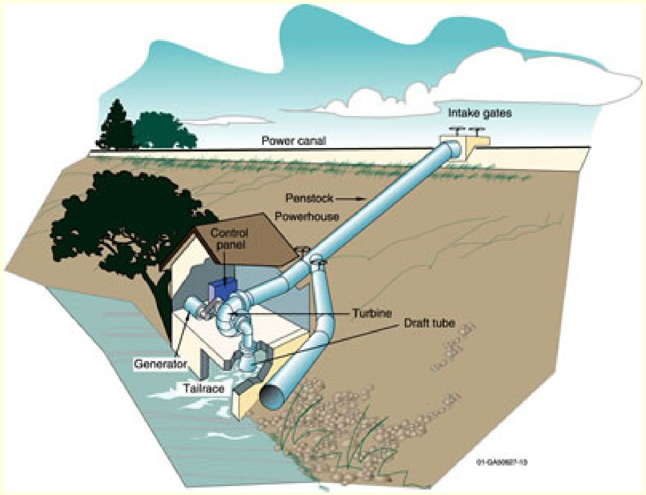
- A diversion (small), sometimes called run-of-river, facility channels a portion of a river through a canal or penstock. It may not require the use of a dam.



The Tazimina project in Alaska is a diversion hydropower plant. No dam was required.

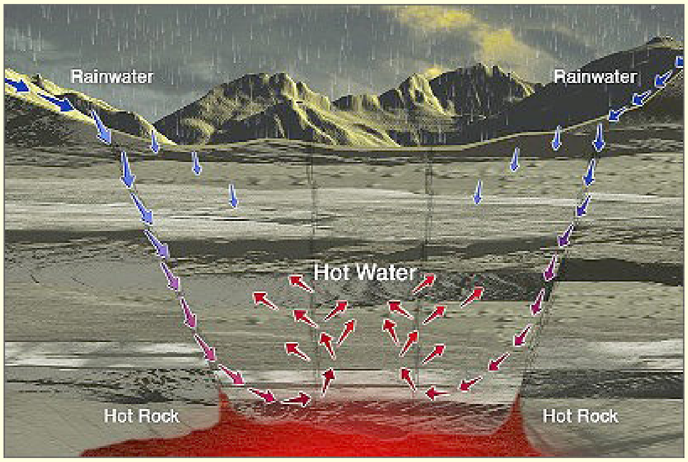
Micro Hydropower

- A micro hydropower plant has a capacity of up to 100 kilowatts. A small or micro-hydroelectric power system can produce enough electricity for a home, farm, ranch, or village



Geothermal Energy Systems

- Geothermal ("Earth-heat") energy comes from the residual heat left over from the Earth's formation and from the radioactive decay of atoms deep inside the earth.
- This heat is brought up to the earth's crust by molten rock (magma) and by conduction through solid rock. There it raises the temperature of the earth's surface and of groundwater trapped in the fissures and pores of underground rock, forming zones called hydrothermal (hot water) reservoirs.



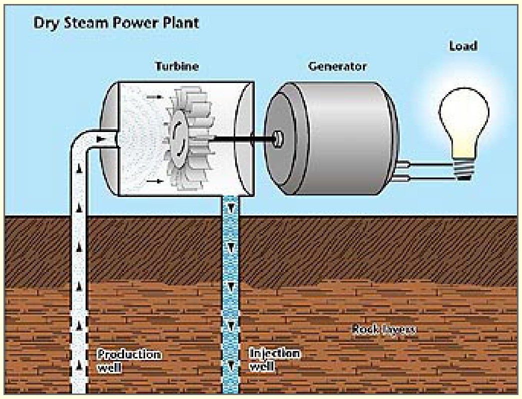
Geothermal water cycle.

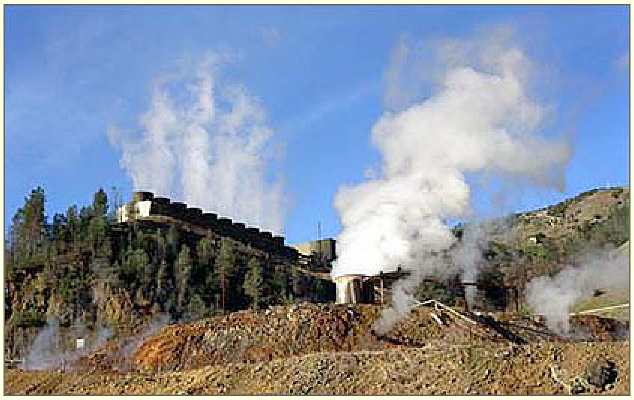
Electricity Production

- Geothermal power can be generated by modular units ranging in size from a few hundred kilowatts to more than 100 MW in size. The cost of producing geothermal electricity ranges from roughly 5 cents/kWh to 8 cents/kWh.

- Three technologies can be used to convert hydrothermal fluids to electricity. The type of conversion used depends on the state of the fluid resource (whether steam or water) and its temperature. These are:
  - Steam power plant
  - High water temperature power plant
  - Moderate water temperature power plant

Steam power plant

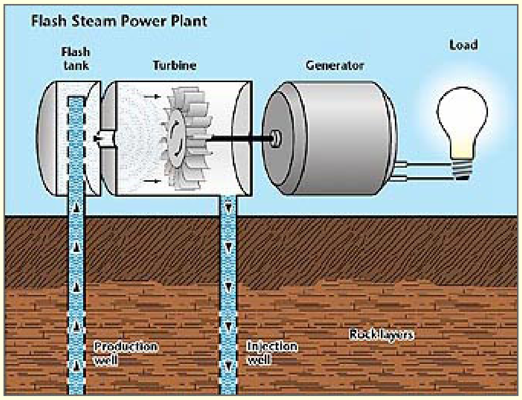


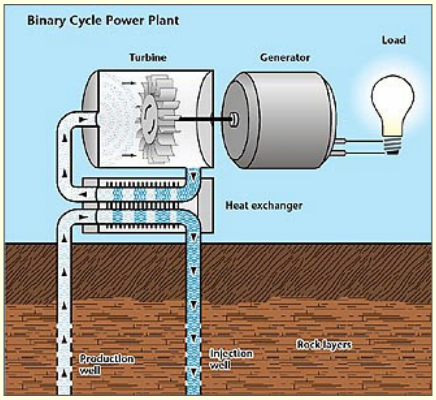


With a 750-MW output, The Geysers in California is the largest producer of geothermal electricity in the world. (Photo: David Parsons)

High-Temperature Water power plant

Moderate-Temperature Water power plant





The Mammoth geothermal plant, located in the eastern Sierra Nevada mountain range in California, showcases the environmentally friendly nature of geothermal power. Three air-cooled binary units generate a total of 28 MW of electricity, and release essentially no emissions into the atmosphere or land surface.

Direct Use of Hydrothermal Resources

- Hot water from geothermal resources can be used directly to provide water and space heating.
- Direct use applications include crop drying, industrial processes, resorts and spas; and heating buildings, greenhouses, and fish farms.

Renewable Energy World Market

- **According to a recent Reuter's article, the world solar market jumped 70 % in 2004.**
- **Two big drivers in that growth were Japan and Germany.**
- **Renewable energy creates 200,000 jobs in Europe.**
- **Solar electricity production growth jumped 67 percent last year.**
- **World solar cell production reached 1,256 MW.**
- **Grid Connected Solar PV grew by more than 40%.**
- **Off-grid PV grew by about 10%.**
- **Wind power is today the fastest growing electricity generation technology.**
- **Impressive wind annual growth rates of more than 35% between 1996 and 2001 have made Europe into the frontrunner in wind energy technology development.**
- **At the end of 2003 the installed capacity of wind power reached 28,440MW in the EU 15 and more than 39,000MW world wide.**
- **The industry is capable of continuing its high growth rates if other countries follow the success stories of Germany, Spain and Denmark, which together accounted for more than 80% of the 2003 market.**

- **Since 2000, the market has clearly passed the mark of 1million m2 newly installed solar collectors per year.**
- **After a significant contraction in 2002, mainly originated in Germany, a new peak over 1.4 million m2 was reached in 2003.**
- **Taking into account the last estimates, the surface in operation at the end of 2003 is roughly 11.9 million m2.**
- **The European Union would already be very close to reaching the target of 100 million m2, corresponding to 266 m2 per 1,000 inhabitants.**
- **The present biomass contribution to the total energy demand approach 14-15 %(1.2 billion toe/year) with much higher contribution in developing countries (38%) for heating and cooking.**
- **Annual bio-fuels production, ethanol and bio-diesel, increased by 14%.**
- **Small hydro-power grew 10-15%, mainly in China.**
- **the present state of market progress and a strong political support, the current expectation is that the overall contribution of renewable energy to energy consumption in 2020 will be 20%.**

Renewable Energy Financing Opportunities in the World

- **$ 28 billion was invested in "new" renewable energy in 2004.**

This amount comes from:

- **WB and UN system: $ 500 million**
- **European investment bank: $ 600-700 million**
- **The rest comes from private sector and local banks.**
- **An additional $ 4-5 billion in new plant and equipment was invested in 2004 by the Solar PV manufacturing industry.**
- **Several million dollars was invested by the ethanol industry in new production plants.**
- **These investments compare to a $ 110-150 billion invested annually in the power sector worldwide, or 20-25% of the total power sector investment.**
- **Investment shares in 2004 were:**

$ 9.5 billion for wind power

$ 7.5 billion for solar PV

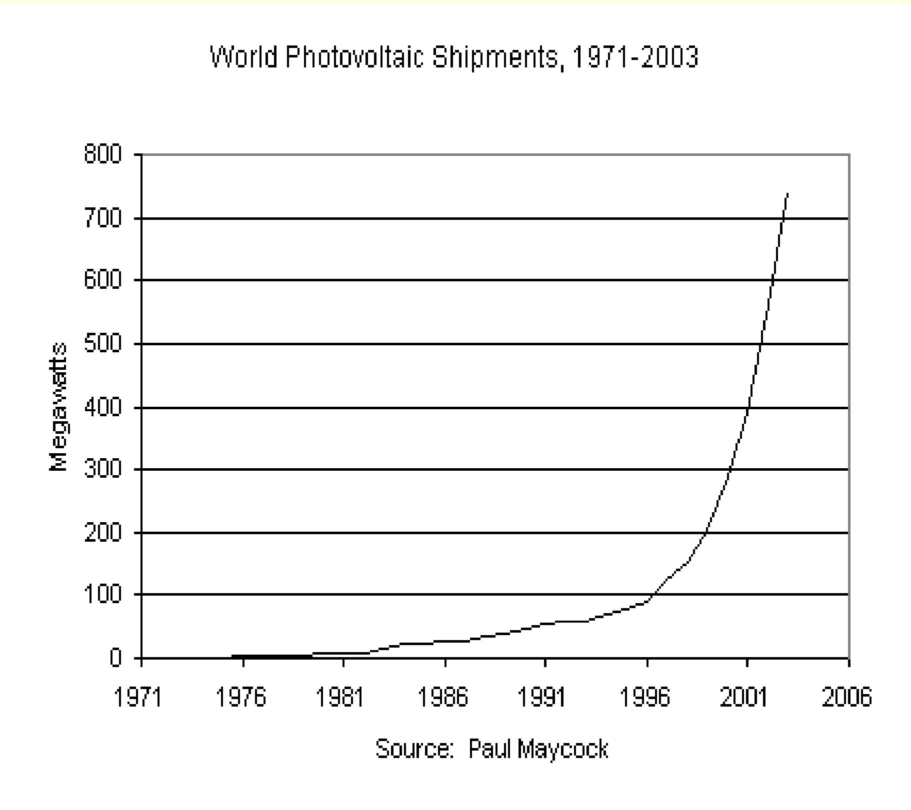
$ 6 billion for solar hot water/heating

$ 5 billion for the remaining technologies such as geothermal power and heat, small hydro power, and biomass.

Selected Examples of Government Incentives for Solar Energy

Country	Year	Incentive
Japan	1992	**New Sunshine Program:** Established to introduce renewable energy throughout the country. Targets were set and a net metering law enacted.
Japan	1994	**70,000 Roofs Program:** Initially, 50 percent of PV installation costs were subsidized and the annual budget (for R&D and market incentives) was $18.3 million. In 2003, the subsidy was reduced to 15 percent and the budget allocation increased to $186 million.
United States	1997	**Million Solar Roofs Initiative:** National program designed to facilitate the installation of solar energy systems on one million U.S. buildings by 2010.
Germany	1998	**100,000 Roofs Program:** Provided 10-year loans with reduced interest rates to buyers of PV systems. It ended early, in 2003, when all targets were met.
Germany	1999	**Renewable Energy Sources Act (Feed-In Tariff):** Customer applications receive 56¢ per kWh for solar-generated electricity sold back to the grid.
Italy	2001	**10,000 Roofs Program:** Regions offer different investment subsidies to promote building-integrated photovoltaic applications.
Japan	2003	**Renewable Power Portfolio Standard:** Requires that renewable energy be provided at a constant percentage of the electric power supply. This legislation aims for renewable energy to be 3.2 percent of the total by 2010.
China	2004	Allocation of $1.21 billion to adopt solar and wind energy for power generation in remote areas of West China.

Sources: Arnulf Jager-Waldau, **PV Status Report 2003** (Ispra, Italy: September 2003); Paul Maycock, "China PV Booming," **Photovoltaic News**, May 2004; Jane Pulaski and Larry Sherwood, "Power Roofs," **Solar Today**, July/August 2004, pp.36-39; Janet L. Sawin, **Mainstreaming Renewable Energy in the 21st Century**, Worldwatch Paper 169 (Washington, DC: Worldwatch Institute, May 2004).


World Photovoltaic Shipments, 1971-2003
Megawatts
800
700
600
500
400
300
200
100
0
1971
1976
1981
1986
1991
1996
2001
2006
Source: Paul Maycock

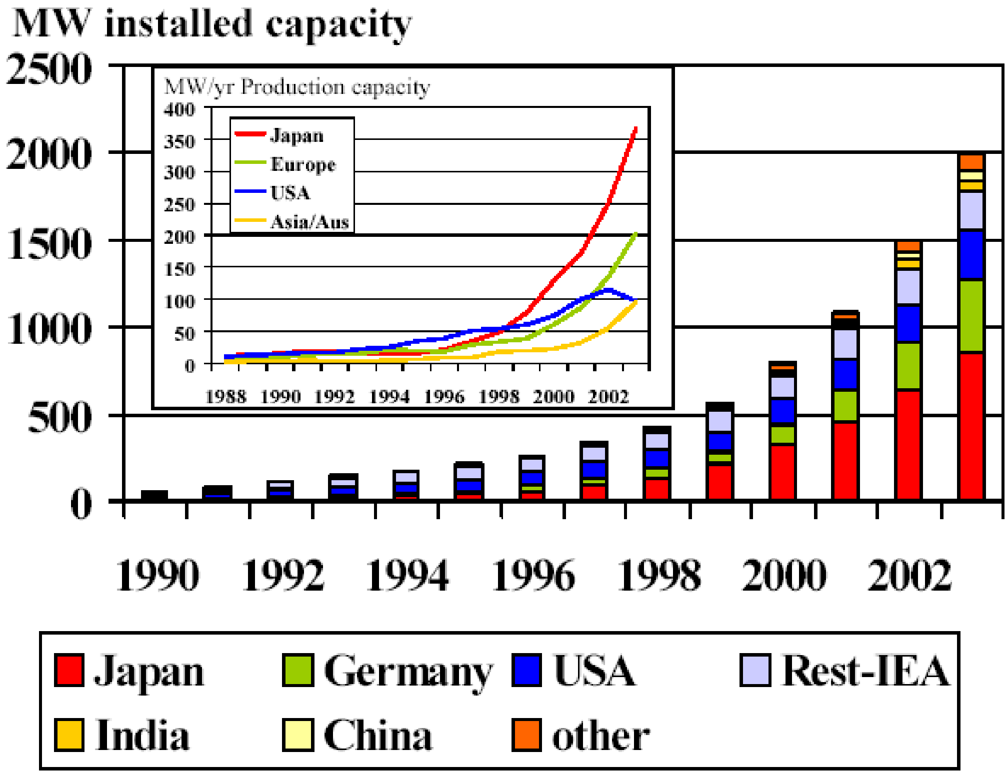
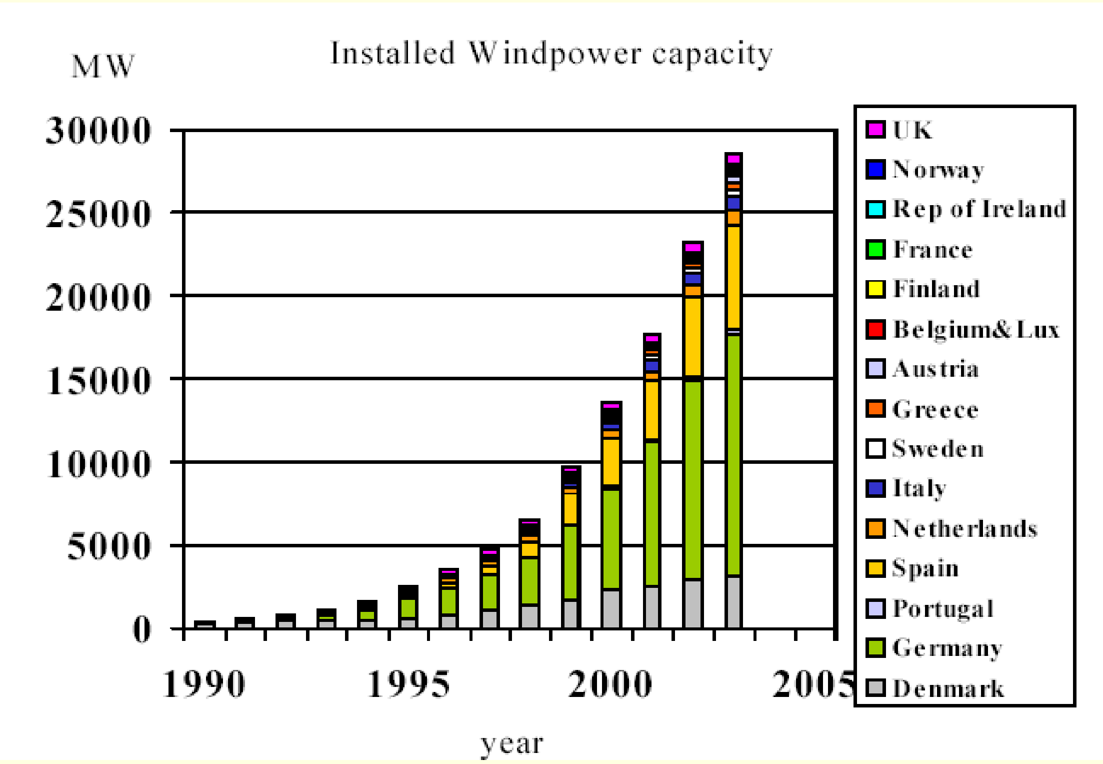
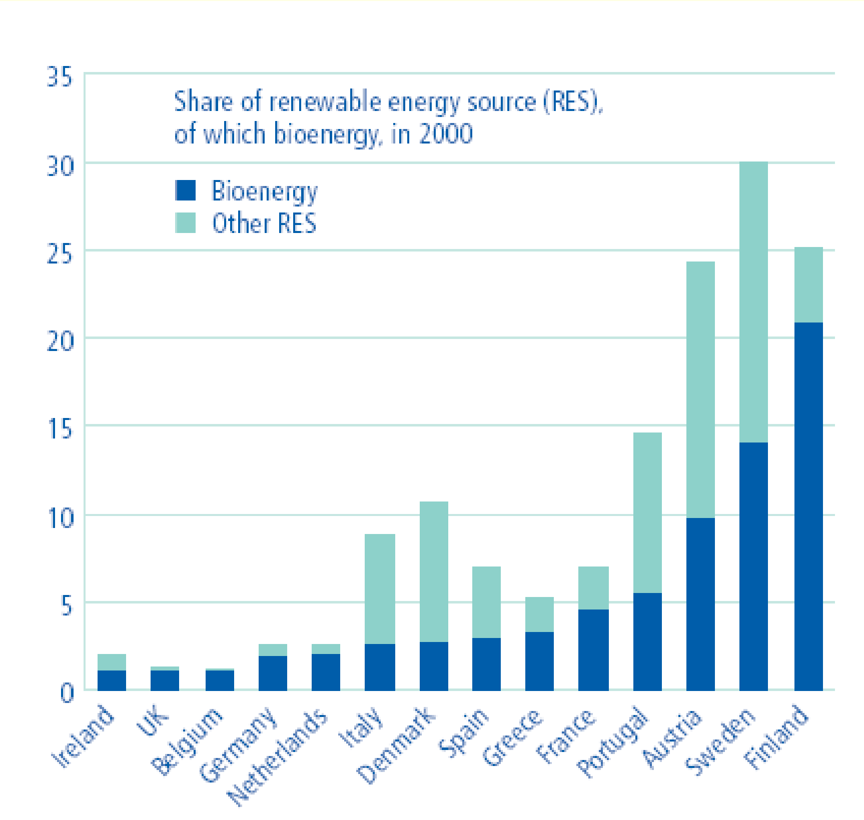


Figure 8: World wide installed PV capacities [7]

Top ten European manufacturers of solar cells

Company	Production Total 2002 (MW)	Production Total 2001 (MW)	Growth
1- Isofotón (Spain)	27.4	18.7	46%
2- RWE Schott Solar (Germany)	24.5	18.1	35%
3- Photowatt (France)	17.0	13.5	26%
4- BP Solar (Spain)	16.7	12.2	37%
5- Q-Cells (Germany)	9.0	0.4	23%
6- Ersol (Germany)	9.0	3.9	4%
7- Shell Solar (Netherlands)	9.0	10.3	-13%
8- Astra Solar(Spain)	6.0	6.0	0%
9- Sunways (Germany)	4.8	3.0	60%
10- Dunasolar (Hungary)	3.0	2.5	20%
TOTAL	**148**	**121**	**22%**


Installed Windpower capacity
MW
30000
25000
20000
15000
10000
5000
0
1990
1995
2000
2005
year
UK
Norway
Rep of Ireland
France
Finland
Belgium&Lux
Austria
Greece
Sweden
Italy
Netherlands
Spain
Portugal
Germany
Denmark



Share of renewable energy source (RES), of which bioenergy, in 2000
Bioenergy
Other RES
35
30
25
20
15
10
5
0
Ireland
UK
Belgium
Germany
Netherlands
Italy
Denmark
Spain
Greece
France
Portugal
Austria
Sweden
Finland

Table 1: Share of renewable energies on TPES in selected countries in 2001 (EU: 2002); TPES = Total primary energy supply. [5]

country	TPES [PJ]	Renewables-share	conbtribution to renewables from		
			hydro	biomass	other*)
China	47,704	21%	10%	90%	0%
India	22,253	40%	3%	96.9%	0.1%
USA	95,518	4%	18%	67.6%	14.9%
Nigeria	3,994	78%	1%	99.2%	0%
Brazil	7,740	36%	35%	65.3%	0%
Indonesia	6,376	34%	2%	93.2%	5%
Canada	10,392	16%	73%	26.7%	0.1%
Pakistan	2,700	40%	6%	93.7%	0%
Vietnam	1,650	62%	6%	93.6%	0%
Phillippines	1,767	46%	3%	50.4%	46.4%
Russia	26,364	3%	80%	20.1%	0.4%
Ethiopia	804	94%	1%	99.1%	0%
Japan	21,801	3%	46%	31%	23.4%
EU-15**)	51,600	5.9%	61%	32.6%	6.4%
-Germany**)	12,160	3.1%	--	--	--
-Sweden **)	1,336	35.1%	47.2%	50.6%	2.2%
-Austria**)	1,037	22.8%	44.4%	54.3%	1.3%
World	420,000	13.5%	2.2%	10.8%	0.5%

12

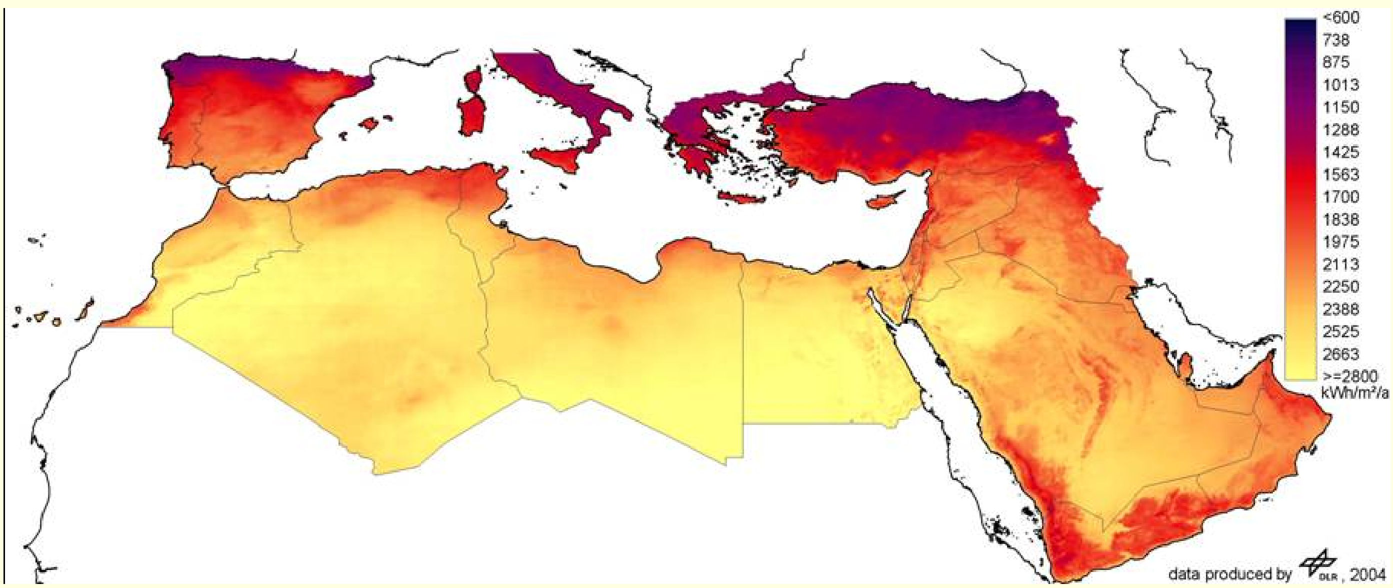
RE Potentials in Arab region

Solar Energy Potentials

- **The economical production of solar electricity requires radiation of 1700 kWh/m2/year or 4-5 kW/hr/m2/day.**
- **All Arab countries are among those who intercept more than the amount of 1700 kWh/m2/year**

Direct normal and global horizontal irradiant of Arab Countries

Country	Direct normal irradiance kWh/m^2/y (for CSP)	Global horizontal irradiance kWh/m^2/y (for PV)
Bahrain	2,050	2,160
Iraq	2,000	2,050
Jordan	2,700	2,310
Kuwait	2,100	1,900
Lebanon	2,000	1,920
Oman	2,200	2,050
Qatar	2,000	2,140
Saudi Arabia	2,500	2,130
Syria	2,200	2,360
UAE	2,200	2,120
Yemen	2,200	2,250
Algeria	2,700	1,970
Egypt	2,800	2,450
Libya	2,700	1,940
Morocco	2,600	2,000
Tunisia	2,400	1,980



Annual direct normal irradiance of the year 2002.

cons
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More t
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7.32%
Table
share

- E
- A
- C
- F
- In

- N
- N
- N
- E
- N