

Lecture 2: Renewable Energy Sources

KEMS821 Renewable Energy
Production

RENEWABLE ENERGY

'The term "renewable energy resource" is used for energy flows which are replenished at the same rate as they are "used" '

—Sørensen, 1979

"Energy [from] sources that are, within a short time frame relative to the Earth's natural cycles, sustainable, and include non-carbon technologies such as solar energy, hydropower, and wind, as well as carbon-neutral technologies such as biomass."

—IPCC

There are four fundamental forms of energy.

Kinetic energy

**possessed by any moving object
Incl. thermal energy or heat**

Gravitational potential energy

energy associated with the gravitational pull of the Earth (and Sun)

Electrical energy

energy associated with electrical forces which hold together the atoms and molecules of all materials

Incl. chemical energy; electromagnetic energy; electricity (intermediate form of electrical energy)

Atomic or nuclear energy

energy bound up in the central nuclei of atoms

Renewable Energy Sources (RES) or renewables can be divided into three areas.

Solar energy

available annual energy 3 900 000 000 PJ/year

Planetary energy

available annual energy 94 000 PJ/year

Geothermal energy

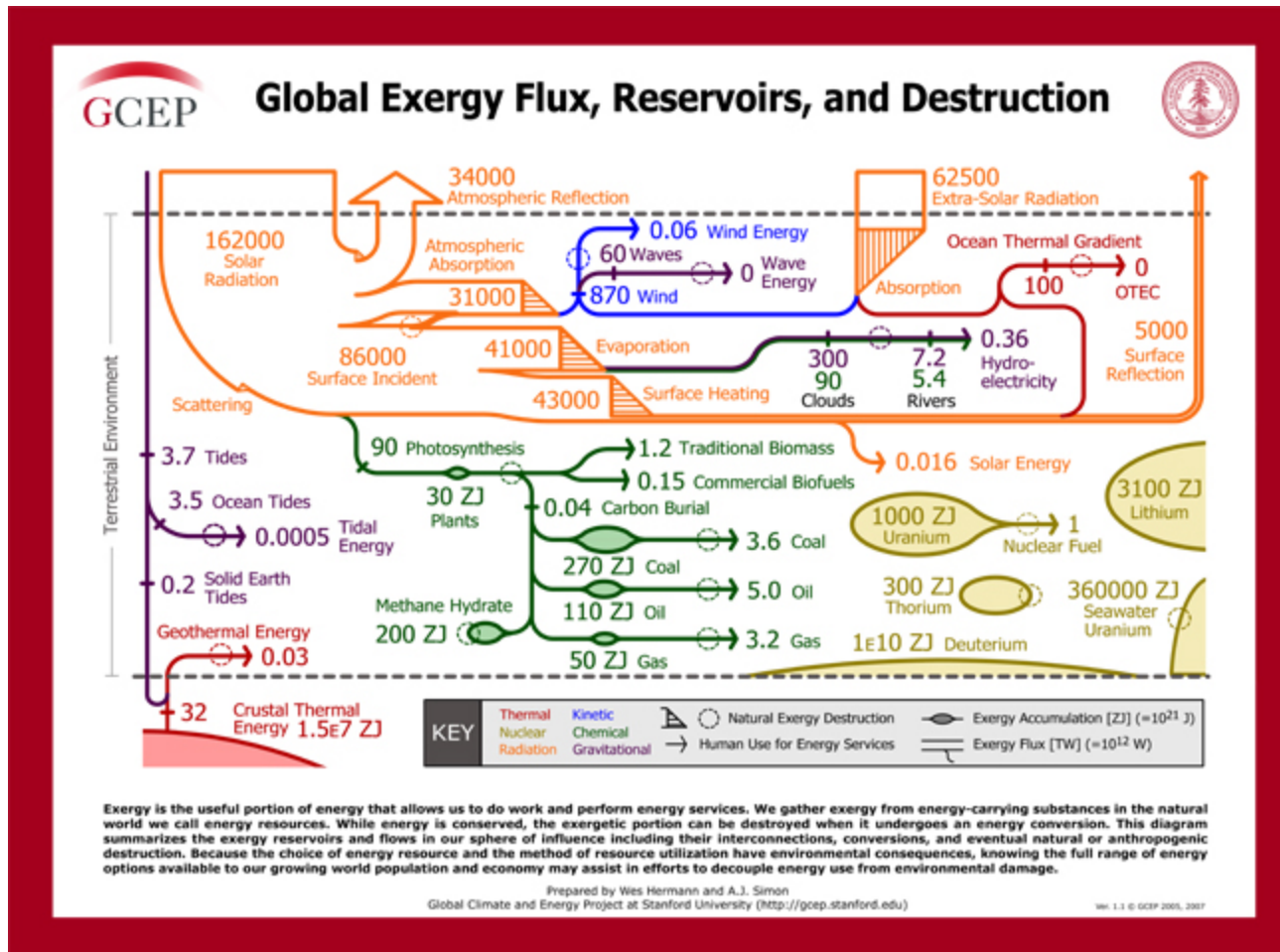
available annual energy 996 000 PJ/year

N.B.

Energy stored in wind or rain, which can also be technically exploited, originate from *natural energy conversion*.

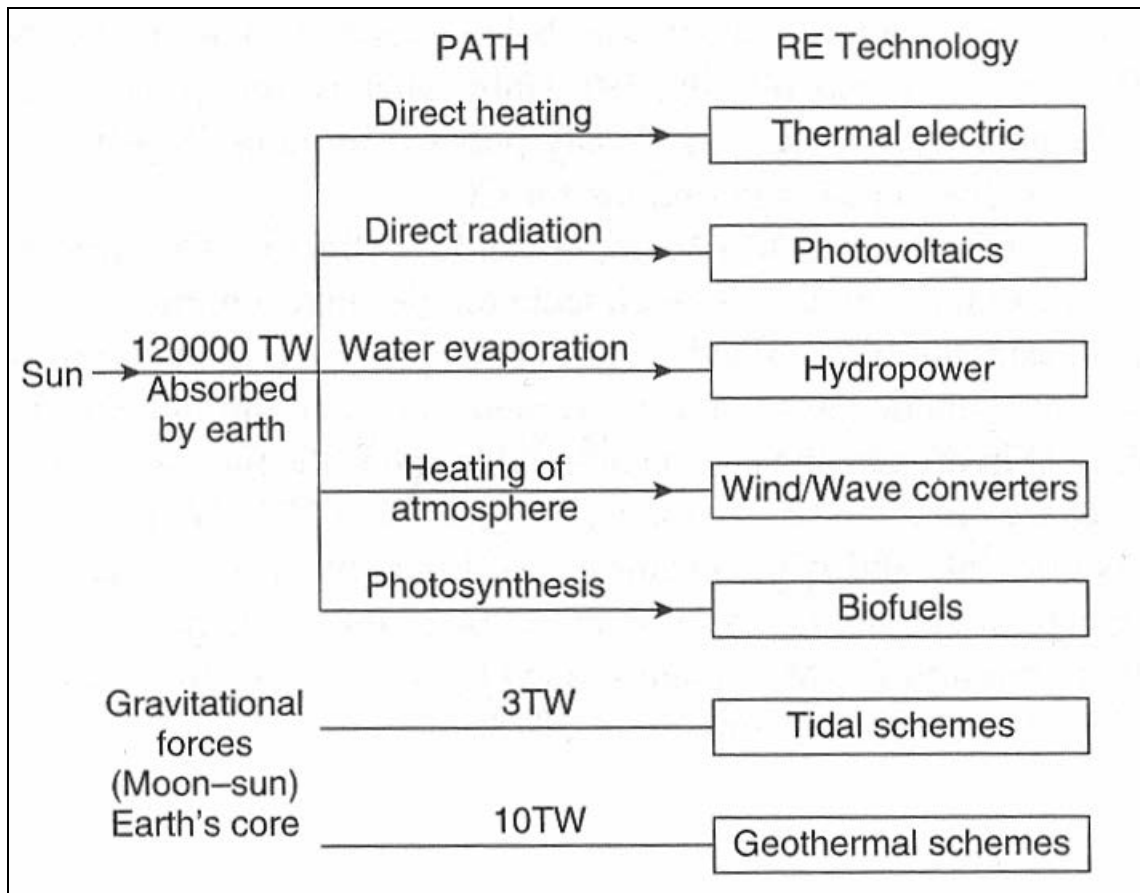
Exergy is the useful portion of energy that allows us to do work and perform energy services.

Ref.: [doi:10.1016/j.energy.2005.09.006](https://doi.org/10.1016/j.energy.2005.09.006)



Source: Jussi Maunuksela (2012)

The main source of easily accessible renewable energy is the sun.



On average the rate of solar radiation intercepted by the earth's surface is about 8000 times as large as the average rate of world primary energy consumption.

Figure 'energy paths that can be tapped to generate sustainable electricity' from the book by Freris & Infield.

Solar radiation is available both directly and indirectly.

Direct solar energy

Directly as solar radiation directly converted into useful energy, for instance electricity or heat.

Indirect solar energy

Indirectly in the form of power from wind, biomass, hydro, and marine sources.



Solar thermal signifies the thermal use of solar energy in general.

Conversion of solar energy to heat

requires a light-absorbing material, or a collector, which is able to distribute the absorbed radiant energy over internal degrees of freedom associated with kinetic energy of motion at the molecular level.

Absorption of solar energy

will rise the temperature of the collector or transfer energy to a reservoir, if the collector is connected to one.

“Passive” system

“natural” heat flow paths between collectors and load areas.

“Active” system

energy is added (pumps, etc.) to bring the collector heat gain to the load areas.

Solar energy may be converted to electricity by one of two means:

Solar thermal conversion

Conversion of solar radiation to heat that in turn is added to a thermodynamic cycle to produce mechanical work or electricity.



Photovoltaic conversion

Direct conversion of the solar radiant-energy photons to electricity without the benefit of a thermodynamic cycle or working fluid.

The term 'photovoltaic' is derived by combining two words: the Greek word for light '*photos*' the name of the electromotive force '*volt*'.



There are two basic types of device currently used to capture and utilise solar radiation.

Solar thermal collectors,
which are used to heat air, water or
other liquids, depending on the
application.



Photovoltaic (PV) collectors,
which convert sunlight directly into
electricity.



Non-concentrating solar collectors can produce temperatures up to about 100°C.

Applications

Heating and cooling of buildings

Provision of domestic hot water and industrial process heat.



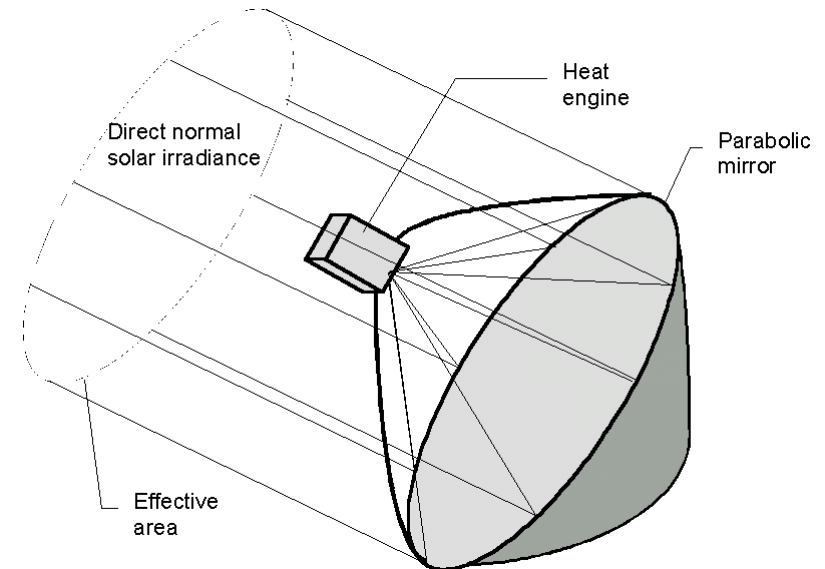
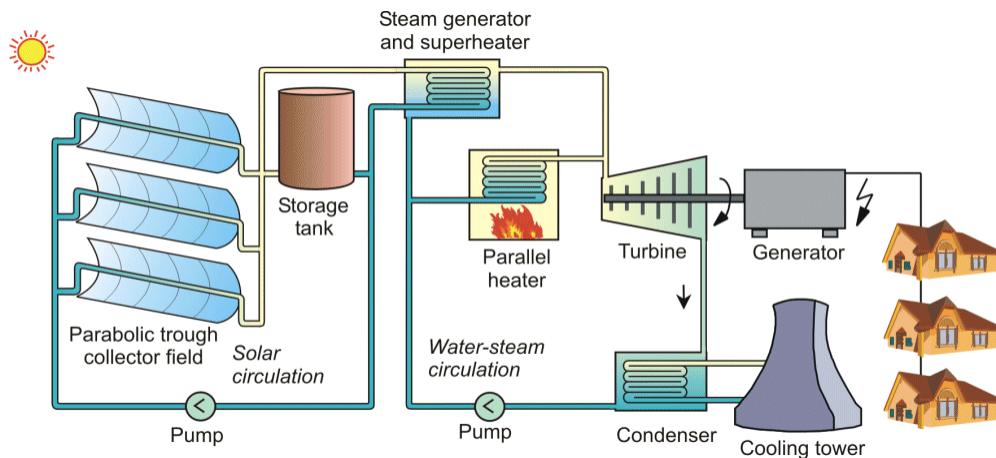
Medium-temperature concentrating collectors such as parabolic troughs / dishes provide temperatures of 100 - 400°C.

Applications

Process heat

Refrigeration

Electricity production



Figures from Understanding Renewable Energy Systems by Volker Quaschnig.

Central-receiver types of solar concentrating collectors can produce temperatures as high as 2000°C or more.

Applications

Electricity generation

Industrial furnace applications



**Figures courtesy of
DOE/NREL**

Besides collector systems that use solar energy actively, so-called passive use of solar energy is possible.



Passive solar building designs

Well-oriented buildings with intelligently designed glass facades etc.

**Conventional energy consumption can be reduced by as much as 75%.
Growing trend towards the use of passive solar in conjunction with BIPV.**



Natural processes transform solar energy into other types of energy that can be utilized by technical energy converters.

Types of indirect energy

Evaporation

Precipitation

Water flow

Melting of snow

Wave movements

Ocean currents

Biomass production

Heating of Earth's surface and the atmosphere

Wind.

Global Water Cycle

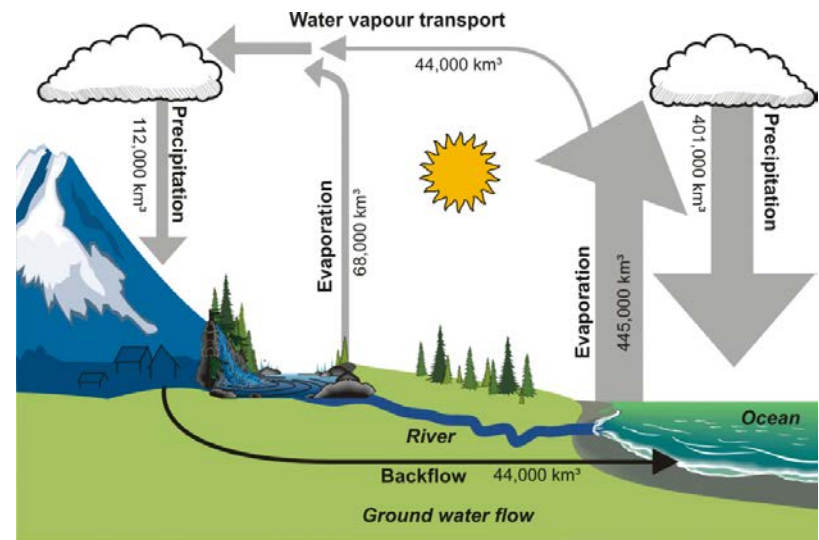


Figure from Understanding Renewable Energy Systems by Volker Quaschnig.

Hydro-electric power is currently easily the largest of the Renewable Energy Sources.

One of the most mature RE technologies

About 160 EJ is stored in rivers and seas, which is equivalent to roughly 40 % of the global energy demand, of which about one-quarter is technically exploited (Europe well exploited).

Controversial

Hydro-electric power plants have a negative impact on nature and local conditions.

Figure from Understanding Renewable Energy Systems by Volker Quaschning/Source: Itaipu Binacional (2003).



Bioenergy is mankind's oldest source of energy.

Humans have been using biomass as an energy source for many thousands of years.

Wood was the most important material for heating and cooking for a long time until it was superseded by coal, crude oil and natural gas.



Bioenergy is arguably the one truly Renewable Energy Resource

Renewable energy resource

Each new crop or harvest represents a partial renewal of its resource base. (Wood fuel is a RES if “consumption rate” \leq “renewal rate”.)

Major World Energy Source

‘Biomass’ from plants is one of the major world fuel sources (about 9 % of the global primary energy use, 2001)

Biofuels

Interest in biofuels – ethanol and biodiesel – is at an all-time high.

N.B.

Stored bioenergy can be used on demand!

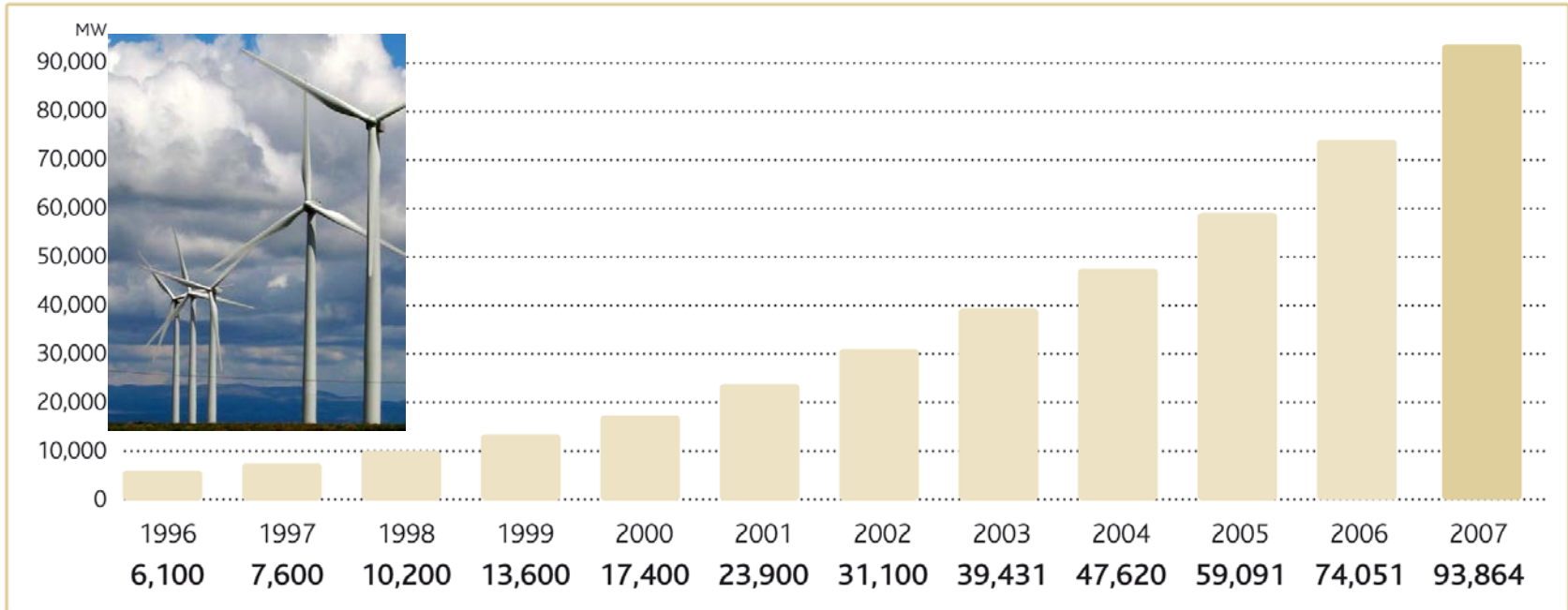
The history of wind power goes back many centuries.

Irrigation, land draining, grain milling, transportation, etc.



Wind energy capacity has grown rapidly since 1990, doubling every 3 ½ years.

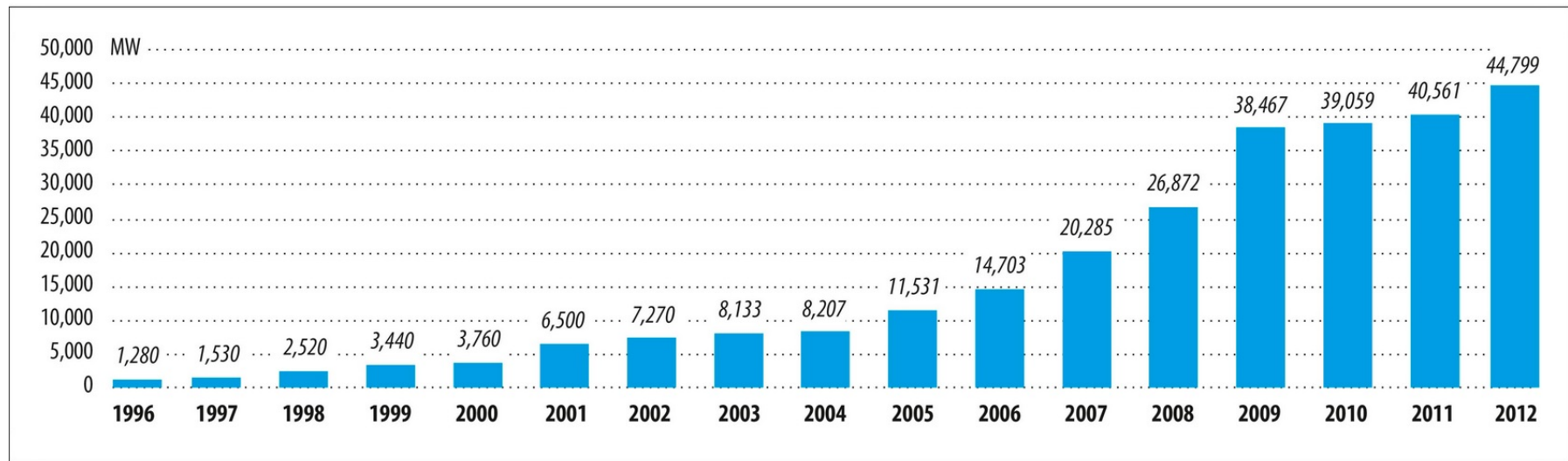
GLOBAL CUMULATIVE INSTALLED CAPACITY 1996-2007



Historical power source

More than 100 years ago, wind power had a dominant role in the energy supply of many countries (mechanical power).

Global Annual Installed Wind Capacity 1996-2012



Source: GWEC

The ocean tides are the direct consequences of the gravitational interaction between the Earth, Moon and Sun.

Planetary energy

The different celestial bodies, in particular our moon, exchange mutual forces with Earth. The motion of the celestial bodies results in continuously varying forces at any specific point on the Earth's surface.

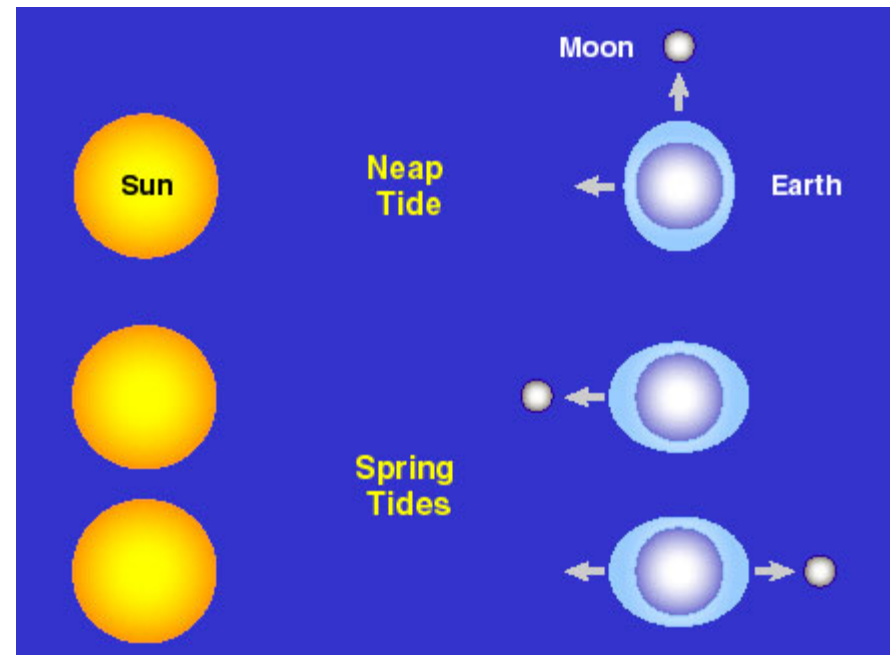


Figure from

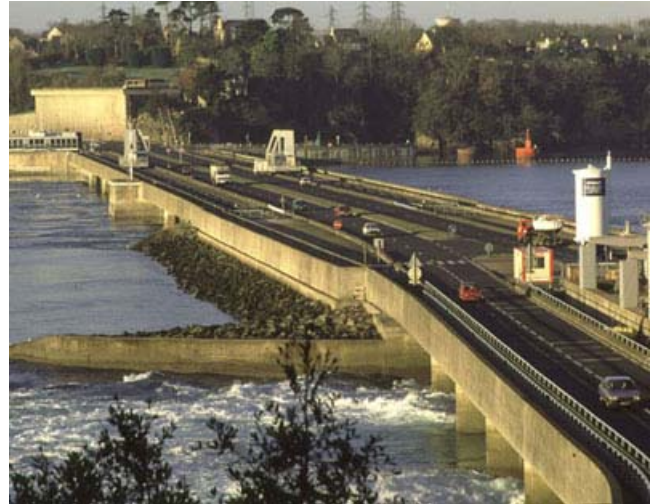
<http://csep10.phys.utk.edu/astr161/lect/time/tides.html>

There are two basic approaches to tidal energy exploitation.

Tidal Barrage

Exploiting the cyclic rise and fall of the sea level through extraintment.

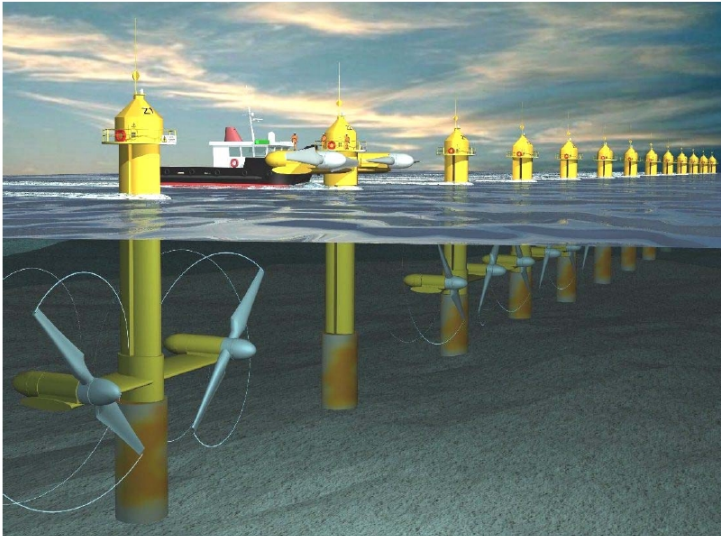
Foto (right): La Rance tidal scheme by Michel Coupard / Stillpictures



Tidal Stream Generators

Harnessing local tidal currents by turbines.

Picture (left): Marine Current Turbines Ltd's concept in Whittaker et al. (2003).



Geothermal energy is contained as thermal energy in the Earth's interior.

The origin of this thermal energy?

- gravitational contraction of the earth when it was formed.**
- heat from the decay of the small quantities of radioactive materials contained within earth's core.**

What is the problem?

In the Earth's interior, temperatures are somewhere between 3000°C and 10,000°C. Despite the fact that this heat is present in huge, practically inexhaustible quantities, it is unevenly distributed, seldom concentrated, and often at depths too great to be exploited industrially.

Not strictly renewable?

If steam or hot water are extracted at a greater rate than heat is replenished from surrounding rocks, a geothermal size will cool down after a number of years and become exhausted.

Geothermal power stations can utilize geothermal heat and convert it into electricity and/or feed it into district heating systems.



Old Faithful, the most famous geyser in Yellowstone (left) and the geothermal power plant at the Geysers near Calistoga, California (right). (Courtesy of DOE/NREL)

GLOBAL USE OF RENEWABLE ENERGY SOURCES

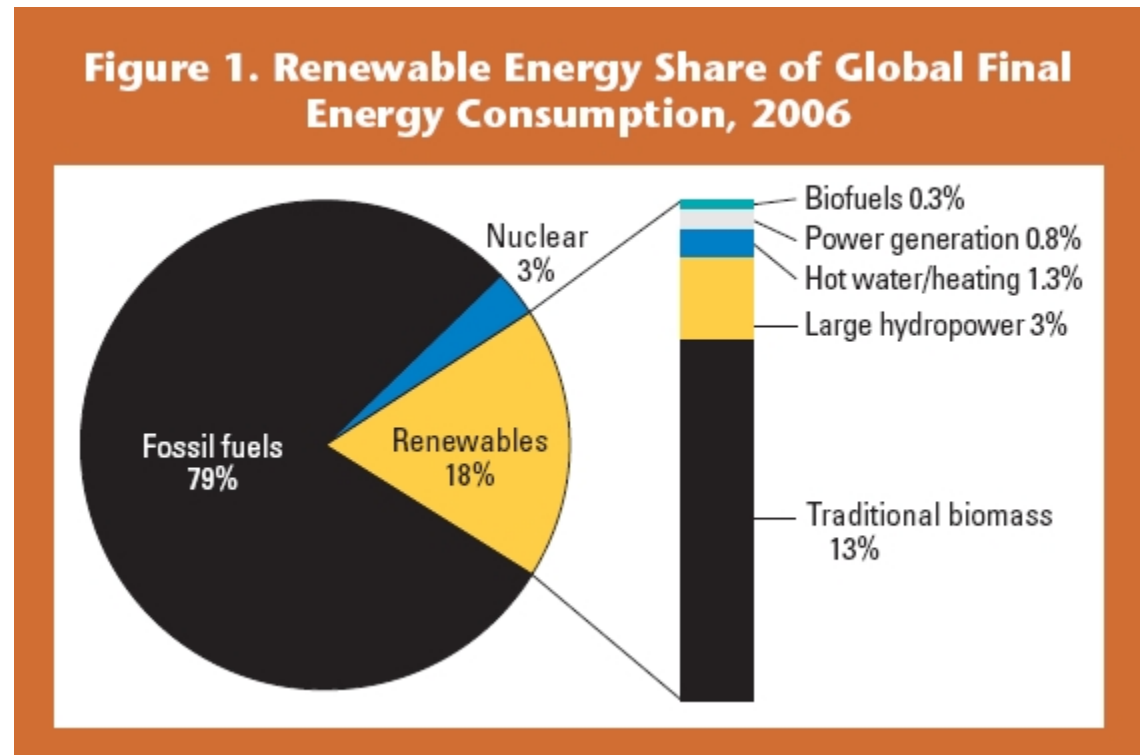
“The contribution of renewable energy sources to the global primary energy supply was 12,7% in 2005.”

—IEA, Key World Energy Statistics 2007

Renewable energy supplies 18% of the World's final energy consumption.

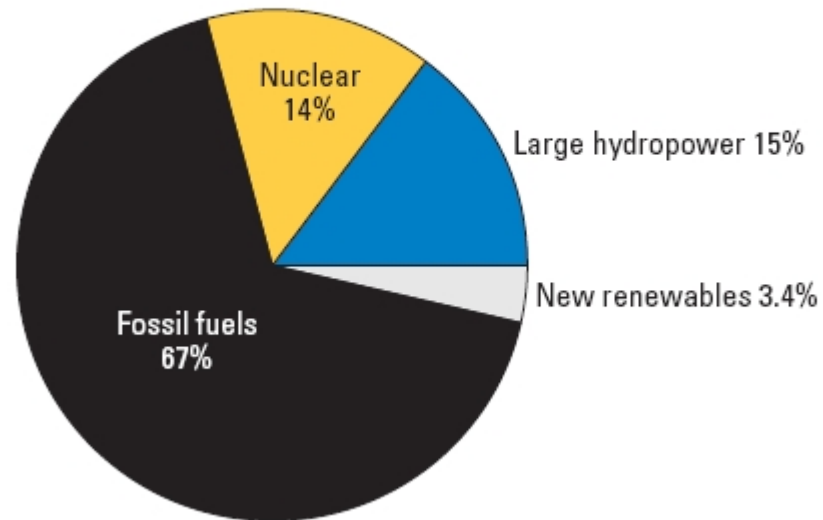
Renewables:
Traditional biomass
Large hydro
“new” renewables

Source:
REN21, Renewables 2007
– Global status report



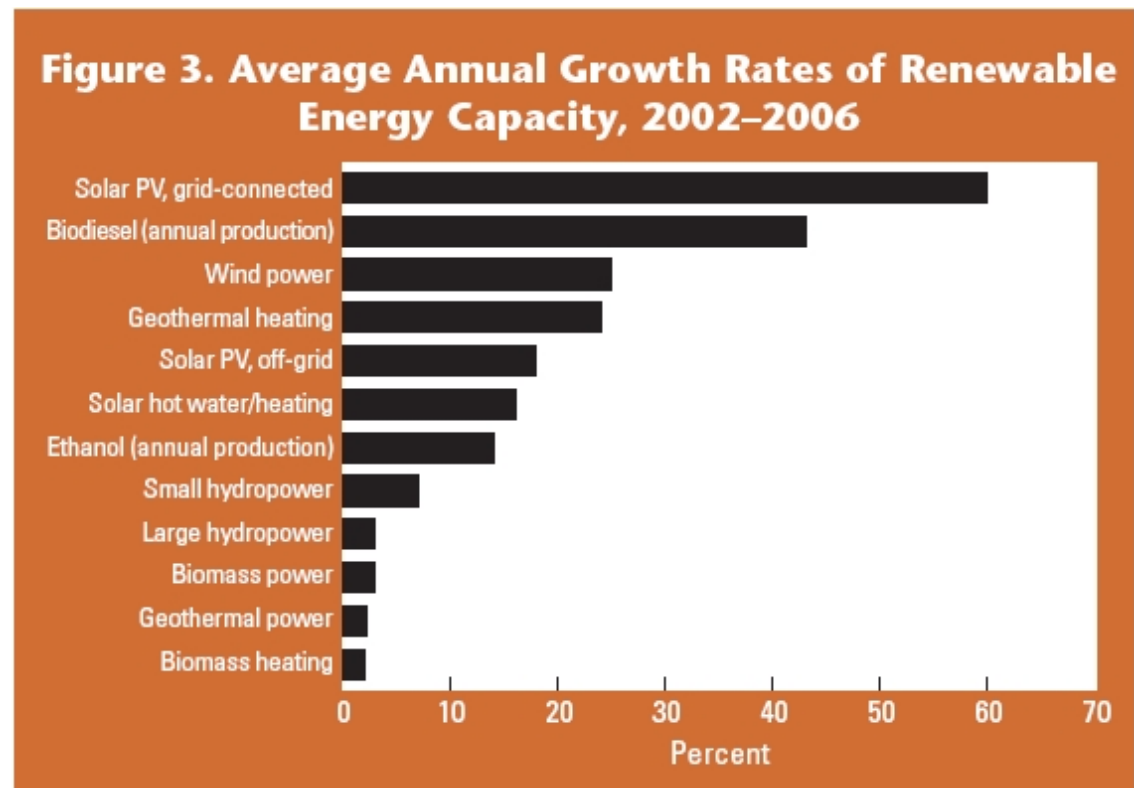
Renewable energy comprises about 5% of global power generating capacity and supplies about 3,4% of global electricity production.

Figure 2. Share of Global Electricity from Renewable Energy, 2006



Source:
REN21, Renewables 2007
– Global status report

Global renewable energy capacity grew at rates of 15-30 % annually during 2002-2006.



Source:
REN21, Renewables 2007
– Global status report

Table R1. Renewable Energy Added and Existing Capacities, 2006

	Added during 2006	Existing at end of 2006
Power generation (GW)		
Large hydropower	12-14	770
Wind turbines	15	74
Small hydropower	7	73
Biomass power	n/a	45
Geothermal power	0.2	9.5
Solar PV, grid-connected	1.6	5.1
Solar PV, off-grid	0.3	2.7
Concentrating solar thermal power (CSP)	< 0.1	0.4
Ocean (tidal) power	~ 0	0.3
Hot water/heating (GWth)		
Biomass heating	n/a	235
Solar collectors for hot water/heating (glazed)	18	105
Geothermal heating	n/a	33
Transport fuels (billion liters/year)		
Ethanol production	5	39
Biodiesel production	2.1	6

Source: See Endnote 2.

Source: REN21, Renewables 2007 – Global status report

In early 2007, the EC adopted new binding targets for 2020, including 20 percent of final energy and 10 percent of transport fuels.

Source:
REN21, Renewables 2007
– Global status report

