Undergraduate Program in Central European Studies

CERGE-EI and the School of Humanities at Charles University
Address: Politických vězňů 7, 110 00 Praha 1
Tel. : +420 224 005 201, +420 224 005 133, Fax : +420 224 005 225
E-mail: upces@cerge-ei.cz
Web: http://www.cerge-ei.cz/abroad

Environmental Policy in the Central European Context

Time: Tuesday 4pm
Location: at CERGE-EI, Room # 10

Professor: Jana Krajcova
Email: jana.krajcova@cerge-ei.cz
Web: http://home.cerge-ei.cz/richmanova/Teaching.html

9 Environmental Policy in the world context – Renewable resources

Renewable Resources

From Wikipedia, the free encyclopedia

- A natural resource is a **renewable resource** if it is replaced by natural processes at a rate comparable or faster than its rate of consumption by humans.
- The term has a connotation of **sustainability** of the natural environment.
- Gasoline, coal, natural gas, diesel, and other commodities derived from fossil fuels are **non-renewable**.
- Unlike fossil fuels, a renewable resource can have a **sustainable yield**.
  1. Perpetual resources (no danger of a lack of long-term availability)
     a. solar radiation,
     b. tides,
     c. winds
     d. hydropower
     e. geothermal power
  2. Commodities or other (if harvesting is performed in a sustainable manner)
     a. wood
     b. paper
     c. leather
     d. biomass (biological material derived from living, or recently living organisms)
     e. biofuel (wide range of fuels which are in some way derived from biomass)

  → must be carefully managed to avoid exceeding the world's capacity to replenish them

  → A life cycle assessment provides a systematic means of evaluating renewability

The Nesjavellir Geothermal Power Plant in Iceland is an example of renewable energy.

A wind farm in Spain.

Sector-wise categorization:

1. **Electricity sector**
    a. wind
    b. biomass
    c. biogas
    d. geothermal
    e. solar PV
    f. hydro power
2. **Heating sector**
    a. geothermal
    b. biomass
    c. solar thermal
3. **Transport sector**
    a. ethanol
    b. biodiesel

Renewable energy

Solar energy

- the energy derived directly from the Sun.
- the most abundant source of energy on Earth along with nuclear energy.
- The fastest growing type of alternative energy, increasing at 50 percent a year, is the **photovoltaic cell**, which converts sunlight directly into electricity.
- The Sun yearly delivers more than 10,000 times the energy that humans currently use.

Wind power

- derived from uneven heating of the Earth's surface from the Sun and the warm core.
- Most modern wind power is generated in the form of electricity by converting the rotation of turbine blades into electrical current by means of an electrical generator.
- In windmills (a much older technology) wind energy is used to turn mechanical machinery to do physical work, like crushing grain or pumping water.

Hydropower

- energy derived from the movement of water in rivers and oceans (or other energy differentials),
- can be used to generate electricity using turbines,
- or can be used mechanically to do useful work.
- small potential for additional growth as potential has either been exploited, or limited by legal frameworks on water management

Geothermal power

- directly harnesses the natural flow of heat from the ground.
- The available energy from natural decay of radioactive elements in the Earth's crust and mantle is approximately equal to that of incoming solar energy.

- Iceland, Mexico and US highest growth rate of geothermal electricity in recent years

Biomass

- biological material derived from living, or recently living organisms, such as wood, waste, (hydrogen) gas, and alcohol fuels.
- commonly a plant matter grown to generate electricity or produce heat. In this sense, living biomass can also be included, as plants can also generate electricity while still alive.
- recently, strong competition for feedstocks has developed from agricultural markets, affecting the viability of projects in many countries
- **Alcohol** derived from corn, sugar cane, switchgrass, etc. is also a renewable source of energy.
- **Biodiesel -** oils from plants and seeds can be used as a substitute for non-renewable diesel.
- The most conventional way on how biomass is used however, still relies on direct incineration. Forest residues for example (such as dead trees, branches and tree stumps), yard clippings, wood chips and garbage are often used.
- biomass also includes plant or animal matter used for production of fibers or chemicals.
- may also include biodegradable wastes that can be burnt as fuel.
- It excludes organic materials such as fossil fuels which have been transformed by geological processes into substances such as coal or petroleum. Although fossil fuels have their origin in ancient biomass, they are not considered biomass by the generally accepted definition because they contain carbon that has been "out" of the carbon cycle for a very long time. Their combustion therefore disturbs the carbon dioxide content in the atmosphere.

OECD = Organization for Economic Co-operation and Development

- a forum where the governments of thirty democracies work together to address the economic, social and environmental challenges of globalization.
- efforts to understand and to help governments respond to new developments and concerns, such as corporate governance, the information economy and the challenges of an ageing population.
- governments can compare policy experiences, seek answers to common problems, identify good practice and work to co-ordinate domestic and international policies.
- member countries are: Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Republic of Korea, Luxembourg, Mexico, Netherlands, New Zealand, Norway, Poland, Portugal, Slovak Republic, Spain, Sweden, Switzerland, Turkey, United Kingdom and United States.

INTERNATIONAL ENERGY AGENCY

The International Energy Agency (IEA) is an autonomous body which was established in November 1974 within the framework of the Organisation for Economic Co-operation and Development (OECD) to implement an international energy programme.

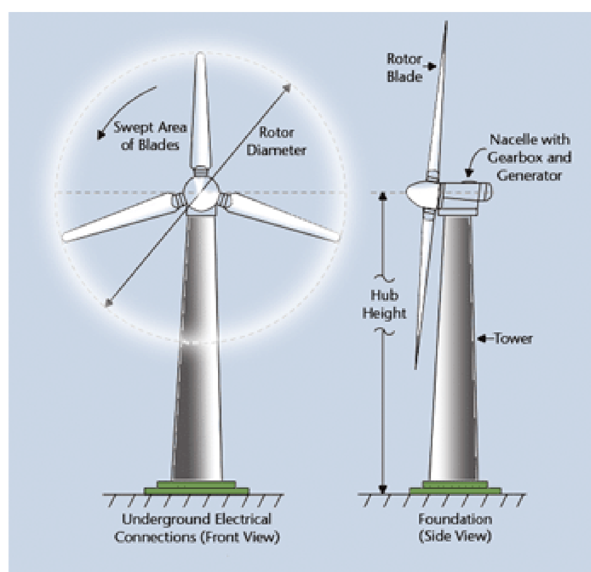
It carries out a comprehensive programme of energy co-operation among twenty-seven of the OECD thirty member countries. The basic aims of the IEA are:

- To maintain and improve systems for coping with oil supply disruptions.
- To promote rational energy policies in a global context through co-operative relations with non-member countries, industry and international organisations.
- To operate a permanent information system on the international oil market.
- To improve the world's energy supply and demand structure by developing alternative energy sources and increasing the efficiency of energy use.
- To promote international collaboration on energy technology.
- To assist in the integration of environmental and energy policies.

The IEA member countries are: Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Japan, Republic of Korea, Luxembourg, Netherlands, New Zealand, Norway, Portugal, Slovak Republic, Spain, Sweden, Switzerland, Turkey, United Kingdom and United States. Poland is expected to become a member in 2008. The European Commission also participates in the work of the IEA.

<u>OECD report: Renewable energy essentials: WIND</u>

- Wind turbines **extract kinetic energy from moving air flow (wind)** and **convert it into electricity** via an aerodynamic rotor connected by a transmission system to an electric generator.
- Today's standard turbine has **three blades** rotating on a horizontal axis, upwind of the tower, with a synchronous or asynchronous **generator connected to the grid**.
- The electricity output of a turbine is roughly proportional to the rotor area, so **fewer larger rotors (on taller towers) use the wind resource more efficiently** than more numerous, smaller machines.
- The largest wind turbines today are **5-6 MW** units with a rotor diameter of up to **126 metres**. Turbines have doubled in size approximately every five years, but a slowdown in this rate is likely for onshore



Drawing of the rotor and blades of a wind turbine, courtesy of ESN turbines, due to transport, weight and installation constraints.

- The estimated **lifetime** of an individual wind turbine is **20 to 25 years**. Life spans may stretch as the technology continues to mature.
- Due to extensive testing and certification, the reliability of wind turbines – the proportion of the time they are technically available for operation – is around **99%**.
- world generating capacity of wind energy is **growing at 20-30%** per year, and surpassed **90GW** in **2007** – 50 times installed capacity in 1990.
- [***Installed capacity*** *refers to the maximum amount of electric energy that can be produced by all turbines operating to their maximum capacity at a given time. No power station ever produces at maximum capacity over a sustained period of time due to maintenance needs, lack of demand or, lack of wind.*]
- Approximately **152TWh** of wind electricity were generated in **2006** [*Energy in watt hours is the multiplication of power in watts and time in hours*]
- wind power plants are capital=intensive => the cost of capital (discount rate is a decisive factor)
- annual investment topped **USD 50 billion in 2007**.
- The global wind industry employs around **200 000 people**.
- Turbine costs have decreased by a factor of four since the 1980s. Since 2004, however they have increased by 20-80%, due to tight supply of turbines and components, and high commodity prices (in 2007, **onshore** turbine costs ranged from **USD 1.2m – 1.8m per MW**)
- recent production costs **onshore** range from **USD 75/MWh to 97/MWh** at high to medium quality wind resource sites. Onshore wind is competitive at sites with good resource and grid access.
- The IEA Energy Technology Perspectives 2008 suggests that wind technology could feasibly provide 9% (approx. 2 700 TWh) of global electricity in 2030. By 2050, the IEA's advanced "BLUE" Scenario, which requires significant technology innovation, suggests that as much as 12% (approx. 5 200 TWh) could be feasible. (taking into account competing generation technologies)
- The Global Wind Energy Council has prepared an Advanced Scenario that suggests that, if stronger early action is taken, wind electricity production could reach still higher: 5 200 TWh in 2030 and 7 200 TWh in 2050.

Wind power in total generated 152 TWh of electricity in 2006. In 2007, wind power plants provided for 20% of electricity consumption in Denmark, 10% in Spain, and 6% in Germany. More than 20GW of capacity were installed in 2007 alone, led by the United States, China and Spain. Cumulative installed capacities are shown in the map below. The largest individual wind power plant operating in 2007 (in Texas) had a capacity greater than 700 MW, the same order of magnitude as conventional power plants.

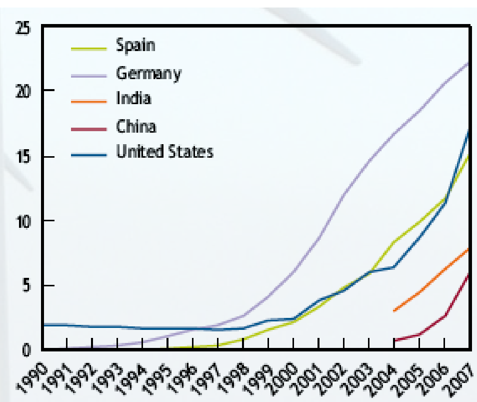


Figure 1. Cumulative installed gigawatts of wind power in leading countries, 1990 – 2007

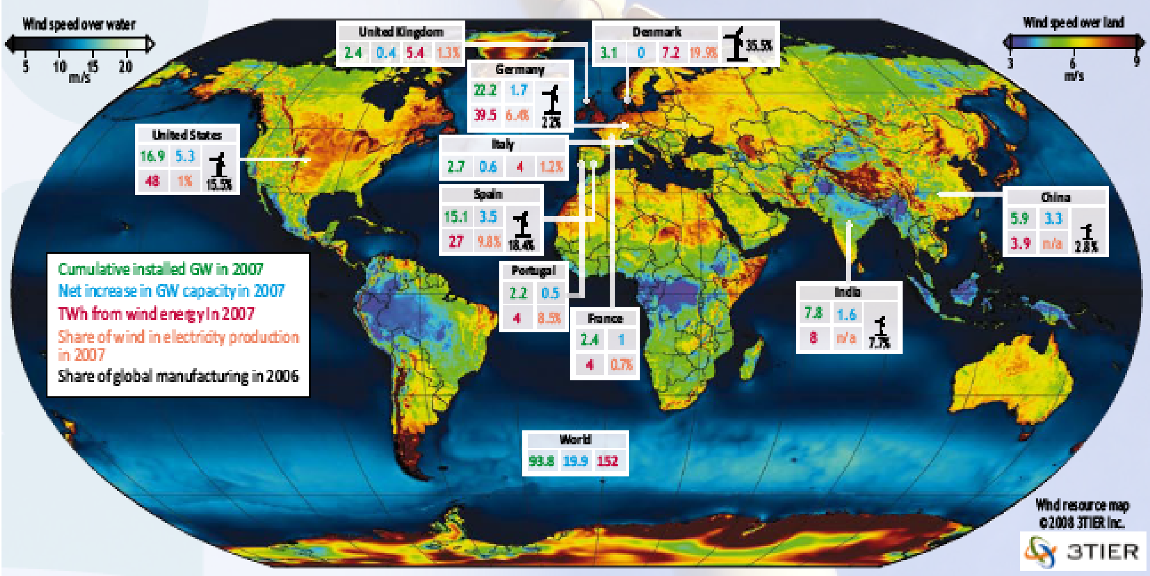
Offshore wind power plants

- offshore installed capacity topped **1.1 GW in 2007**, located in just six countries, including Denmark (420 MW), United Kingdom (300 MW), Netherlands (130 MW), Ireland (25 MW), and Sweden (135 MW).
- Several large projects are planned in other countries.
- Offshore wind power plants can produce up to **50% more electricity than their onshore** cousins, due to higher and steadier wind speeds.
- Other advantages include **greatly reduced visual impact, less turbulence, and lower noise** constraints – allowing higher rotor speeds.
- with current technology the hardware and its installation are **more expensive.**
- costs are largely dependent on water depth and distance from shore; foundations, installation and grid connection are more costly, turbine cost is typically **20%** higher, towers and foundations about **150%**

The wind resource

- average global wind speeds on- and offshore are **predictable.**
- the energy content of the wind is proportional to the cube of the wind speed, so a slighter faster average speed yields significantly greater output.

Figure 2. World onshore and offshore resource map at 80m height and 15 km resolution, with installed capacity, production and manufacturing data for leading countries



Map notes: Figures for 2007 capacity increase for India and China are gross. TWh produced in India and China are for 2006. Most Danish activity in 2007 was in re-powering. Leading states in the Unites States, in terms of share of national electricity production, include Minnesota (5%), Iowa (5%), New Mexico (4%) and Oregon (3.5%).

- a good wind speed site for an average development is around 7m/s (25 kmph, 16mph) and above, at a hub height of around 80m.

- the importance of a high quality wind regime is illustrated by the fact that the US produced more wind electricity in 2007 than any other country, even though it does not have the largest installed capacity.
- **offshore** wind energy **represented 1.8% of total installed capacity** (in 2006) but produced **3.3% of total wind electricity**. High quality wind resources are distributed throughout the globe.
- Six countries worldwide account for almost all wind turbine manufacturing (Denmark being the birthplace and still producing over a third of all turbines sold worldwide)
- Investment reached **USD 50.2 billion in 2007**, accounting for **43% of new investments in renewable energy**

Barriers to wind energy development include

→ uncertainty relating to the future of /lack of incentive schemes (e.g. annual renewal of the Production Tax Credit in the USA),
→ concerns about the impacts of variability on power system reliability,
→ access to transmission,
→ perceived visual and ecological impacts,
→ the structure of conventional electricity markets (evolved around conventional generation and utilities, and in many cases could be optimized to facilitate wind power participation)

Variability

- Wind power plants – like wave, tidal, and solar plants – depend on a variable resource; the wind does not blow all the time in any one place.
- the capacity factor of wind turbines ranges from 20% to 40%, lower than for conventional base-load technologies.
- the flexibility of the power system must increase also, to provide for times when wind power output is low.
- the system can also respond to fluctuating wind power output through the use of **stored energy**, **import from other areas** and through enabling **demand side response**.

Impacts (costs relating to social and environmental damage)

- Wind power plants require **no fossil fuel** and produce **little environmental pollution** during their manufacture, operation and decommissioning.
- CO2 emissions for wind energy are small, (around **10g of CO2 per kWh**).
- If external costs were taken into account in normal cost assessments, studies suggest that wind energy would already be competitive with most power technologies.
- wind turbines may be considered by some to be **visually intrusive.** Micro-sitting techniques can be used to reduce visual impacts.
- Issues relating to **aerodynamic noise** are largely resolved with suitable codes relating to the allowable distance from residential areas.
- Following concern about potential **avian, bat** and **marine** impacts, most environmental assessments have suggested that these are easily minimised through **careful siting of turbines**.

Development

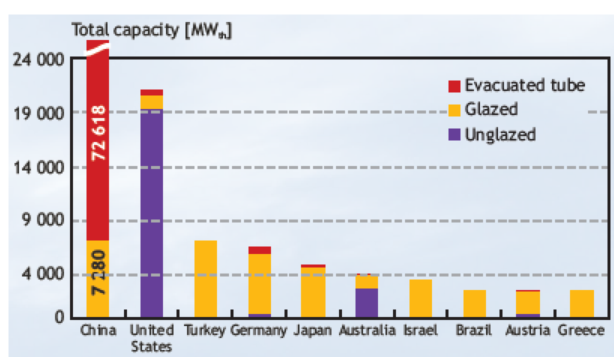
- **Technology efficiency gains** are ongoing
    - More efficient blades and drive trains,
    - lighter nacelles (rotor plus generator)
    - fewer components

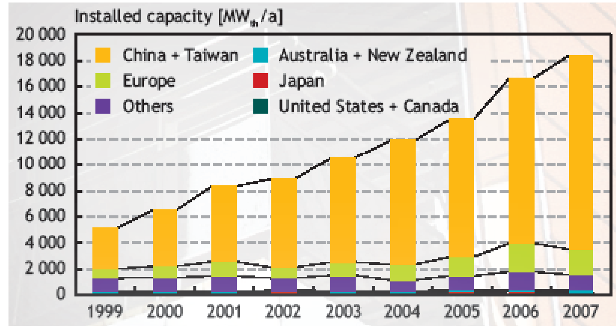
  mean a higher electricity output per unit of materials required in the manufacturing process and will also to some extent counter rising capital costs associated with higher commodity prices (e.g. copper and steel).
- **the move offshore** can be said to be driving wind energy technology development generally. Most offshore wind at present is **installed in shallow water**. Floating turbines, for the deep offshore environment, are at the demonstration phase with a **2.3 MW** prototype scheduled to be deployed in 2009 off the coast of Norway in the North Sea, and another **2.5** prototype scheduled to be installed in 2009 off the Apulia region in Italy.
- Subjects for **further research**
    - more refined resource assessment;
    - materials with higher strength to mass ratios;
    - advanced grid integration & power quality and control technologies;
    - standardization and certification;
    - development of low-wind regime turbines;
    - improved forecasting;
    - increased fatigue resistance of major components such as gearboxes;
    - better models for aerodynamics and aeroelasticity;
    - generators based on superconductor technology;
    - deep-offshore foundations;
    - high-altitude "kite" concepts.

Solar power

A. OECD report: Renewable energy essentials: Solar Heating and Cooling

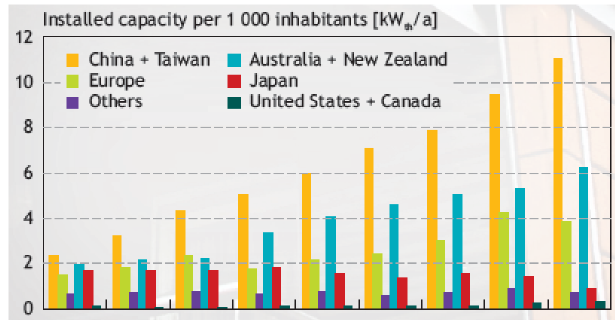
- solar heating and cooling technologies use the sunlight to produce directly usable heat for water and space heating or industrial processes, or to run air-conditioning systems
- the solar thermal collector capacity in operation worldwide equaled 171 GWthermal, corresponding to 244 mil. m2 at the end of 2008
- China alone accounted for more than half global capacity (101 GWth), other leaders are USA,



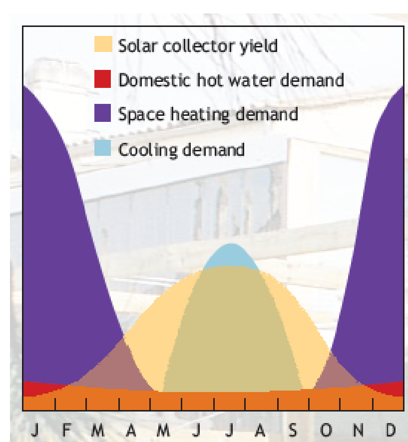


Germany and Turkey.

- with respect to capacity installed per 1000 inhabitants the leading countries are Cyprus, Israel and Austria
- solar thermal energy for domestic hot water preparation is common all over the world
- so-called combi-systems, integrating hot water preparation and space-heating show a rapidly growing market in European countries



- large-scale solar systems for district heating show considerable growth rates in the Scandinavian countries, Germany and Austria
- low temperature solar collectors for water and space heating are very efficient
- high temperature solar collectors for refrigeration, industrial process heat and electricity generation require improvements
- heat storage represents a key technological challenge
- the energy produced in 2007 was about **89 TWh,** amongst the new renewable energy sources (excluding biomass and hydropower), solar thermal energy comes **second to wind**, still represents less than **1%** of global primary energy demand
- Solar resource is virtually **unlimited,** the earth receives from the sun each hour as much energy as humankind currently consumes in a year
- the problem is that solar resource is **dispersed** and does not always correspond in time and place to the demand for heat; in absence of affordable ways **to store large amounts of heat** from one season to another, the contribution of solar heat to space heating is currently limited
- The IEA World Energy OUtlook 2008 foresees a contribution from solar thermal of **45 MToe** [Million Tons of Oil Equivalent] to final energy demand in **2030**, extending that trend to **2050** would mean about **180 MToe**, or about **18% of** forecasted heat demand
- The European Solar Thermal Industry Association forecasts and installed capacity of **1019GWth by 2030** in the EU, supplying about **15%** of the low heat demand. By **2050** it could further increase to **2716 GWth** accounting for about **47%** of the overall heat demand in EU27, or roughly about **20% of the region's overall energy demand**



Costs

- costs vary greatly according to climate conditions, requiring more or less complex installations
- solar domestic **hot water** systems cost in Europe **EUR 50-160 per MWh** of heat, which is usually more expensive than heat from natural gas, but often proves competitive with retail electricity prices

- for solar **combi-systems**, the cost is about **EUR 160-500 per MWh**
- these costs are expected to decline by 2030
- solar cooling systems require more expensive investments, but costs are reduced if a solar-thermal collector is designed to be used for both summer cooling and winter heating; solar cooling benefits from better time-match between supply and demand

Incentives

- natural (China, Cyprus and Turkey – low-cost solar water heaters already an economic alternative)
- incentive-driven (grants for households and companies in Austria and Germany)
- solar ordinances (Israel's 30-year old ordinance applies to all new residential buildings, hotels, homes for elderly and boarding schools, Spain followed 2 years ago)
- forthcoming stringent regulations of specific net energy consumption in new buildings in most European countries will likely benefit solar heat markets

Barriers

- **Economic** – high up-front expenses, lack of internalization of environmental costs of alternatives and high levels of subsidies to fossil fuels in some countries, slow rotation of building stock (technologies possible in new construction)
- **Institutional** – property developers and building owners renting their property have little incentive to invest for the benefit of current occupants, in companies, resources for investment and operating cost often separated, in multi-dweller buildings incentives are low too
- **Legal** – lack of awareness, reluctance to manage a more complex system, permitting is often an issue

Impacts

- requires no fossil fuel and produces little pollution during its manufacture, operation and decommissioning.
- CO2 emissions are small
- if external costs of energy technologies were systematically taken into account, solar thermal energy could be already competitive with most heating technologies
- no big visual impact (placed on the roof, integrated into roof systems and building envelopes)

R&D

- effective optical coatings on surfaces and low cost, anti-reflective, self-cleaning, glazing materials need to be developed
- new polymeric materials and carbon nano tubes and components to withstand high temperatures must be improved to prolong lifetime
- advanced and more compact storage

<u>OECD report: Renewable energy essentials: Concentrating Solar Power</u>

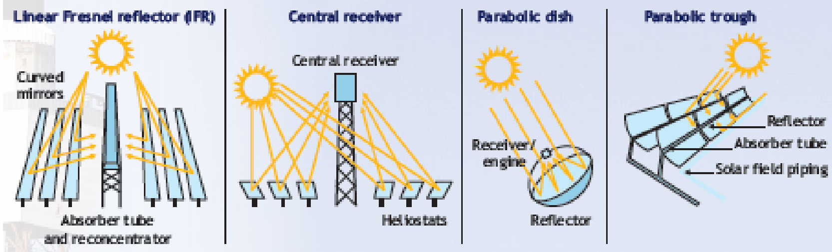
- Concentrating solar thermal power (CSP) **turns sunlight into electricity**.

- CSP requires clear skies and strong sunlight, which is abundant in the southwestern United States, Mexico, North Africa, the Middle East, Central Asia, South Africa and Australia. Southern Europe and parts of China and India may also have sufficient solar resources.
- CSP technology showed especially strong growth in Spain and the United States since 2006. Installed capacities near **1 GW** and projects under development or construction exceed **15 GW** worldwide.
- Investment costs range from **USD 4.2 to 8.4 per watt**, depending on the solar resource and the size of the storage; electricity costs range from US cents **17-25 per kWh**, mostly depending on the quality of the solar resource.
- The BLUE scenario of the IEA publication, Energy Technology Perspectives 2008, foresees that CSP will provide **5% of world electricity by 2050**. Preliminary results of the forthcoming IEA CSP Roadmap suggest a contribution of **12% to global electricity** supply **by 2050**.
- Concentrated solar thermal power (CSP) is a re-emerging market. The Luz Company built **354 MW** of commercial plants in California, still in operations today, during 1984-1991. Activity re-started with the construction of an **11-MW plant** in Spain, and a **64-MW** plant in Nevada, by 2006. There are currently hundreds of MW under construction, and thousands of MW under development worldwide.
- Spain and the United States together represent **90%** of the market; Algeria, Egypt and Morocco are building integrated solar combined cycle plants; Australia, China, India, Iran, Israel, Italy, Jordan, Mexico, South Africa and the United Arab Emirates are finalizing or considering projects.
- Concentrating sunrays requires **clear skies,** which are usually found in semi-arid, hot regions. The resource is measured as Direct Normal Insolation (DNI), which is the energy received on a (tracking) surface perpendicular to the sunrays.
- Areas suitable to CSP technologies are found between 15° to 40° parallels – and occasionally at higher latitude.
- The most favorable areas are found in large parts of North Africa, Middle East, southern Africa, western India, the southwestern United States, Mexico, places in South America, and Australia. Other suitable areas are in the extreme south of Europe and Turkey, central Asian countries, western China.
- **backup fuels and storage** (typically based on molten salts) needed to guarantee full capacity

4 main technologies,

- **troughs** and **fresnel reflectors** track the sun on one axis,
- **dishes** and **towers** track the sun on two axes.

Figure 5: Troughs, towers, LFR and dishes
Source: CSP Global Outlook 2009.



Troughs or parabolic cylinders

- concentrate the solar rays on long heat collector pipes (moving with the troughs).
- current plants use some synthetic oil as heat transfer fluid.
- alternatives: direct steam generation, or use of molten salts as transfer fluid
- most mature technology and the bulk of current projects; some have significant storage capacities, remains dominant
- solar to electricity conversion can reach than 15% (annual mean value).

Linear Fresnel reflectors (LFR)

- use slightly curved mirrors reflecting the solar rays on a long, fixed receiver.
- Investment costs per mirror area are lower but the annual efficiency remains below 10%.
- saturated steam is directly generated in the receiver tubes.

Towers or central receiver systems (CRS)

- concentrate the sunrays on top of a fixed tower which allows for higher temperatures and efficiencies than linear systems.
- generate saturated or superheated steam directly, or use molten salts, air or other media as heat transfer fluids.
- Solar fields of thousands of small heliostats are proposed as a cheap alternative to state-of-the-art field design.

Parabolic dishes

- concentrate the sunrays **on a focal point that is moving together with the dish tracking the sun**, offering the highest optical efficiency on much smaller capacities (typically tens of kW).
- Mass production may allow them to compete with the larger systems, which benefit from economies of scale.
- dish systems are less compatible with thermal storage than other CSP technologies, but require no cooling water.
- The deployment of CSP plants is driven by **feed-in tariffs** in Spain, and Renewable Energy Portfolio Standards and a grant programme in the United States. Projects in Egypt and Morocco are supported by grants from the Global Environment Facility. Algeria, South Africa and the Gujarat State in India have also established feed-in tariffs for CSP.

A ***feed-in tariff*** *(****FiT****,* ***feed-in law****,* ***advanced renewable tariff*** *or* ***renewable energy payments****) is a policy mechanism designed to encourage the adoption of renewable energy sources and to help accelerate the move toward grid parity. It typically includes three key provisions:*

1) *guaranteed grid access,*
2) *long-term contracts for the electricity produced, and*
3) *purchase prices that are methodologically based on the cost of renewable energy generation and tend towards grid parity.*

Under a feed-in tariff, an ***obligation*** *is imposed on regional or national electric grid utilities* ***to buy renewable electricity*** *(electricity generated from renewable sources, such as solar power, wind power, wave and tidal power, biomass, hydropower and geothermal power), from all eligible participants.*

Barriers

- Low costs of fossil fuels
- direct or indirect government subsidies for fossil fuels.
- suitable areas are often semi-arid and water scarcity might be an issue, unless costlier dry cooling is used.
- Permitting and connection to the grid might also be challenging.

Potential

- The technical potential for CSP is virtually unlimited.
- An area of 100 miles squared in Nevada could power the entire US economy.
- The technical potential of the Middle East and North Africa (MENA) is more than 100 times the total current electricity consumption of the MENA and European regions together.

Impacts

- life-cycle CO2 emissions of solar-only CSP plants are assessed at **17 g/kWh** against, e.g., **776 g/kWh for coal** plants and **396 g/kWh for natural gas** combined cycle plants.
- to the extent that **some fossil fuel is used as a back-up**, a CSP plant or an ISCC **cannot be qualified as a "zero-emitting" plant**.
- an MW trough plant requires about **1.2 million cubic meters of water per year**, mostly **for cooling** the steam cycle, and **for cleaning** the mirrors. Dry air cooling systems could considerably reduce the consumption of water, at a cost.
- The **use of molten salts** and **synthetic oil** in a CSP plant bears some **risk** of spillage or fire. This may in turn hinder acceptance of a project by the local population.

R&D

- R&D supported in particular by Germany, the European Commission and the US Department of Energy.
- Improvements can be expected **on all components of CSP plants,** e.g.
    - direct steam generation with troughs to increase the overall efficiency)
    - novel options for storage: phase-change materials and concrete

  - **Towers** have even greater **room for improvements**. Many innovative designs are currently proposed, with one or several towers sharing fields of heliostats, a great variety of central receiver designs, heat fluids and storage options. Towers with air receivers feeding the gas turbine of a combined cycle power plant could offer record solar-to-electricity efficiency of around 35%.

Policy instruments

- Wind development in the US supported by a mix of federal and state policies including a 10-year production tax credit (acts like feed-in premium) and a 5-year accelerated depreciation
- The main policy instruments currently used in the EU Member States to achieve the targets set for electricity produced from renewable energy sources are:
  1. The quota obligation system (with TGC)
  2. The feed-in tariff system,
  3. The tendering system.

Quota obligation system with Tradable Green Certificate

The government defines targets for RES-E deployment and obliges a particular party of the electricity supply-chain (e. g. generator, wholesaler or consumer) with their fulfilment. Once defined, a parallel market for renewable energy certificates is established and their price is set following demand and supply conditions (forced by the obligation). Hence, for RES-E producers, financial support may arise from selling certificates in addition to the revenues from selling electricity on the power market.

Tradable Green Certificate

- terminology used in Europe
- also known as Renewable **Energy Certificates** (RECs) in the USA,
- a tradable commodity proving that certain electricity is generated using renewable energy sources.
- Typically one certificate represents generation of 1 Megawatthour of electricity.
- the certificates can be traded separately from the energy produced.
- Several countries use green certificates as a mean to make the support of green electricity generation closer to a market economy instead of more bureaucratic investment support and feed-in tariffs. Such national trading schemes are in use in e.g. Poland, Sweden, the UK, Italy, Belgium (Wallonia and Flanders), and some US states.
- These certificates can be sold and traded or bartered, and the owner of the REC can claim to have purchased renewable energy.
- While traditional carbon emissions trading programs promote low-carbon technologies by increasing the cost of emitting carbon, RECs can incentivize carbon-neutral renewable energy **by providing a production subsidy to electricity generated from renewable sources**.
- In states that have a REC program, a green energy provider (such as a wind farm) is credited with one REC for every 1,000 kWh or 1 MWh of electricity it produces (for reference, an average residential customer consumes about 800 kWh in a month). A

certifying agency gives each REC a unique identification number to make sure it doesn't get double-counted. The green energy is then fed into the electrical grid (by mandate), and the accompanying REC can then be sold on the open market.

Table 4.3: Overview of the Main RES-E Support Schemes in selected EU Member States as Implemented in 2007

Country	Main electricity support schemes	Comments
Austria	FITs combined with regional investment incentives	Until December 2004, **FITs** were guaranteed for 13 years. In November 2005 it was announced that from 2006 onwards full FITs would be available for ten years, with 75 per cent available in year 11 and 50 per cent in year 12. New FIT levels are announced annually and support is granted on a first-come, first-served basis. From May 2006 there has been a smaller government budget for RES-E support. At present, a new amendment is tabled, which suggests extending the duration of FIT fuel-independent technologies to 13 years (now ten years) and fuel-dependent technologies to 15 years (now ten years).
Belgium	Quota obligation system/TGC combined with minimum prices for electricity from RES	The federal government has set **minimum prices for electricity from RES**. Flanders and Wallonia have introduced a quota obligation system (based on TGCs) with the obligation on electricity suppliers. In all three of the regions, including Brussels, a separate market for green certificates has been created. Offshore wind is supported at the federal level.
Cyprus	FITs (since 2006), supported by investment grant scheme for the promotion of RES	An **Enhanced Grant Scheme** was introduced in January 2006, in the form of government grants worth 30-55 per cent of investment, to provide financial incentives for all renewable energy. FITs with long-term contracts (15 years) were also introduced in 2006.
Czech Republic	FITs (since 2002), supported by investment grants	Relatively **high FITs with a lifetime guarantee of support**. Producers can choose fixed FITs or a premium tariff (green bonus). For biomass cogeneration, only green bonus applies. FIT levels are announced annually, but are increased by at least 2 per cent each year.
Finland	Energy tax exemption combined with investment incentives	**Tax refund** and investment incentives of up to 40 per cent for wind, and up to 30 per cent for electricity generation from other RES.
Germany	FITs	FITs are guaranteed for 20 years (Renewable Energy Act) and **soft loans** are also available.
Spain	FITs	Electricity producers can choose a **fixed FIT or a premium on top of the conventional electricity price**. No time limit, but fixed tariffs are reduced after either 15, 20 or 25 years depending on technology. System very transparent. Soft loans, tax incentives and regional investment incentives are available.
Sweden	Quota obligation system with TGCs	**Obligation (based on TGCs) on electricity consumers**. Obligation level defined to 2010. Non-compliance leads to a penalty, which is fixed at 150 per cent of the average certificate price in a year. Investment incentive and a small environmental bonus available for wind energy.
UK	Quota obligation system with TGCs	**Obligation (based on TGCs) on electricity suppliers.** Obligation target increases to 2015 and guaranteed to stay at that level (as a minimum) until 2027. Electricity companies that do not comply with the obligation have to pay a buy-out penalty. Buy-out fund is recycled back to suppliers in proportion to the number of TGCs they hold. The UK is currently considering differentiating certificates by RES-E technology. Tax exemption for electricity generated from RES is available (Levy Exemption Certificates which give exemption from the Climate Change Levy).

Source: Ragwitz et al. (2007)