Technology Cooperation in the Energy Sector

Cost trends of Renewable Energy Technologies for the Power Generation

Short report

giz Technology Cooperation in the Energy Sector

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1. Introduction

Unlike conventional power plants, whose electricity generation costs have become dominated by fuel costs (with the exception of nuclear power), the key aspects determining the costs of renewable systems are their investment cost and natural resource availability – such as solar irradiation, the wind resource or the availability of organic matter for biomass systems.

The future cost trajectory of electricity generated from renewable sources depends in each case on a technology's present maturity, its further development and economies of scale arising from the broad dissemination of corresponding systems.

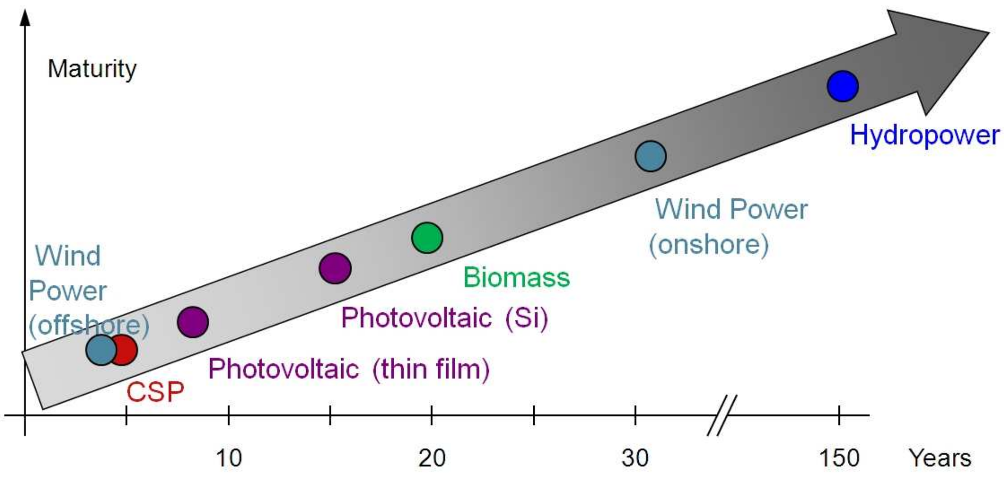
The explicit and implicit promotion of conventional systems is one of the greatest obstacles facing the expansion of renewable technologies, which some claim to be uneconomic. The International Energy Agency estimates that USD 312 billion in support for conventional energy technologies was provided worldwide in 2009, whereas renewable systems received a mere USD 57 billion; the IEA expects this trend to continue.

2. Technologies

The technical maturity of a particular technology determines the potential to further refine it – and, consequently, the potential for further cost reductions. Yet there are also technological and operational parameters that limit the potential for cost reductions, despite very good energy yield prospects.

For example, take offshore wind turbines: their installation and maintenance are much more costly than that of onshore systems due to the transportation routes and installation conditions. This necessarily results in additional costs which can scarcely be optimised through technical refinement. Yet wind conditions offshore are very good, allowing almost constant electricity supply – and therefore giving the electricity thus produced a higher value.

Photovoltaics, and in particular thin-film technology, currently hold the greatest potential for further development.

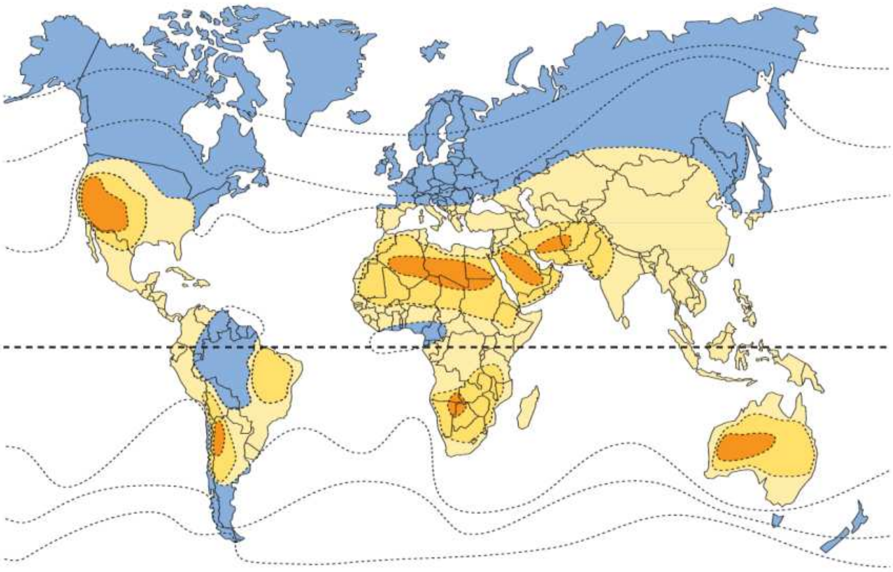


Source: Own diagram

Figure 1: Technical maturity and duration of utilization of renewable energy technologies for the power generation

2.1. Solar power generation

The prospects for employing concentrating solar power (CSP, mainly solar thermal) depend on a high proportion of direct normal irradiation (DNI).

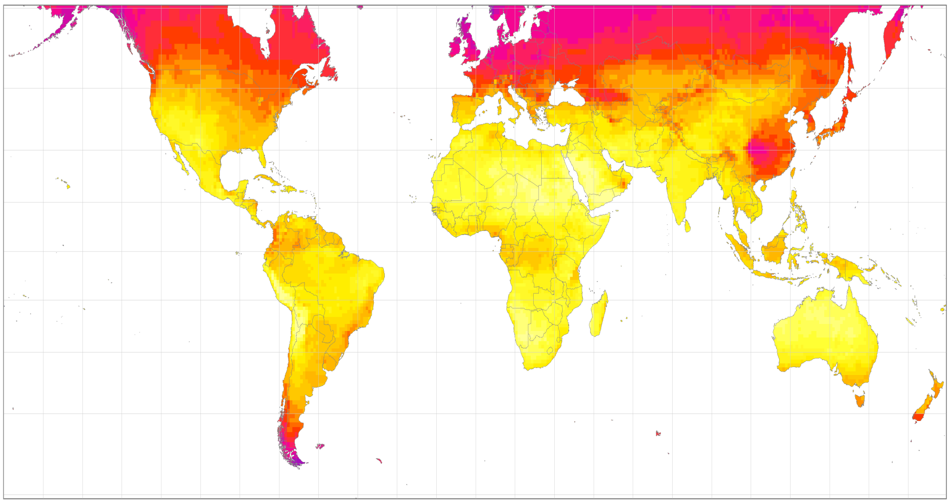


Source: Schott AG, Memorandum zur solarthermischen Kraftwerkstechnologie, 2006

Figure 2: Potential locations for employing concentrated solar power with a high proportion of direct normal irradiation

The main potential locations are therefore dry, subtropical zones (with low humidity).

Photovoltaic systems also work best with direct irradiation, but can achieve sufficient yield under diffuse sunlight. Thin-film modules perform better than crystalline silicon solar cells under diffuse light conditions or when orientation to the sun is suboptimal. It should also be noted that at high levels of direct irradiation (for example in deserts), the ambient temperature can also be very high, which reduces the efficiency of the solar cells. Crystalline silicon solar cells are more affected by this phenomenon.



Source: Meteotest; data base Meteonorm (www.meteonorm.com), 2011

Figure 3: Global radiation worldwide (the brighter the map, the higher the irradiation)

From an operational perspective, the main difference between technologies resides in their ability to store heat. Hence solar thermal systems such as

- Parabolic troughs
- Fresnel lens collectors
- Solar towers, and
- Solar dishes

can produce electricity even after dark, whereas photovoltaic systems are always tied to the position of the sun. Even sun-tracking systems can only increase their yield during morning and evening hours.

For technical reasons, hybrid systems comprising conventional thermal plants and solar thermal plants (ISCC, integrated solar combined cycle systems) can only generate a small proportion of solar electricity (typically 3-5%). The solar plant only marginally increases the efficiency rating of the conventional plant.

For combined cycle power plants (gas and steam), the thermal output of the steam turbines cannot exceed 30% of the overall output, as they are operated by the hot offgases from the gas turbines. A greater contribution from the steam turbine would compromise the performance of the gas turbine. The solar thermal plant can similarly only contribute a maximum of 30% of heat to the steam turbine – otherwise the latter's operation will be compromised. Generally, the solar share is well below this figure: even in very optimistic conditions, it falls short of 10%. In the medium to long term, hybrid operation is not a practical option for reasons of economic efficiency and security of supply, given its dependence on fossil fuels.

Operating solar thermal plants is more maintenance-intensive, and the individual components do not hold the same cost reduction potential that photovoltaic technology does. However, the advantage of solar thermal lies in its ability to store heat. The increased capacity utilisation of the components in solar thermal installations **with** heat storage means they can generate electricity approximately 10% more cheaply than such installations **without** heat storage.

2.2. Wind

In terms of development, wind power systems have a head start of at least a decade over solar technologies. Wind technology is already available on an industrial scale: this means potential for cost savings here is much smaller than in the newer photovoltaic and solar thermal electricity generation sectors.

In contrast with solar installations, wind power necessitates little exclusive (net) land use. It is possible to use land under wind parks for agriculture, almost without restriction.

2.3. Biomass

In general, agricultural biogas facilities are only found where regulatory or tax incentives exist for them. Such incentives include strict environmental protection regulations on the discharge and/or treatment of waste substances from cattle farming. Tax incentives for the generation of electricity from biomass may be delivered as investment grants (as in South Africa) or legally guaranteed (feed-in) tariffs as in the German Renewable Energy Sources Act (EEG; e. g. China has followed this model).

The cost of investment in agricultural biogas plants varies from project to project and is usually heavily dependent on the technology used for the particular installation. In order to keep investment costs low, the proportion of local production and service input is kept as high as possible in countries with comparatively low wage levels. This local labour can be procured primarily in structural and civil engineering (construction of the fermenter, foundations, access roads, supply pipes etc). However, compliance with time and quality specifications (especially in fermenter construction) must be ensured if the imputed cost savings are indeed to be made.

3. Economic efficiency

3.1. Electricity production costs

While in the case of solar installations the irradiation at the site is usually a known value (the solar energy incident on one square metre during the period of one year), the figure used for wind installations is relative.

In order to consolidate the electricity generation resulting from the fluctuations in the operation of wind turbines and formulate a reference figure, the concept of annual *full load hours* is applied. This figure states the (theoretical) number of hours in a year for which a wind turbine generates electricity at full capacity, with the assumption being that the turbine is at a standstill for the remainder of the year. In fact, however, the turbine will operate for much longer periods during any given year, but not at full capacity. The maximum value is the number of hours in a year: 8,760. Conventional plants also never achieve this value due to stoppages for maintenance, repairs, and the like.

This figure is used as a comparative measure of plant capacity utilisation. The number of full load hours for a wind turbine is calculated by combining the wind resource at the site with the design of the turbine in question. Within certain limits, larger rotors can compensate for lower wind levels.

The power plant mix in Germany, at around EUR 0.06-0.07/kWh, can be used as a comparator for the current production cost of electricity. However, this figure does not include the many forms of support and subsidy for coal and nuclear energy. After attributing such subsidies to the specific types of generation, the figure for these would be EUR 0.08-0.10/kWh. A further markup would be required to reflect the lack of liability insurance (up to EUR 1.8/kWh, Wuppertal Institute, 2007)[1] and the cost of final storage for nuclear waste.

The production cost of electricity is composed of investment and operating costs, determined in turn primarily by fuel costs, and only to a lesser extent by maintenance and repairs, as well as provisions for decommissioning. It would only be reasonable to add any additional perpetual costs for the final storage of nuclear waste.

While the production costs of electricity from conventional plants are largely determined by their fuel consumption, the production costs of electricity from renewable systems are determined in equal measure by the investment made and the natural resource (wind profile, irradiation) at the operating site.

Nuclear power plants are a special case: investment costs are also the major factor here, although only because the cost of nuclear waste disposal and the insurance risk for operating the plants are borne by the public purse.

A large number of direct support measures (such as subsidies) and indirect measures (such as tax relief, market price mechanisms) conceal the true electricity generation costs, meaning that in general the figures used are unrealistic.

On the whole, it should be noted that conventional energy technologies (including nuclear) around the world receive many times more subsidies than renewable systems. The International Energy Agency (IEA) estimates that in 2009 the distribution of subsidies globally was USD 57 billion dollars for renewables and USD 312 billion for conventional technologies; by 2015, this gap could widen to USD 100 billion versus USD 600 billion.

3.2. Investment

The reason why solar thermal plants have less potential for cost reduction than photovoltaics is their greater complexity.

Solar thermal plants have considerably more components than PV systems. What is more, the electrical losses in a PV plant can be minimised simply (for example through conductor cross-sections or inverter design), whereas minimising thermal losses costs considerable effort. In particular, there is a conflict between the optimisation of different aspects: on the one hand increasing the temperature of the working medium gives greater turbine efficiency, and on the other the increased temperature differential with the surroundings brings a significant rise in heat loss. In addition to the optical parabolic mirror or general concentrator system, (optical quality, stability of construction) the ability to track the sun, thermal transmission equipment and all the facilities of a thermal power plant are employed (except the burner).

In the long term, solar towers (or central receivers) are expected to exhibit the highest degree of efficiency, and therefore the lowest electricity generation costs, of all the CSP technologies. The particularly high concentration factor produces a high temperature level and thus ensures high thermodynamic efficiency.

There is little value in a comparison of renewable and conventional systems in terms of investment costs, as their operating costs (for example for fuel!) differ greatly.

1 Cf. Kernenergie im energiepolitischen Zieldreieck von Klimaschutz, Versorgungssicherheit und Wirtschaftlichkeit, Wuppertal Institute, 2007, pp. 12 ff

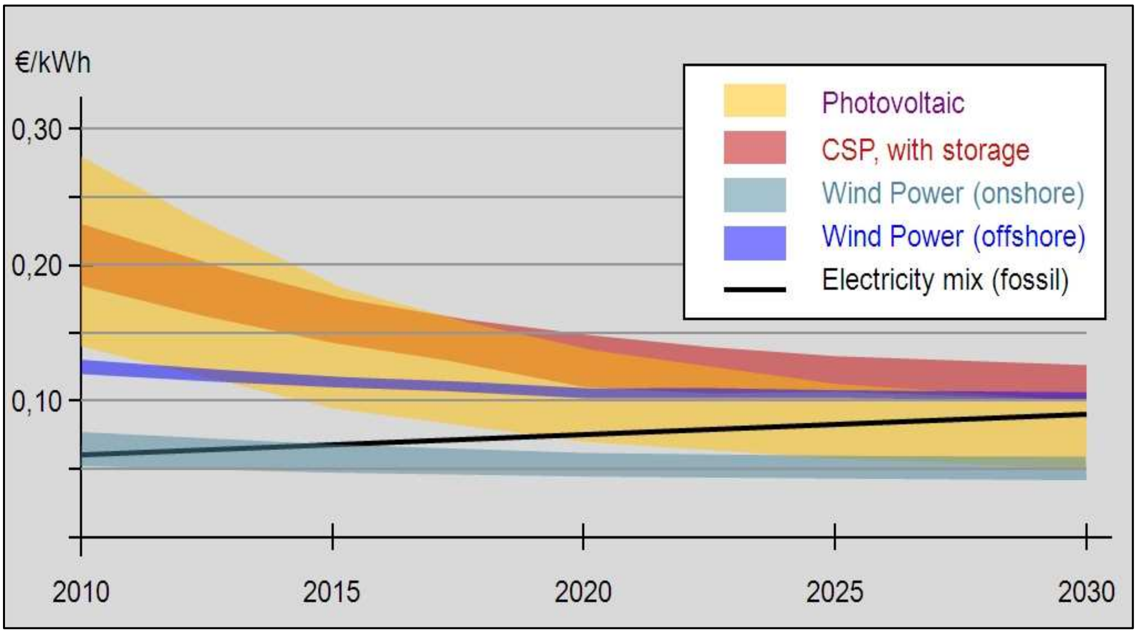
3.3. Cost trend

Practically all renewable energy sources have the potential to generate electricity at the same level of costs as the present generation mix by 2030. Onshore wind and photovoltaics have the best prospects. Little data is available on offshore wind farms at present, but we predict that despite their healthy output, the electricity generation costs of offshore wind systems will be higher than those on shore. The fossil fuel generation mix applied is based on the 2009 German Federal Environment Ministry (BMU) lead scenario for Germany, which includes power plants the investment cost of which has already been largely depreciated. This presents a clear imbalance compared with the investment involved in new renewable systems.

Irrespective of the medium to long term fuel supply question, electricity generation costs for nuclear power plants currently under construction will lie in the approximate range EUR 0.15-0.20/kWh – not including allowances provided free of charge such as the waiving of the requirement for liability insurance and of final waste storage costs.

Due to variation in the size of installations (the larger the installation, the lower the electricity generation costs) and in the local resources available at the operation site (irradiation, wind profile), electricity generation costs vary widely.

It is not possible to produce a useful cost estimate for electricity from biomass installations, as the installation types and biomass feedstocks vary widely. As a rule, these feedstocks will be organic waste from agriculture, industry (for example paper manufacture) or households. Of primary importance for a cost benefit balance are pre-processing (sorting) and the potential revenue from materials recycling. The targeted agricultural cultivation of feedstocks which is practised in Germany is expected to be the exception rather than the rule, due to the competition this creates with food crops.

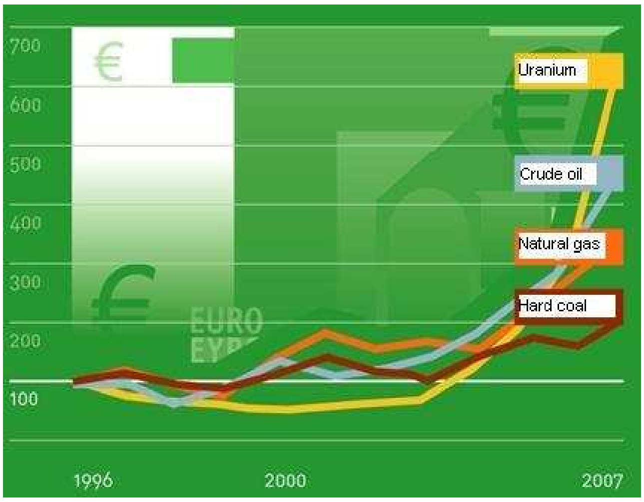


Source: Fraunhofer ISE, Studie Stromgestehungskosten Erneuerbare Energien

Figure 4: Electricity production cost trends (until 2030) for different renewable energy technologies

3.4. Costs and benefits

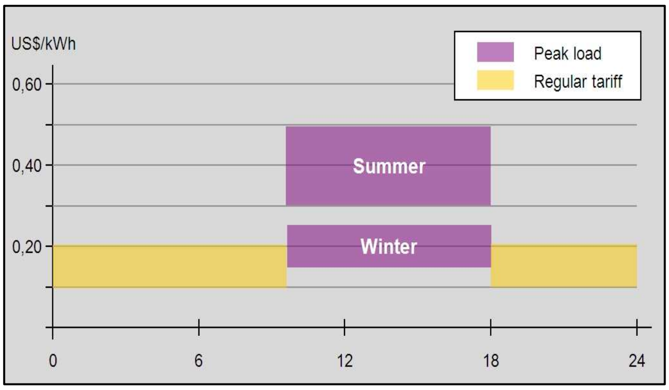
Unlike conventional power plants, whose electricity generation costs have become dominated by fuel costs (with the exception of nuclear power), the key aspects determining the costs of renewable systems are their investment cost and local conditions – for example the wind speed profile or solar irradiation, as well as the cost of maintenance.



Source: Agentur für Erneuerbare Energien (German Renewable Energy Agency)

Figure 5: Cost trends for fossil fuels (Index: 1996 = 100)

These costs are set against the value of the electricity generated; this rises alongside its availability and suitability to meet actual demand. Control and peak load energy are valued especially highly (see figure 6).

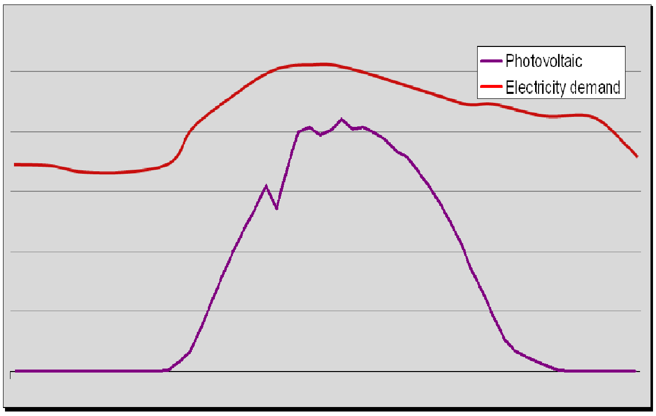


Source: Greenpeace / European Photovoltaic Industry Association EPIA, Solar Generation VI

Figure 6: Variable electricity rates in California with higher prices for peak load

The almost continuous wind blowing at offshore sites means it is reasonable to compare them with hydropower plants. Even these cannot operate at full capacity all year round. Ice in winter and low water levels in summer reduce their output. Capacity utilisation for both types of plant is in fact of the same order of magnitude (4,000 to 5,000 full load hours a year).

CSP plants require a minimum of 2,000 kWh/m²a in direct irradiation – a rough estimate would therefore be 2,000 full load hours annually (which might increase by 10 to 30% more in some locations). The storage capacity is designed for six hours' full load operation. This would deliver a further 2,000 to 2,200 full load hours a year, giving a total of around 4,000 to 4,500 full load hours. The advantages here are (a) the output profile, which matches the demand profile relatively well over the course of a day (see figure 7), and (b) the storage capacity, which allows electricity to be generated according to demand even after sunset.



Source: IfaS; BDEW, 2009

Figure 7: Diurnal curves of the solar supply (supply of electricity from photovoltaic systems) and electricity demand (not to scale, exemplary one day in July)

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