16

Energy Efficiency and Electrical Power Generation

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1. Introduction

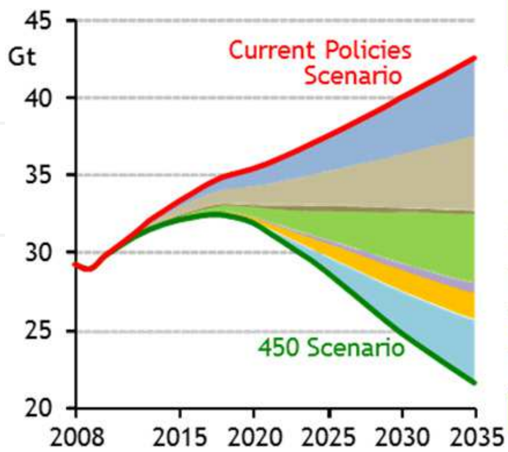
Reducing demand for energy, through energy efficiency measures and conservation, is the cheapest and most effective way for enhancing energy security, providing a stable basis for economic planning as well as cutting carbon emissions.

Energy efficiency is the most influential means of achieving sustainable energy future. It will significantly economize on energy use, reduce investments in energy infrastructure, reduce costs and maximize consumer welfare; as important it cuts off on emissions. In its World Energy Outlook 2010, the International Energy Agency (IEA), adopted the BLUE Map scenario which sets a goal of halving global energy-related CO2 emissions by 2050, compared to 2005 levels, and sets out the least-cost pathway to achieve that goal; through the deployment of existing low-carbon technologies (IEA-WEO 2010).

In 2050, with business as usual, global CO_2 emissions are expected to reach 57 Gt of CO_2. The Blue Map emissions aim at reducing them to only 14 Gt. Although this has become a rather unrealistic goal, however, what of interest to us here is that the most effective means of achieving these emissions reduction is through energy efficiency in end-use fuel and electricity generation. In the IEA 450 Scenario, energy efficiency is capable, by 2035, of achieving up to 48% of the abatement goal, more than twice that of renewables or Carbon Capture and Storage (CCS). The total reductions in CO_2 emissions as a direct result of energy efficiency measures are almost equal to the combined containment by all other means - CCS, renewables, fuel switching, nuclear, etc. (see Figure One).

This is a survey Chapter that deals with many aspects pertaining to energy efficiency, particularly in the electricity generation sector also industry. The electrical power generation sector is chosen for special emphasis due to its present low efficiency and the growing importance of electrification in the global economy and final energy use, as we are going to see later. It is not intended in this Chapter to go into the intimate details of technologies of electricity generation and how they affect and improve efficiency and reduce carbon emission in a carbon-constrained world. Such issues are covered in the literature (Sioshansi, 2010). What we are doing in here is outlining the important subject of energy efficiency and how the power generation activity fits into this, the present status and future prospects.

At the end of the Chapter there is a short section that refers to Energy Governance, which is important in attaining energy efficiency in all energy utilization activities including that of electricity generation. This section also deals with energy subsidies that proliferate in the electricity sector, particularly in oil exporting countries and some developing countries, and are detrimental to achieving energy efficiency including that of electricity generation.



	Abatement 2020	2030	2035
Efficiency	71%	49%	48%
- *End-use (direct)*	34%	24%	24%
- *End-use (indirect)*	33%	23%	23%
- *Power plants*	3%	2%	1%
Renewables	18%	21%	21%
Biofuels	1%	3%	3%
Nuclear	7%	9%	8%
CCS	2%	17%	19%
Total (Gt CO_2)	3.5	15.1	20.9

Fig. 1. IEA 450 Scenarios for Reducing Global CO2 Emissions. Source: (IEA –WEO 2010)

2. Energy efficiency

Let us first of all start by defining what we mean by "energy efficiency". According to the IEA – something is more efficient if it contributes more services for the same energy input, or the same services for less energy input. For example when a compact florescent light (CFL) bulb uses less energy than an incandescent bulb to produce the same amount of light, the CFL is considered to be more energy efficient (IEA- Governance). Energy efficiency is also defined as "percentage of total energy input to a machine or equipment that is consumed in useful work and not wasted as useless heat" (ABB 2010). The EU Directives define efficiency as "a ratio between an output of performance, service, goods or energy and an input of energy" (ESD Article 3 b).

The exact value of global energy efficiency is a debatable figure. Of the 12,500 million tons of oil equivalent (Mtoe) of primary energy consumed in 2010, 8,600 Mtoe are delivered as total final energy to users and consumers. There are estimated 7,500 Mtoe lost, mostly as low and medium–temperature heat (WEA). This means that globally the energy efficiency ratio does not exceed 40%, which is extremely low and demonstrates the future strides that can be achieved in this quarter. A large proportion of the energy losses in delivering final energy to consumers are in the electricity generation sector, and that is why this sector receives emphasis in this paper. Losses in converting delivered energy into useful energy in final use also occur in all sectors of the economy, mainly in industry, transport and building.

Energy efficiency has to be differentiated from energy conservation. Energy conservation refers to efforts made to reduce energy consumption. Energy conservation can be achieved through increased efficient energy use, in conjunction with decreased energy consumption and/or reduced consumption from conventional energy sources (Wikipedia 2011). Whereas conservation can be achieved through behavioral changes, education and pricing, energy efficiency can be mainly improved by technology, investments, codes and practices also energy pricing. Energy efficiency also needs to be differentiated from energy management which means timing energy use in a manner that minimizes cost and maximizes useful utilization of efficient facilities.

Energy is consumed for production, services and comfort. Its extent of use varies from one country and region to another depending on technology achievement, prices of energy products, economic output and weather. Primary energy intensity of a country is its total primary energy consumption per unit of the country's gross national product (GDP). Primary energy intensity measures the total amount of energy required to generate one unit of GDP. GDP is expressed at constant exchange rate or purchasing power parity (ppp) to remove the impact of inflation and changes in currency rates. Using purchasing power parity rates instead of exchange rates to convert GDP in the same currency (e.g., $) makes it possible to account for differences in general price levels: it increases the value of GDP in regions with low cost of living (case of developing countries) and, therefore, decreases their energy intensities.

Prior to the age of increasing energy prices, i.e. pre – 1973, the growth of energy consumption used almost to mirror that of global economic growth, i.e. elasticity of energy demand versus that of economic growth was almost 1:1, with little improvement in global energy intensity. However, in recent years, and due to rising energy prices, environmental awareness and resource depletion, as well as technology oriented efficiency programs, significant trends took place in reducing energy intensity. Global energy intensity decreased by 1.4% per year over the last two decades and is continuing to do so (see Figure Two). Over the last twenty years the world economy grew at an average of 3.2% annually, while primary energy consumption grew from 8,800 Mtoe to 12,500 Mtoe i.e. an annual average of 1.9% only. This lead to these significant improvements is energy intensity. (See - Global Energy Efficiency Trends - ABB 2010).

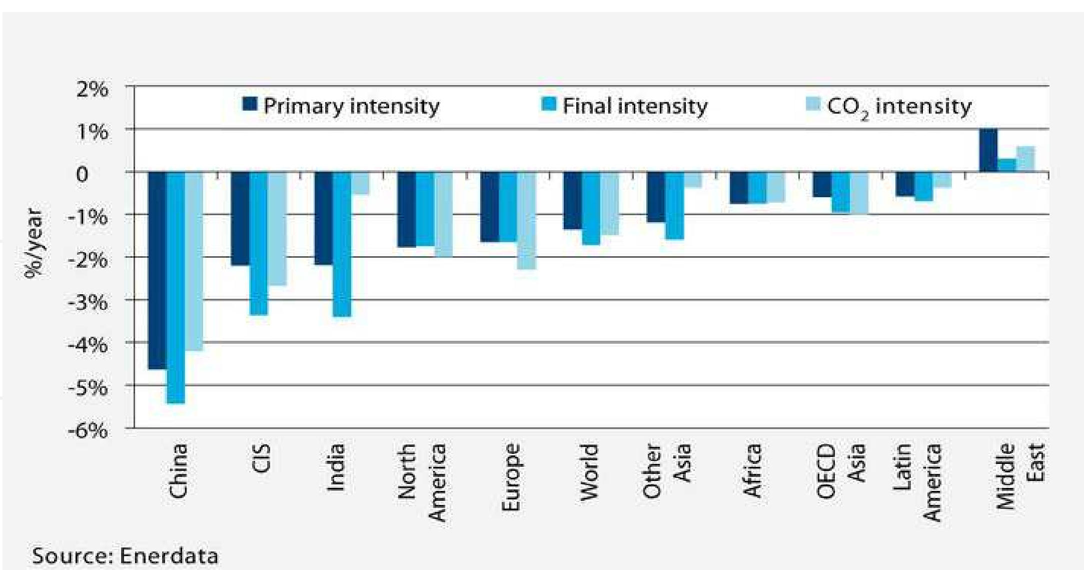


Fig. 2. Energy and CO_2 intensity trends (1990-2009) (% / year). Source: ABB 2010.

Most reductions in energy intensity occurred in OECD countries. One of the reasons of the decrease of the energy intensity in OECD countries is that the heavy and high energy intensity industries (steel and cement industries, aluminum smelters, etc.) moved out of these countries into places where energy is still cheap (like China and India) and where there is less national emphasis on environmental and emission issues. OECD economies are emphasizing the services sector which is less energy intensive, while many developing countries are building and expanding their industrial base with emphasis on heavy industries and utilization of local natural resources while exporting industrial products to OECD countries. Correspondingly the true country figure of energy intensity should be modified to reflect imports to OECD countries of industrial material that carry a high energy bill (more of that later in the Industry sector).

3. Efficiency in the electricity generation sector

The efficiency of electricity generation is a complex phenomenon. It depends on many factors and varies from one country to another. National primary energy endowments plays a prominent role; countries with viable hydro electric sites try to exploit these as a priority, so they will also exploit local coal resources in spite of their environmental impacts. The endowment of national (or imported) resources of natural gas presents opportunities for high efficiency and relatively inexpensive electricity generation. Nuclear is limited to few countries with relatively advanced financial and human resources and its efficiency is below average, also below average is the efficiency of new renewable generation – wind and solar.

This Chapter will cover these issues with a global view pointing out to global averages but also to individual technologies. It will cover the existing generation technologies and tries to predict future world averages depending on trends and furthering new technologies particularly in replacing vintage plant with more efficient CCGT and high efficiency coal plant with advanced parameters.

Energy losses occur in every activity in the electricity sector, not only in the utilization of electricity, but mainly in the electricity supply industry – electricity production (generation), its transmission to consumer centers as well as its distribution to users and consumers. It is mainly in electricity generation where the majority of losses occur. Till today the average net efficiency of electricity generation worldwide is around 34%, with almost two thirds of calorific content of primary fuel input into electricity generators is lost as waste heat (Khatib 2003). It has to be emphasized that there are no exact dedicated data on global net electricity generation and its exact consumption of fuels. So we have to rely on published data in the global annual energy surveys, the latest of which is the "International Energy Outlook 2011" of the US Energy Information Administration (IEO, 2011). Efficiency of electricity generation, which was as low as 25% in the 1950s, significantly improved to around 34% - 35% today, and is continuously but slowly improving mainly through the increasing use of combined cycle facilities firing natural gas and improved technologies in material use. In this Chapter when we are referring to net electricity generation efficiencies we are only accounting for net power sent out from the station, thus ignoring the energy use by the plant auxiliaries which can be as high as 5-6 % of generated power in case of steam plants and 1-2 % in gas turbine plants.

Figure Three (IEA- ETP 2010) shows how the efficiency of coal firing power stations was held steady at almost 34% over the last twenty years, while that of gas firing facilities improved from 34% in 1990 to an average of 43% in 2010 through the wide introduction of combined cycle gas turbine plant (CCGT) facilities firing natural gas.

Electrical efficiency is most important because the world is electrifying. Energy services are now being increasingly offered in the form of electricity, rather than in any other form -

mechanical or human. Whereas energy demand is expected to grow at an annual rate of 1.6 % over the next 25 years, that of electricity is expected to grow at a rate of 2.3 %, reflecting this growing electrification (IEO 2011); that is why improving efficiency of electricity production figures so high in any effort to improve global energy efficiency – see Figure 3.

There are also major losses in the electricity grid – the transmission network as well as distribution lines. The transmission network that delivers bulk electricity from major power stations into bulk supply substations, can incur losses as high as 1 – 3 % of transmitted energy (depending in the length and voltage of the network). Other 6 – 10% losses occur in the distribution networks (also depending on the network configuration - length and conductors). Therefore, world average transmission and distribution (T&D) losses are around 8 – 9 % of energy sent–out from the power station (IEA-ETP 2010). When this is taken into account, of the primary energy input into the power plant only 30 – 32% of this energy reaches consumers, i.e. less than one third. This demonstrates the efficiency dilemma of the electrical power system.

3.1 Efficiency of electricity generation

Efficiency of the electricity generation depends on the mode of generation. Hydroelectric production has an efficiency of over 90%; whereas vintage thermal plants firing coal have efficiencies of no more than 25%. Modern steam plant, firing coal, is becoming the preferred means of generation, particularly in China and India, where thermal plants represent 80% of production due to availability of cheap coal. Steam generation, mainly firing coal, presently represents half of world electricity generation and future improvements in efficiency of electricity production depend on technology advancement in this quarter. Major losses mainly occur in the thermal plant itself, in condensing steam; also in auxiliaries and generators and these can be as high as 5-6% of the generated electricity.

3.2 Improving efficiency of electricity generation

There are two approaches to improve steam power generation efficiency: one is through increasing live steam parameters (pressure and temperature) to develop supercritical (SC) and ultra-supercritical (USC) technologies; another is by system integration, a typical example is Integrated Gasification Combined Cycle (IGCC). In the next 10 years, SC and USC will be built in significant numbers, and these new plants are likely to remain in use until 2050 for electricity production from coal because of their flexibility and general advantages of lower cost, reliability, high availability, maintainability, and operability. IGCC currently looks promising in its ability to produce deep CO_2 reductions at least cost while maintaining high generation efficiency.

Pulverized coal combustion (PCC) is currently the predominant technology for generating electricity from coal and represents 43% of fuels used in electricity generation. It also accounts for more than 97% of the world's coal-fired electrical capacity. Most existing plants operated at less than SC steam conditions, i.e. less than 34% efficiency, with best examples reaching 39% efficiency.

New pulverized coal power plants – utilizing SC and USC – operate at increasingly higher temperatures and pressures and therefore achieve higher efficiencies than conventional units. Supercritical power generation has become the dominant technology for new plants in industrialized countries. Now considerable efforts are underway in the United States, Europe, Japan and also China, to develop 700 C–class Advanced Ultra-Supercritical (A-USC) steam turbines. If successful, this will raise the efficiency of the A-USC units to about 50% by 2020 (Lui - 2010).

Natural gas (NG) presently accounts for 20% of electricity production. The increasing availability of NG and its prices are favoring the utilization of NG in high efficiency combined cycle gas turbines (CCGT) where efficiencies of over 50% are becoming common and as high as 60% are increasingly possible. This increasing CCGT trend and improvements in the efficiency of thermal plant through the increasing use of critical and super critical steam turbines means that the efficiency of electricity generation is destined to continue to improve, although slowly, in the future.

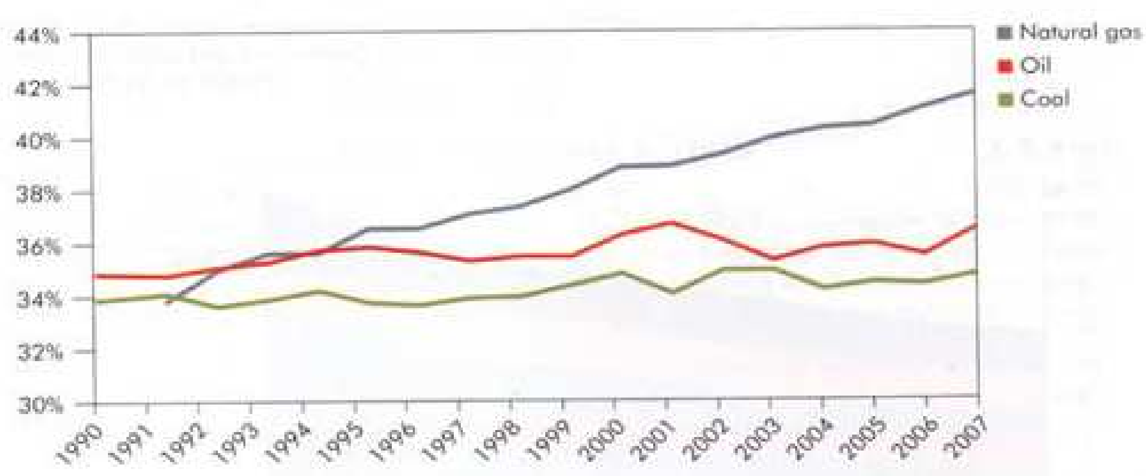


Fig. 3. Development of Efficiency of Thermal Generating Plant. Source: ETP 2010.

3.3 Future trends in efficiency of electricity generation

As already indicated the efficiency of electricity generation is destined to continue to improve year after another. Such improvements are prompted by the rising cost of primary fuels, but also and as important by environmental considerations. Mitigating carbon emissions from generating plants is a global environmental concern. Carbon taxation, which is becoming common in most OECD countries and few other countries, will enhance already mentioned technological trends to improve efficiency of coal plants and switch to cleaner renewable resources, particularly hydro and wind, also the more efficient CCGT plant firing natural gas.

But such global improvements are going to be very slow due to the existence of a vast inventory of vintage low efficiency plants which have long lives (sometimes even extended), the high investment cost of introducing new plants and also the efficiency penalty of mitigating emissions through the introduction of clean technologies, like that of carbon capture and storage (CCS) which tend to significantly reduce efficiency of new plants fitted with such facilities.

Table 1 below gives a prediction of the future development of electricity generation in coming next twenty five years and its rising proportion of primary energy sources.

Year	Expected Net Generation (TWh)	Fuel consumption (Quad BTU)	% of global use
2005	19 125	194	38.4
2015	22 652	227	39.4
2025	28 665	281	41.8
2035	35 175	337	43.8

Source: IEO 2011

Table 1. Future Electricity Generation Trends

The fact is that the annual amount of fuels destined to electricity generation will grow at a rate of almost 2.1% annually, while net electricity generation will grow at a higher rate of 2.3%, indication an annual improvement of efficiency of 0.2% percentage points, Figure 4. Over a period of 25 years (2011-2035) this means that the efficiency of electricity generation is likely to improve by 5% as indicated in Table 1 above.

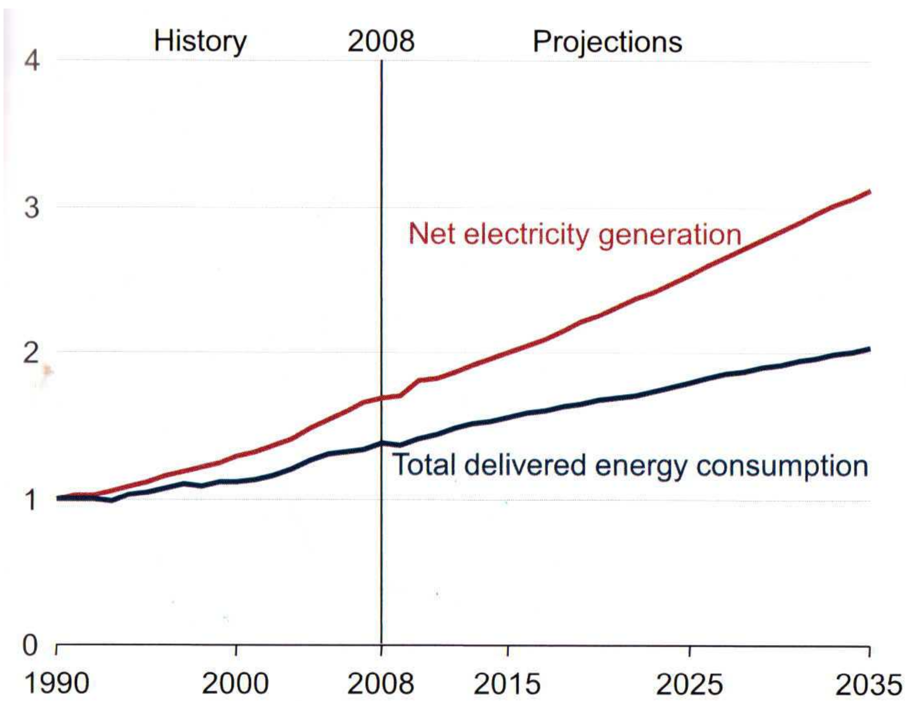


Fig. 4. Future trends in energy consumption and electricity generation. Source: EEA, 2011.

3.4 Carbon emissions from electricity generation

Thermal power stations firing coal are major emitters of CO_2 with around 750 – 1000 grams CO_2/kWh in 2010. With net electricity generation of 20,500 TWh in that year, total CO_2 emissions from the electricity sector amount to around 12,000 million tons, this is 40% of global carbon emissions. With each one percentage point improvement in efficiency of electricity generation, CO_2 emissions can be reduced by as high as 350Mt annually (Creyts, 2007).

It has to be realized that slow but continuous progress has been achieved in reducing emissions from generation plant during recent years. Past vintage plants of the late twentieth century burning coal operated at an efficiency of 25% while emitting 1.30 tons CO_2

/MWh. New thermal generation operating at an efficiency of 45% and burning coal is emitting only 0.720 tons CO_2 /MWH, while a new CCGT burning NG can has an efficiency of 60 % and emits only 0.320 tons CO_2 /MWH. This is only one quarter of the emissions per unit of electricity one quarter of a century ago.

Nuclear plants, due to security reasons have to operate at relatively moderate temperatures and pressures. Correspondingly its efficiency tends to be at 35% or lower. This is a low efficiency value compared to modern thermal plants. However a nuclear plant has the advantage of no emissions. The same applies to new renewable resources (wind and solar) which tend to have low or no emissions but operate at low efficiency in comparison to hydro plants which have high efficiency.

3.5 The smart grid and energy efficiency

The introduction of the Smart Grid is the latest innovation in the electricity supply industry. It allows for two way communication between suppliers and consumers and also the connection of the distributed generation to the national grid, correspondingly it enhances the integrity of the supply and its management. As important it will contribute to improve the efficiency of the public electricity generation. It will enable both the suppliers and consumers to manage demand as to reduce peaks, improve load factors and thus enhance loading of efficient generators and reduce the contribution of the inefficient peaking plant. But it will take many years until the beneficial effects of smart grids begin to significantly show in improved global efficiency of electricity generation (Khatib, 2011).

3.6 Factors affecting the efficiency of generating plant

Power plant efficiencies are typically defined as the amount of heat content in (BTU) per the amount of electric energy out (kWh), commonly called a heat rate (BTU/kWh). Such efficiency is affected by (NPC, 2007):

- Design Choices that present a tradeoff between capital cost, efficiency, operational flexibility and availability
- Operational practices that aims at full load, avoiding steam leakages and utilizing integration systems, etc.
- Fuel, particularly utilizing hard dry coal that possesses less water and ash.
- Environmental Control, to reduce emissions (NO_x and SO_x); represent *parasitic loads* that decrease efficiency. Similar penalties are introduced by applying CCS technologies that significantly increase cost and reduce plant efficiency.
- Ambient temperature, colder cooling improve efficiency of generating power, however high altitude negatively affect output and efficiency of gas turbines.
- Method of Cooling- methods for cooling steam turbine effluent can be through once-through cooling, wet cooling tower and indirect dry cooling. There are penalties to utilize wet cooling towers which can range 0.8-1.5% and as high as 4.2-8.8% with a dry cooling tower.

To this must be added penalties brought about by aging, normal deterioration and bad operation, low maintenance and management practices. Deterioration can be addressed by: refurbishment, replacement in kind, upgrade with advanced design, modify original design, repowering and retirement with replacement by new construction.

3.7 Improving efficiency of the generating cycle

The main consideration in improving the efficiency of the generating cycle is through ustilising the heart content of the exhaust gases and cooling water. This is done mainly through combined cycle gas turbines (CCGT) in which the exhaust gases of the GT are fed into a steam boiler and steam turbine generator- thus increasing efficiency of the generating cycle by 50%. A typical CCGT plant now operates in the range of 45-55%, but efficiencies as high as 60% are already achievable.

The other means to improve the efficiency is by combined electricity and heat production where the condensed steam from the steam turbine outlet is ustilied as a heat source mainly in industry but also various applications including district heating (if possible). This also considerably improves efficiency of utilising fuels. An average efficiency of around 50% can be reached in the EU by conventional thermal electricity and heat production. Tremendous strides have been achieved in this regard during the last twenty years as demonstrated in the following Figure 5.

Improvements in efficiency of the utilization of generation fuels can be attained through the combined production of power and water in which the steam from the generating process is utilized for desalination by the flashing process, thus significantly improving the utilization of the generation fuels. Further improvements in output and efficiency are obtained by many new technologies like cooling the input air to gas turbines and Direct Steam Injection Heaters.

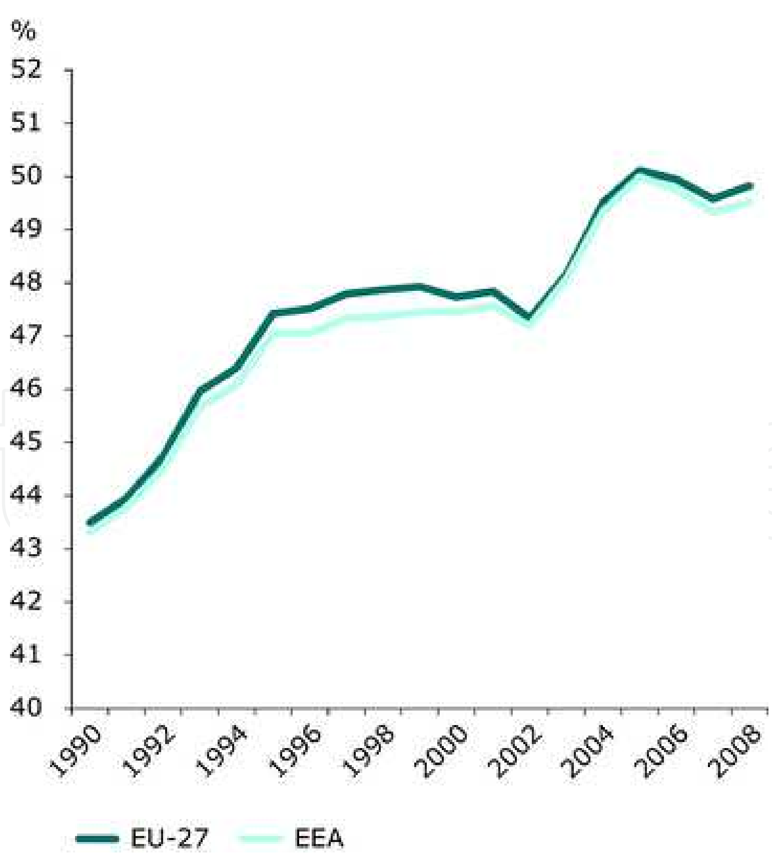


Fig. 5. Development of efficiency of conventional thermal electricity and heat production. Source: EEA 2011.

4. Energy efficiency in industry

Industry is the major energy user by sector, slightly ahead of power generation, buildings and transport. It is also a major user of electricity. In 2011 it is expected to use one quarter of global electricity production compared to one fifth in 1990. Due to advancement in technology major improvements took place in the efficiency of energy use in the industrial sector during recent years. The energy required per unit of value added (industrial energy intensity) has decreased in all regions since 1990. As a result of the globalization of industrial activities, energy intensity levels are converging. At world level, it fell by 1.6 percent / year between 1990 and 2009 (1 percent / year between 2000 and 2009).

Industrial energy intensity is lowest in Europe and OECD Asia, where it stands 40 percent below the world average since 1990. Due to the migration of heavy industries to the developing world, the European industrial energy intensity has decreased by 2.5 percent / year, while North America and OECD Asia show reductions of around 1.5 percent / year over the period. Energy intensity is slightly higher in North America than in Europe and OECD Asia, it stands just 13 percent below the world average and 50 percent above the EU average. Industrial cogeneration (CHP) is aiding the improvement in energy use in industry.

As mentioned above, one of the main reasons for improvements in the industrial energy intensity of Europe and North America is the shift of much of the heavy industrial production from these countries into China, India and few other developing countries which are rich in cheap energy resources.

Energy intensive industries are: the steel industry (20% of global energy use in industry), chemical industry (14%), cement industry (11%), paper industry (6%) and the aluminum industry. These heavy industries account for over than 55% of global energy use in industry. (ABB 2010)

Advancement in technology in heavy industries (like: increasing use of electric process in steel, change from heavy into light chemicals, the dry process in cement production and recycling in the aluminum industry, etc.), was the main reason for improvements in efficiency in energy use in industry.

The energy required per unit of industrial value added has been decreasing in all regions; as a result of the globalization of industrial activities, energy intensity levels are converging. The global economic crisis in 2009 had a strong impact on industrial trends, especially in developed countries, where energy-intensive industries were severely hit.

In the steel industry, which is the main industrial energy consumer, significant progress has been made over the last 20 years thanks to the spread of the electric process. However, the main producers, in cheap energy regions, still use outdated processes like open-hearth furnaces (Russia and Ukraine) or small-sized plants and low quality ore (China).

In the chemical industry, the energy consumption per unit of value added decreased in all main producing countries except in the United States, which is the world's main producer of chemical products and also the country with the highest energy intensity. The spread of dry processes and kilns using pre-heaters and pre-calciners let to reductions in the average energy consumption per ton of cement (specific energy consumption) in several large producing countries. The sharpest drop in specific energy consumption was achieved in China, thanks to the replacement of small cement plants by larger facilities.

Nevertheless, a great deal still remains to be done, as shown by the significant energy savings potentials identified in the references. The energy efficiency improvement potential can be as high as 40 percent in the case of steel and 20 percent in other industries.

5. Energy governance

To achieve the benefits of energy efficiency calls not only on technological advancement but also on institutional, legal, public awareness and similar coordination arrangements. This is called "energy governance" and is defined as "combination of legislative frame works, funding mechanisms, institutional arrangements and coordination mechanism, which work together to support implementation of energy efficiency strategies, policies and programs". Such energy governance is needed to overcome the many barriers to energy efficiency. These barriers are market, financial, institutional and technological, as well as lack of awareness and information.

To these must be added another major barrier which is "energy subsidies". The existence of subsidies is a major barrier to the attainment of the goals of energy efficiency, including that of generation and this is dealt with in detail below.

5.1 Dealing with barriers

It is not intended here to go into full details of how to deal with barriers to energy efficiency. These are detailed elsewhere (IEA-Energy Governance).

It is enough to mention here the importance of regulatory, pricing, fiscal and financial measures in overcoming such barriers. The most important is setting minimum energy performance standards (MEPS) for equipment, apparatus, buildings and vehicles with obligatory energy audits to ensure attainment of MEPS as well as appliances labeling and enforce building certification. Pricing has to aim at avoiding unnecessary subsidies with an increasing electricity tariff so that higher consumption is penalized by higher unit tariff that curbs overuse. Fiscal and financial measures need to provide incentive to energy efficiency investments, by providing revolving funds and contingent financing facilities.

Awareness and dissemination of information is most important in facilitating adoption of energy measures, particularly among the public. This is lacking in many cases and requires public information campaigns and promotions, enforcing the already mentioned appliances labeling, also demonstration and training. The energy service companies (ESCOs) can play a major role in this regard. They can provide the services demanded by industry as well as the public in certification, audits, training and promotion as well as disseminating public information. They also can be intermediaries in facilitating funding. Such ESCOs are now common in industrialized countries but are missing in most developing economies where their services are most badly needed.

5.2 Energy subsidies as a major impediment to energy efficiency

A subsidy implies selling an energy product (refined fuel or electricity) at prices lower than the product's opportunity cost. The opportunity cost is the price which the product would have obtained had it been exported instead of direct burning or utilization in local electricity production. We have to note that energy cost includes, beside the fuel's opportunity cost, the amortization of investment as well as operational and maintenance costs.

If we apply this definition, subsides proliferate energy use in most of the developing world. Electricity tariff subsidies are more widespread than subsides in selling refined products like petroleum for cars. This is due to the fact that electricity is a basic commodity that is widely used in all aspects of the economy as well as the society, particularly among limited income groups. This forces governments to provide it (like water) at prices lower than actual cost.

The dangers of subsidies manifest themselves in over use of the cheap resources more than is required by actual needs. Instead of spending the country's limited resources on human development, subsidies lead to waste, inefficiency and over use. This is besides the harmful environmental implications of this over use.

There is always the call for the need to provide energy in subsidized manner to certain limited income consumer groups as well as industries. If there is real need for this, then the subsidy should be made in cash and not in energy bills. Electricity subsidies lead to inefficient use and waste. Correspondingly it is essential to charge fair electricity prices that cover actual cost to avoid waste. Subsidizing the industry and economy can be in cash payment or other fiscal means, if need be.

Energy subsidies proliferates mostly in oil/energy exporting countries where refined products are provided at only a fraction of what they command in the export market and electricity tariffs are so low thus encouraging waste and over use. In few instances, in oil and gas rich countries, electricity is also provided free!!

The IEA (IEA-WEO 2011) estimates that the value of fossil-fuel consumption subsidies, including electricity generation, in 2010, amounted to $400 billion. Most of these subsidies encouraged wasteful over use with social, economical and environmental damage. Most important they were an impediment to achieving the goals of energy efficiency. The value of the energy products market now approaches $5 trillion annually. Subsidies account to almost 8% of this market value. If market pricing can reduce this by a half almost 4% of world energy consumption can be saved by phasing out subsidies.

The following Table 2 refers to the World's top energy subsidized economies. Mostly they are oil exporting countries.

Iran	82
Saudi Arabia	44
Russia	39
China	25
India	23
Egypt	20
Venezuela	20

(Source: IEA - World Energy Outlook 2011)

Table 2. Energy Subsidies in Billion $ (2010).

6. Conclusions

This chapter dealt with many aspects pertaining to energy efficiency, particularly in the electricity generation sector. The electrical power generation sector is chosen for special emphasis due to its present low efficiency and the growing importance of electricity as the major energy carrier.

Energy efficiency can be defined as percentage of total energy input to a machine, equipment or a facility that is consumed in useful work and not wasted as useless heat. The exact value of the global energy efficiency is debatable. Presently, however, it does not exceed 40%; that of the average net electricity generation is even lower at 34%. These are extremely low figures and demonstrate the strides that can be achieved in this quarter. Most of the energy losses in delivering final energy to consumers are in the power system, and that is why this sector is central to this discussion. Significant losses in converting delivered primary energy into useful energy in final use also occur in all sectors of the economy, mainly in industry, transport and buildings.

Generation efficiency has to be differentiated from electricity conservation or demand side management. Whereas conservation can be achieved through behavioral changes, education and pricing, power generation efficiency can be mainly improved by technology, investment, codes and practices also energy (and carbon) pricing, introducing edits and enforcing regulations. Power generation efficiency varies from one country and region to another depending on economic output, technology achievements, price of electricity, and weather. Many barriers exist that are delaying the deployment of generation efficient technologies.

In the global quest for curbing emissions, generation efficiency and electricity conservation figures out to be the most effective and cheapest means to reduce carbon emissions. In many cases it is a win-win situation where benefits can be attained at minimum (or no) cost, with short pay-back periods. However this means overcoming many barriers, one of which is the proliferation of subsidies in the developing world. Any environmental strategy that does not have power generation efficiency and electricity conservation as a center of interest will be missing the target.

Due to increasing cost of primary energy and its products, also environmental awareness, the efficiency of utilizing energy is improving worldwide year after another. Major efficiency improvements happened in OECD countries in recent years through lowering energy intensity in their economies. However this was assisted by the migration of heavy industries to developing economies. In spite of all technological advances and regulatory arrangements, energy efficiency worldwide does not exceed 40%. This demonstrates the still wide scope for improvements in this regard.

The efficiency of the electricity generating sector demands particular attention. Of the primary energy input to power stations less than one third of the calorific input reaches consumers, in many countries only one quarter. The wider introduction of combined cycle plant and higher parameters in PC plants are gradually improving the electricity sector efficiency. This is particularly important because the world economy is increasingly electrifying.

In the world-wide pursuit for improving energy security and reducing environmental impacts, improvements in energy efficiency are the cheapest and easiest means to attain results. Any global sustainable energy strategy which does not have improvements in energy efficiency as its center of interest will be missing the correct emphasis. No more this is evident than in the case of electrical power generation.

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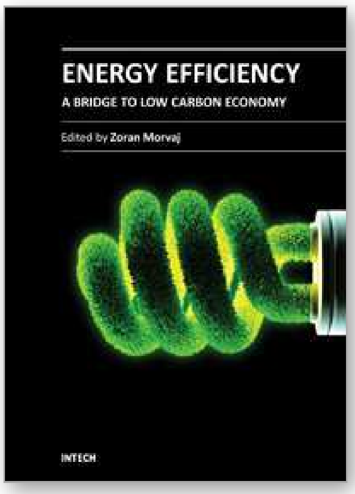

Energy Efficiency - A Bridge to Low Carbon Economy

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Energy efficiency is finally a common sense term. Nowadays almost everyone knows that using energy more efficiently saves money, reduces the emissions of greenhouse gasses and lowers dependence on imported fossil fuels. We are living in a fossil age at the peak of its strength. Competition for securing resources for fuelling economic development is increasing, price of fuels will increase while availability of would gradually decline. Small nations will be first to suffer if caught unprepared in the midst of the struggle for resources among the large players. Here it is where energy efficiency has a potential to lead toward the natural next step - transition away from imported fossil fuels! Someone said that the only thing more harmful then fossil fuel is fossilized thinking. It is our sincere hope that some of chapters in this book will influence you to take a fresh look at the transition to low carbon economy and the role that energy efficiency can play in that process.