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Status Report 2006

Scientific Technical REFERENCE System on RENEWABLE ENERGY and ENERGY END-USE EFFICIENCY

Editor: Arnulf Jäger-Waldau

Institute for Environment and Sustainability

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The mission of Institute for Environment and Sustainability is to provide scientific-technical support to the European Union's Policies for the protection and sustainable development of the European and global environment.

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PREFACE

The European Union is implementing challenging commitments to reduce greenhouse gas emissions by 8% in accord with the Kyoto protocol, and has established ambitious targets for renewable energies and energy end-use efficiency in its White Paper: Energy for the Future: Renewable Sources of Energy.

In the past decade, renewable energy technologies have made significant progress in terms of performance, cost and reliability, thanks to vigorous research, development, demonstration and market introduction programmes at European, national and also regional level. Developments primarily rooted in environmental concerns are now penetrating all societal decision making and have led to a new, dynamic, and exponentially growing industry.

Three major drivers are determining today’s socio-economic framework for the impressive renewables’ industrial and market developments. First, successful application of legally binding feed-in tariffs; secondly, liberalisation of the electricity market, and thus new possibilities for decentralisation of power generation. Third, and in the medium term, there is the undisputed need for massive re-powering the larger part of Europe’s generation capacity. This will incur generally higher electricity costs, which reflect somewhat better the real costs (incl. externalities) of all the different energy technologies. Thus a more favourable market situation for sustainable technology choices will evolve, e.g. for massive renewable power generation. While technology development has been a key driver in the progress of renewables, first examples of significant penetration would have been impossible without appropriate, supporting policies including instruments such as introduction targets, carbon taxes, elimination of non-technical barriers, internalisation of external costs of energy, and harmonisation of market rules.

The efficient end-use of energy is a parallel area where modern technology, policies, better public conscience of the issues and market forces, like the utilities’ interest to exploit the potentials for avoidance of new transmission and generation capacity, have combined to achieve significant results. New integrated marketing concepts, like energy service companies, have been very successful lately, and organisationally break ground for the implementation of sharper physical efficiency concepts as well. This is of particular strategic importance for the New Member States of the EU, as the use of energy, including electricity, in these countries is still significantly less efficient than in the old Member States.

The aim of this Status Report is to provide relevant, validated and independent information on renewable energy and the efficient end-use of electricity to decision makers and the public.

Ispra, December 2006

Arnulf Jäger-Waldau
European Commission
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Disclaimer

We have collected up to date data and validated them to our best knowledge, but do not claim that they are a 100% complete, due to the wide range of data sources and different data collection methods. If there are discrepancies or information missing, we would appreciate if you could to send this information to us including the data source for further updates of this report.

TABLE OF CONTENT

Chapter 1

INTRODUCTION

Arnulf Jäger-Waldau

The European Union's dependency on energy imports has increased from 40 % of gross consumption in the 1980s to 56 % in 2005 and this trend is accelerating [EST 2006]. The European Commission’s Green Paper "A European Strategy for Sustainable, Competitive and Secure Energy" states: *Unless we can make domestic energy more competitive, in the next 20 to 30 years around 70 % of the Union’s energy requirements, compared to 50% today, will be met by imported products – some from regions threatened by insecurity* [EC 2006].

Record oil prices and speculations whether the oil price would peak at $ 105 in 2010, or whether it would be well above, has become a reality. This development has shifted the focus to a more abundant fossil energy resource, i.e. coal. In addition, the Gas Crisis at the beginning of 2006 has demonstrated that Europe is highly vulnerable with respect to its total energy supply. A possible solution is the diversification of supply countries as well as the diversification of energy sources, including renewable energies and a nuclear option.

However, diversification of supply countries is not an easy task, as reserves are concentrated in just a few countries. The Green Paper quotes [EC 2006]: *Today, roughly half of the EU’s gas consumption comes from only three countries (Russia, Norway, Algeria). On current trends, gas imports would increase to 80 % over the next 25 years.*

The development of sustained economic growth all over the world, and notably in the so-called “BRIC” (Brazil, Russia, India and China) as well as the global need for rural development, will increase the total energy demand even further, potentially provoking evermore greenhouse gas emissions. CO_2 emissions from developing countries will exceed those of the IEA member states by 2010. In addition, World CO_2 emissions will increase by 1.8% per year to reach 38 billion tonnes in 2030. Therefore, ambitious reduction targets need to de addressed **immediately**. As 94% of man-made CO_2 emissions in Europe are attributed to the energy sector [EEA 2004], this presents unique research challenges and industrial opportunities for the global energy community.

Global oil consumption has increased by 20% since 1994, and the International Energy Agency (IEA) assumes that global oil demand will grow by 1.6 % per year. However, the current actual growth rates in oil consumption are much larger. Instead of a 2.2 % increase, as predicted by the IEA, the 2004 world crude demand grew by 3.4%, the strongest pace in nearly 30 years and over three times the average growth rates of the last 25 years. The high oil prices and mild winters helped to reduce the growth rates in 2005 and 2006 to 1.3 and 1.2 % respectively [IEA 2006]. Most of the growth now comes from non OECD countries and China's growth rates were in average 7 to 8% for the period of 2000 to 2006. Yet, per capita oil consumption in China, which is already the world’s second largest importer of crude, is still in its infancy.

Environmental concerns are shared by a majority of the EU public nowadays. This adds to the list of weaknesses of fossil fuels and the safety worries over nuclear power, including its fuel system. These concerns include individual and societal damage already caused and potentially to be expected by our current energy supply system, whether such damage is of accidental origin (oil slicks, pit disasters, nuclear accidents, methane leaks), premeditated actions (terrorist attacks, illegal waste disposal, etc.) or connected to normal emission of pollutants. At the same time, the need to stabilise atmospheric greenhouse gases in the 450 to 550 ppmv range leads to the necessity to decarbonise our energy supply.

The crucial question which arises is: What are the technology options to realise such a shift?

Renewable energies are a possible solution, but their current share of the global and European energy supply is still small and will require a continuation of their current high growth rates over the next two to three decades in order to reach a 40 to 50% share. However, such ambitious targets can only be reached, when at the same time the energy efficiency is increased. In the case of electricity end-use efficiency, every kWh of demand reduction corresponds to approximately 3 kWh of primary energy savings, as the average energy conversion efficiency for solid and liquid fuels to electricity is only 33%.

What are the energy challenges we are facing?

- **Sustainability**:
  De-coupling of economic growth from depletion of resources and global warming.
- **Security of Supply**:
  Ensuring long term availability of energy sources.
- **Safety of the Energy Chain**:
  Accidents, political stability, import dependence, public security
- **Growing Demand in Developing Countries**:
  2000 million people have not even basic electricity service.
  An electricity distribution grid outside of large cities will never be economically viable.

This leads to the question what are the possible options to face these challenges. The answer leaves us with very few options to decrease the energy intensity and, as this is not enough, to increase the Union's indigenous energy supply.

- **Decrease Energy Intensity[1] (Mtoe/GNP)**
  - i) Increase Efficiency of Energy End-use (Domestic, Industry, Transport)
  - ii) Increase Efficiency of Electricity Generation
- **Increase [indigenous] Supply**
  - i) New and Renewable Energies
  - ii) Examine Nuclear Option

The decrease of energy intensity by increasing energy end-use efficiency are important and cost effective ways to reduce GHG emissions, but energy efficiency alone cannot solve the problem, as our energy consumption structure – including heating, cooling, transport and electricity use – is a consequence of our lifestyle. Furthermore, the public in the industrialised countries is split over the issue of nuclear energy use. Therefore, the future of nuclear energy is uncertain, particularly in Europe. It depends on several factors, including a solution to the problems of

[1] Energy Intensity is defined as energy units consumed per unit of gross national product produced

managing and stocking nuclear waste, the economic viability of the new generation of power stations, the safety of reactors in Eastern Europe, in particular the New Member States, and the global fight against nuclear proliferation.

Renewable Energies are not facing these safety and security concerns and the European Union has abundant resources. Electricity from large and small-scale hydro, wind power and biomass are already a market reality, but is has to be noted that the future growth rates for hydro are rather limited, as the majority of resources are already tapped. Geothermal electricity is limited by its characteristics of local resources and reservoirs and within the European Union only Italy is utilising this at a larger scale at present. Photovoltaics is already the most cost effective solution for a large number of off-grid applications. The high growth rates of more than 40% for Photovoltaics in on-grid applications over the last few years already led to substantial cost reductions and this trend is expected to continue. Solar thermal electricity is in the phase to demonstrate its potential on an operational scale of 100 MW and more. Tidal as well as wave power need further research and development before they can be commercialised and add their contributions to a renewable electricity production.

However, regardless of the type of renewable energy source there are obstacles of a structural nature to their implementation. The current economic and social system is based on centralised conventional sources of energy (coal, oil, natural gas and nuclear energy) and their distribution system. Due to the fact that the New Member States still have a higher final energy intensity (average ~ 670 toe/1000 €) compared to EU-15 (average ~188 toe/1000 €) [EST 2006a] there is a need to modernise the power mix and generally the electricity generation and distribution system. This can now be taken as a chance to integrate decentralised and renewable electricity generation capacities.

However, the latter is also true for the whole European Union. According to the International Energy Agency's World Energy Investment Outlook 2003, the OECD countries will have to spend approx. US$ 4,000 b or US$ 133.3 b per year by 2030, in order to maintain and expand their electricity grid and power production capacities [IEA 2003]. The EU25, with 18.2% of the total world-wide electricity consumption (and a 29.9% share within the OECD), will have an investment need of almost US$ 39.8 b per year. About half of the costs are for new and refurbished power generation capacities and the other half is for transmission and distribution costs. Distributed generation like renewable energies can help to reduce investment in transmission costs. Due to the long life time of power plants (30 to 50 years), the decisions taken now will influence the socio-economic and ecological key factors of our energy system in 2020 and beyond. In addition, the IEA study points out that fuel costs – even under the moderate 2003 price assumptions – will be in the same order of magnitude as investment in infrastructure, increasing the scale of the challenge, especially for developing countries.

The second main barrier is of financial nature. Renewable Energies need significant initial investment, as was the case for the other energy sources, such as coal, oil and nuclear energy. It should not be forgotten that most of these investments were either made by public companies or secured by public credit guarantees. The European Environment Agency reported that the total energy subsidies in the European Union (EU15) were more than € 29 billion in 2001 [EEA 2004a]. About 18% or € 5.3b were given to renewable energies, whereas the rest went to coal, oil, gas and nuclear. These figures are without external costs and for nuclear exclude the cost of not having to pay for full-liability insurance cover. In addition, the fact that some of Europe's nuclear companies are still state-owned or controlled, and arising liabilities have eventually to be covered or are currently being covered by the taxpayers, are not taken into account as well.

Therefore, the renewable energy market in the European Union cannot be expected to develop regularly without a support policy in the medium term on the part of the public authorities. Support measures stretch from direct subsidies in favour of renewable energy sources or the obligation on the part of electricity producers and utilities to purchase a minimum percentage of electricity produced from renewable sources of energy through to aid to research or financing mechanisms (interest subsidies, guarantee funds, excises or parafiscal tax on other sources of energy).

The implementation of renewable energies into our energy supply and the substantial investments needed to do so, call for an integrated approach to utilise the different technologies and resources available as well as energy savings to minimise demand. No energy source alone can supply the future needs of mankind and even our conventional energy sources face the problem of fluctuating generation capacities. However, we have to bear in mind, that not any alternative energy system will be available when we need it in the coming decades, unless we start to change things now.

Chapter 2

ECONOMIC ASPECTS OF ELECTRICITY FROM RENEWABLE SOURCES

Sandor Szabo

This chapter aims to give a systematic description of the status of renewable energy sources (RES) and technologies within the electricity system from an economic point of view. It strives for an exploratory assessment of the RES electricity and contains the most recent information and some cost projections on developments in the near future (up to 2010).

At the beginning, the mainstream economic approaches on the determination of the production level will be introduced. One major conclusion of this economic theory part reveals that the size of the incumbent operators and the market concentration are at least as important from the reserve requirement point of view as the variability of certain technologies on the reserve requirement. Therefore, the additional reserve requirement most often requested for variable sources, i.e. renewable energies, is strongly debatable. The introduction of the relevant economic approaches is followed by an economic-strategic assessment of the advantages and disadvantages of three renewable energy technologies: Photovoltaics (PV), wind generation and biomass based electricity technologies. Finally the market trends are evaluated by the changes of their position in the electricity generation portfolio in the last decade, measured in the two dimensions of market shares and market growth. This latter analysis makes it possible to evaluate whether the current trends verify the statement of the strategic assessment.

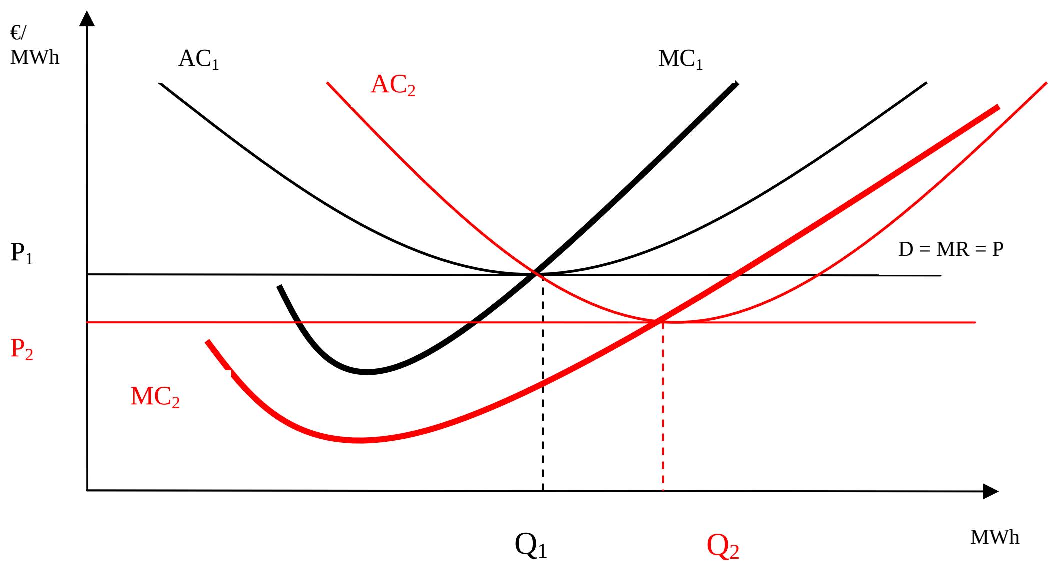
2.1 Microeconomic Approach

The determination of the production level in the microeconomic theory relies on the marginal costs (MC) of the different producers. In a competitive market, where the firms are price takers (the firm cannot change the market price by changing its output, because its share is negligible in the overall supply) the optimal level of output is determined where the firm's marginal cost **becomes equal with the marginal revenue** (the unit price). This is at the output level Q_1. This guarantees allocative efficiency on the market since at this point the firm operates at its lowest average cost level. There are numerous companies on the market and their equilibrium output is determined by their marginal cost function. If companies can lower their marginal cost (because of technological development etc.) the market changes to a new equilibrium: at a lower price level bigger quantities are sold on the market. (see P_2-Q_2 in Fig. 2.1).

In the electricity power markets the equilibrium presented in Fig. 2.1 is not always attainable due to three main reasons:

- Since the storage of electricity is expensive, the supply has to meet continuously the instantaneously changing demand. Therefore, the equilibrium output is always changing relative to the demand and to the output level of other producers, which in turn changes the firm's optimal output level.

- To achieve the above mentioned production level, the market has to be freely accessible (or at least at low transaction cost, i.e. no barriers to enter and depart). Contrary to this condition, the power generation has been characterised by **sunk costs**. Sunk costs mean that once the investment was made in power production facilities it is impossible or entails huge costs to transform the investment to other uses. Though this has been diminished by the emerging technologies that can be utilised efficiently at a small scale.
- The power generation and distribution has always been characterised by certain levels of monopolies. The generation side is now in a transformation phase to a more competitive market, but the transmission part is still considered a **natural monopoly**. Natural monopolies are cases where due to physical reasons it is cheaper to have only one operator or infrastructure than competing ones; e.g. bridges, tunnels and until most recently grid systems. However, the development in the telecommunication sector shows that line infrastructures which were formerly considered a natural monopoly can be operated with competition.

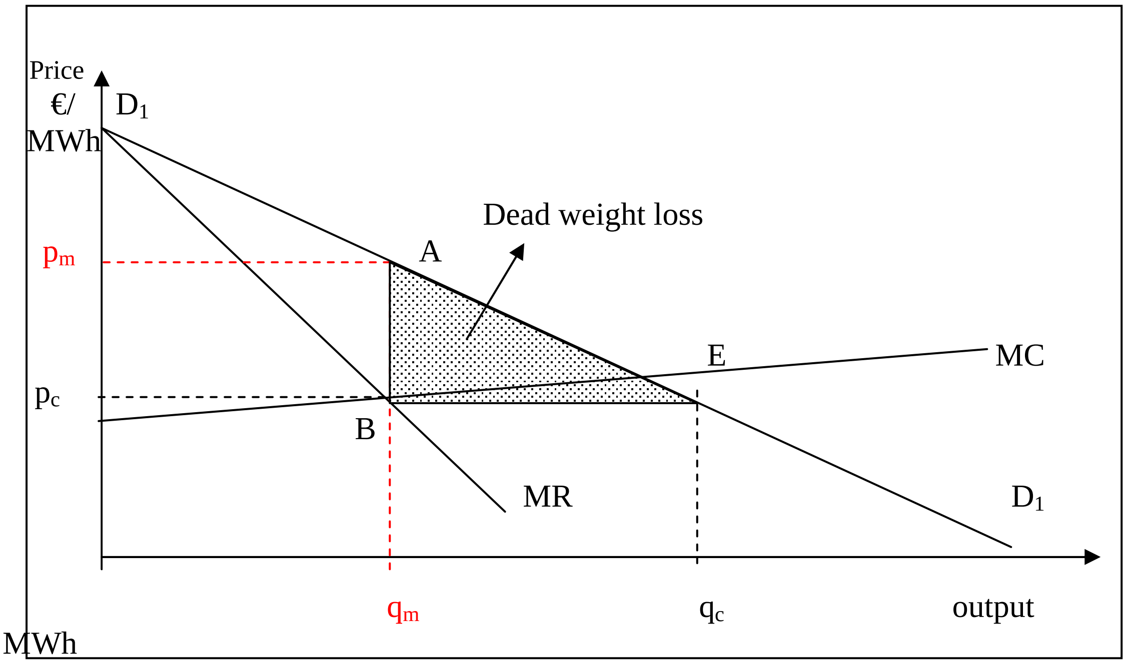


AC ***average cost***: *all the costs to the firm divided by the quantity of products.*
MC ***marginal cost***: *all the costs that can be attached to the increase of one additional unit of production.*
MR ***marginal revenue***: *the revenue from one additional unit of product sold.*
D ***Demand function***: *the competitive market buy huge quantities at the given price level compared to the output of one firm, therefore it is vertical and equals with the unit price.*

Fig. 2.1: Determination of the optimal power-output level in a competitive market

The optimal production level for a **monopolistic market** is determined in a very different way. When a company has an impact not only on the output, but on the price level by changing the production level, the company will – following profit maximising criteria – **produce less** at **a higher price** (compare q_m to q_c and p_m and p_c where "m" stands for monopoly indicated by the red colour, and "c" for competitive market in Fig. 2.2).

This behaviour means a departure from the allocative efficiency described in the previous paragraph. It entails not only the transformation of the consumer surplus to the firm profit (the amount represented by the square CBA p_m in Fig. 2.2, but a loss to the whole society: the amount of welfare represented by the BEA triangle is lost because the firm does not produce the output q_c-q_m which would be produced and purchased by the consumers in the competitive market at a lower price (this is referred to in the economic literature as "dead weight loss").



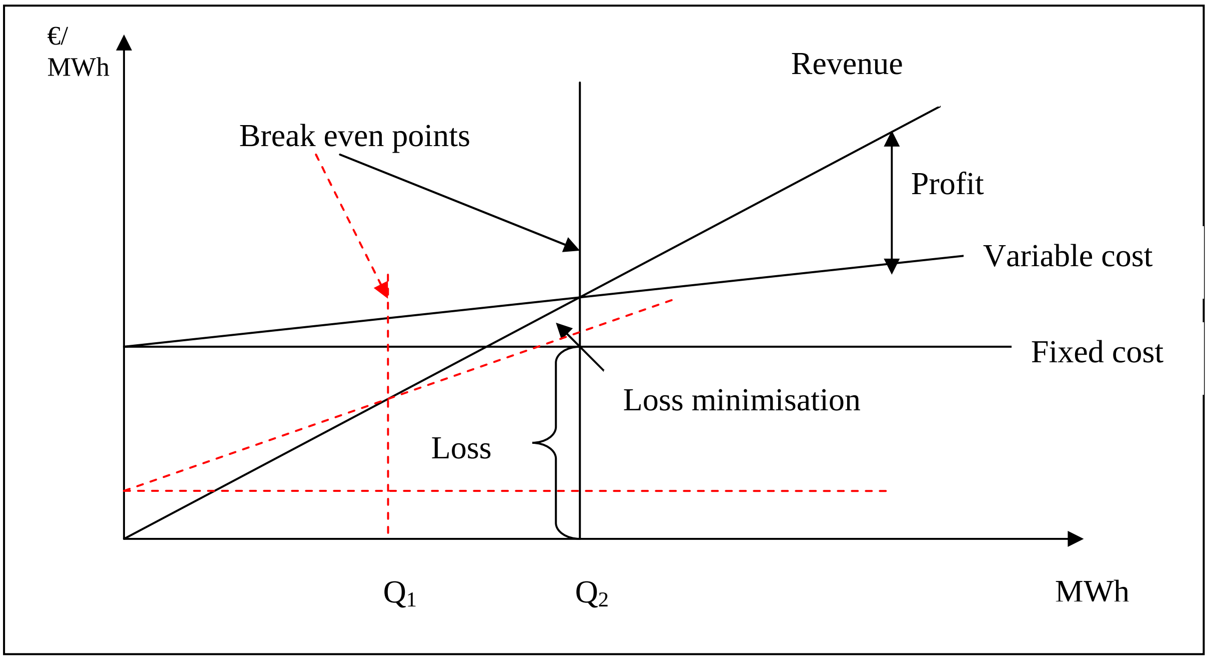
q_m *Product quantity produced by the monopoly at equilibrium*
q_c *Product quantity produced on the competitive market at equilibrium*
p_m *Equilibrium price set by the monopoly*
p_c *Equilibrium price on the competitive market*

Fig. 2.2: Comparison of the optimal power-output levels in the competitive and monopolistic markets

2.2 Determination of the Merit Order

Because of the difficulties to determine the marginal costs of the different companies present in the electricity markets, the optimal production level is established on the basis of variable and fixed costs. Despite the fact that this simplification entails some loss in the accuracy, it is a useful tool to determine the merit order of the different power generation technologies. The break even point is the output level where the production becomes profitable. This break even point is usually much greater for technologies characterised with high fixed cost (high up front cost) and with smaller variable costs (see Q_2 in Fig. 2.3) than for technologies with small investment costs but higher variable costs $Q_{1.}$

Electricity generation from wind, solar and nuclear power are usually classified as power generation technologies characterised by high fixed and low variable cost, while the different gas-fuelled generation technologies are classified as low fixed costs but high operational cost types. However, the dynamics of the cost structure shows a departure from this conventional classification. Two simultaneous changes are present in the power generation asset and production markets. First, technological development leads to a gradual but continuous decrease of the still relatively high investment costs for emerging technologies. Second, the discrepancy between the level of variable costs increases further between the technologies. This latter is caused by the more stringent environmental regulation, resource access problems and structural scarcities.



Explanations:
Break even point*: The output level above which the given technology starts to produce a profit*
Fixed costs*: The costs that are independent from the production level (they have to be paid even without production)*
Variable costs*: The cost that changes with the production level proportionally*
Revenue*: Unit of production sold multiplied by the unit price*
Loss minimisation*: When the investment is made, and the product cannot be sold above the total cost, it is still worth producing if its price exceeds the variable cost, because the part of the investment can be recovered.*

Fig. 2.3: Determination of the break-even point

The following two figures illustrate this development. Despite the fact that the cost/MWh calculations include a number of assumptions, i.e. average utilisation hours, international trade, distribution of reserve capacity costs, long-term contracts etc., the European average figures give a good estimate on the merit order. The 2010 solar and wind investment cost figures are based on business releases [Dga 2006, Ewe 2006], the base load and peak load prices are from exchange market on line information [Eex 2006, Mer 2006].

Figures 2.4 and 2.5 give a good insight into the cost structure of the different technologies relative to each other, and the changes in the merit order. However, in order to get a supply function the available electricity generation capacities for these technologies have to be included in the analysis.

Figure 2.6 in the following sub-chapter uses the supply function when all the existing power capacities are available, as well as the three transformed supply functions for the case when some of the capacities are lost. Using these supply functions, the price fluctuations observed on the electricity spot markets (most recently in July 2006) will be partially explained.

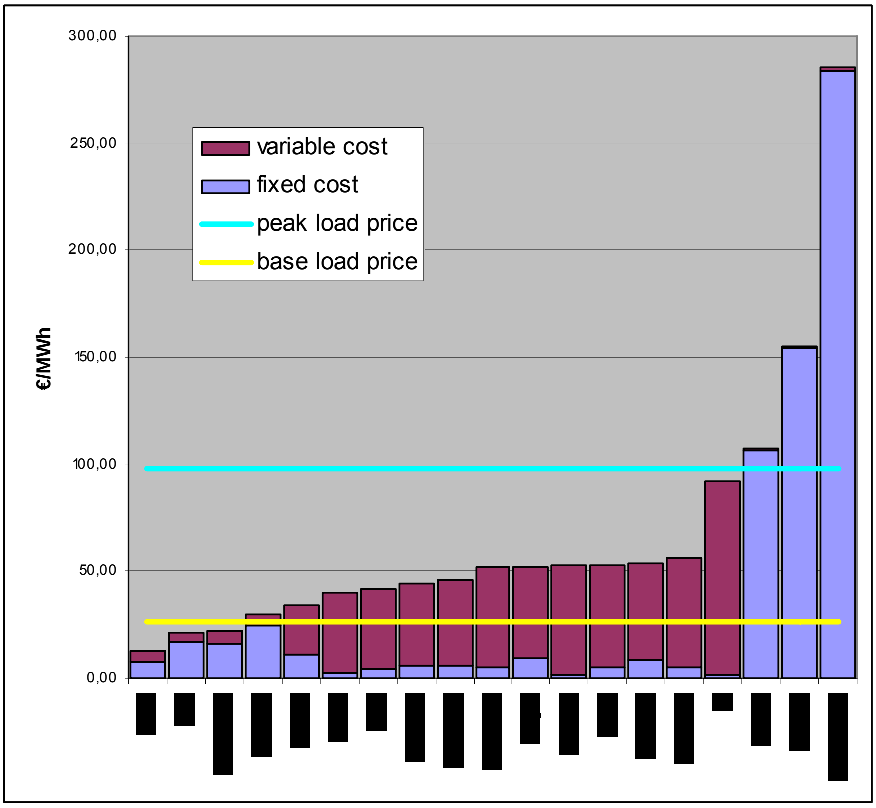


Fig. 2.4: Merit order of the different power plant types in 2005

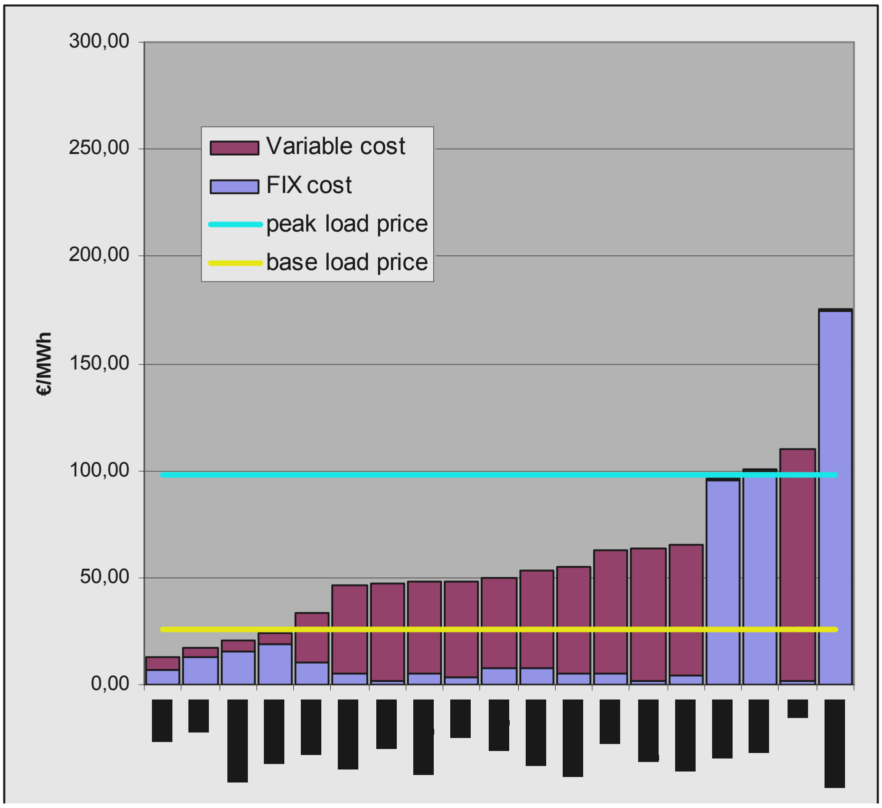


Fig. 2.5: Merit order of the different power plant types in 2010

2.3 Merit Order, Availability and Price Fluctuation on the Electricity Market

One of the most often cited explanations why the share of the renewable energy sources should be kept to a limited share in the electricity generation portfolio is that they undermine system reliability causeing huge price fluctuation because of limited availability. That is where the stricter reserve requirement for RES comes in: in order to keep the system reliability at a predefined level, additional RES (mostly wind and solar) capacities have to cover the additional reserves when their production is down. The further expanded theory gives some insight of how these reserve requirements work in practice.

The following figure explains the effect of capacity shortage on price fluctuations observed mainly at peak hours (see the latest data of July 2006 German and Italian day-ahead market price [Eex 2006, Mer 2006]). However, the price development also shows that the price fluctuations are already present on existing electricity markets, i.e. those without high RES portfolios. Certain weather conditions, like heat waves or long lasting droughts, can lead to effects like water reservoir shortages and non availability of hydro-peak power or cooling water shortage for thermo-power plants. These effects already cause capacity shortages that can only be covered from more expensive sources (see the rising arrows on the diagram).

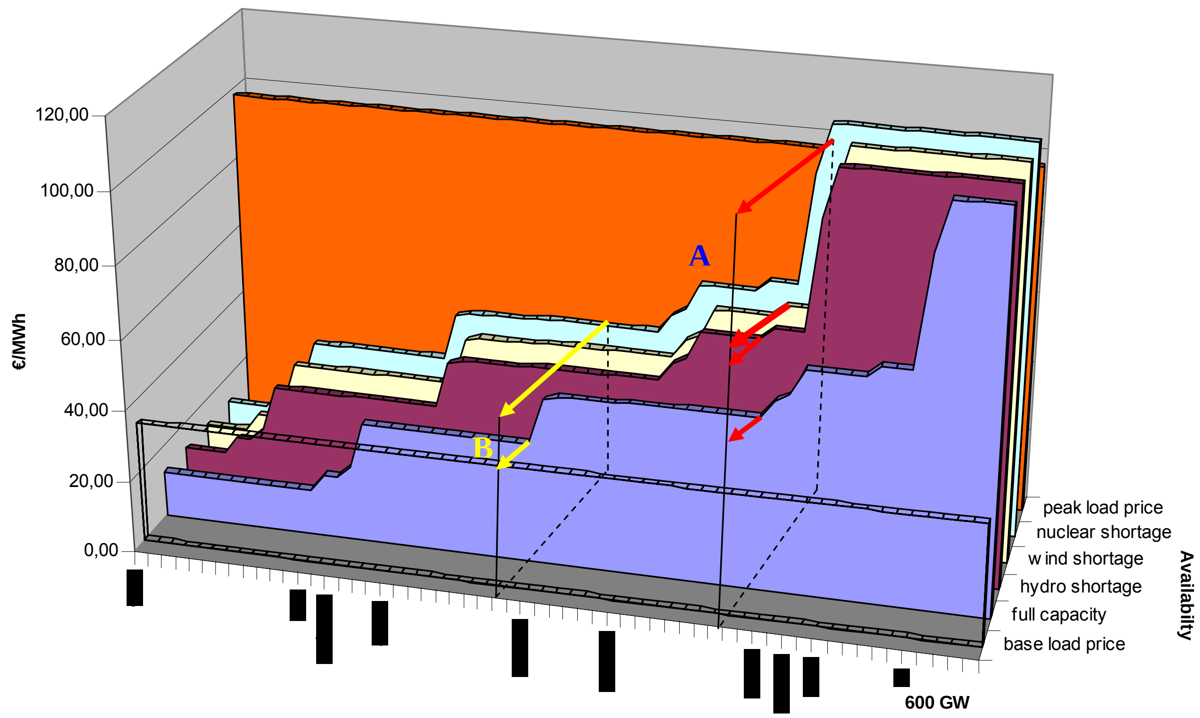


Fig. 2.6: Shortages and price fluctuation

For base load electricity the price fluctuations are low because there is still a large amount of capacities available to substitute the absent capacities (see point B in the diagram). However, in peak hours the magnitude of price volatility can be much more pronounced (see point A).

The missing capacities of cheaper options lead to the use of the more expensive entries in the merit order. As an example we assume a water shortage, which causes a

60 % shortfall of the available hydro capacities as well as a 10 % decrease in nuclear energy (due to cooling water shortage) and an additional absence of wind energy can cause huge cost increases (see in Fig. 2.5 the difference between the highest and lowest red arrows, i..e. approx. 50 €/MWh). These assumptions are not theoretical, but very close to the actual situation in the summer of 2006. However, the wind power shortage causes the smallest price-effects out of these shortages. In fact the size of the incumbent operators is at least as important from the reserve requirement point of view as the variability of certain technologies. Therefore, the additional reserve requirement most often requested for variable sources is strongly debatable. The magnitude of the price fluctuation cannot be explained by the more extensive use of the expensive power generation sources in the case of capacity shortfalls.

However, the dominant part of the price increase can be explained by the opportunistic behaviour of dominant players on the market. When some of the electricity producers are out of the market because of operational or resource problems the power shortages give the remaining generators the possibility to increase the price in the bidding process because of the lack of competitors to keep the price down by their cheaper offers.

Therefore, more market participants, smaller market shares of the incumbent operators, stricter bidding rules play at least such an important part in the system reliability as the limited share of capacities with variable output. Output forecast, and changing system operation techniques also play important roles. These factors will be taken into account in the strategic analysis.

After the description of the possible treatment of the renewable sources within the overall electricity production by the instrument of the mainstream economic theories, it is important to look at a strategic analysis on the renewable energy sources and their technologies.

2.4 The Strategic Assessment: SWOT Analysis

There are many available approaches for a strategic economic assessment of electricity from renewable sources. It can take the form of financial or cost benefit analysis, impact pathway analysis (dose-response), analysis of external costs, analysis of strategic behaviour, etc. All these more sophisticated methods extend the scope of the mainstream economic analyses further. Besides the institutional and behavioural aspects, certain levels of environmental-social functions are integrated into the efficiency criteria (cost minimisation, resource optimisation). There are advantages and disadvantages for all types of approaches considered. The selection of one of these methods is giving emphasis to certain aspects of the product while neglecting others. The product oriented approach is justified on the following basis. While the services provided by the electricity are uniform – that is why for a long time the source of electricity was indifferent from an economic point of view, until the externality theory appeared – the effects of the different fuel sources are very different.

The strength of a **SWOT analysis** (the name is the abbreviation of the keywords: **Strength, Weaknesses, Opportunities and Threats**) comes from its wide-ranging strategic scope. Such an anlysis tries to classify all aspects associated with the product market into four categories. The factors that uniformly favour or disfavour all technologies are omitted (i.e. green certificate systems, carbon value). It leaves policymakers and other stakeholders to weigh according to their experience.

It becomes visible that for the three renewable energy sources discussed, the advantages outnumber their disadvantages. The following market trend analysis shows whether these technologies could exploit these advantages in the trends of the market shares and of the growth.

Electricity from Windpower

	Advantage	Disadvantage
Internal factors	**Strength** • Zero fuel cost/no fuel price risk. • Low maintenance cost • Near zero CO_2 emission • Relatively small operational capacities compared to the combustion based technologies • The smaller up front cost attracts different investor groups • Dispersed supply points – can be beneficial to certain networks • Employment rates for wind energy 2.86 – 1.3 jobs/MW (with gradual annual reduction) [Hea 2003].	**Weaknesses** • High up-front cost compared to the fossil fuel technology • Reserve requirements • Variable output • Restricted utilisation hours: the fixed cost is distributed on a smaller base • The most adequate sites usually require new connections and lines to the grid • Former types of generators (with less intelligent gearing system) reduce the system reliability/adequacy • Social acceptance has to be improved (on amenity and nature protection)
External factors	**Opportunities** • Possible contribution to system adequacy (grid supporting services like frequency and voltage control) • Active power limitation, ramp rate limitation, frequency control reserve • New system operation techniques • More reliable wind forecast • Improvement in storage technologies (air compression etc.) • The correlation of operation hours is small with insolation: therefore their combined use may decrease the output variability (further research is needed)	**Threats** • Local difficulties in areas with relatively high population • Grid connection requirements • Demand side management and storage • Grid infrastructure • System integration costs • Additional system reserve requirements • Congestion management

Photovoltaic Solar Electricity

	Advantages	Disadvantages
Internal factors	**Strengths** • Zero fuel cost/no price risk • Low maintenance cost • Near zero CO_2 emission • Small operational capacities compared to the combustion based technologies. The smaller up front cost attracts household investment • Enormous space available for sites • Dispersed supply points – can be beneficial to certain networks • At most places output correlates with the peak operation hours caused air conditioning • The most adequate sites are usually closest to the consumer • The operation does not require staff, only the maintenance • Employment rates for solar PV are 7.26- 3.15 jobs/MW (with gradual annual reduction) [Hea 2003] • The technology offer companies a new way to communicate with consumers • Diversification, Multiple services (Building integration, Design etc.) increase attractiveness to households, designers • After sales service (i.e. offers in mounting system) improves the image on complexity	**Weaknesses** • High up-front cost compared to the fossil fuel technology • Variable output • Operation • Restricted utilisation hours: the fixed cost is distributed on a smaller base
External factors	**Opportunities** • Possible contribution to system adequacy (grid supporting services like frequency and voltage control) • New system operation techniques • Net metering • The correlation of operation hours is low with wind: therefore their combined use may decrease the output variability (further research is needed) • Improvement in storage technologies (batteries etc.)	**Threats** • Additional grid connection requirements • Grid infrastructure • Additional system reserve requirements

Electricity from Biomass

	Advantages	Disadvantages
Internal factors	**Strengths** • Zero CO_2 balance, contribution to greenhouse gas reduction • Stable, predictable output • Contributes to security of supply as a versatile and constant renewable energy source [Kau 2005] • Cheap transformation of old, retired coal or lignite fuelled power plants that were phased out because were not able to meet the more stringent environmental standards • Creates employment in rural disadvantaged places[Kau 2005] • Employment rates for biomass electricity are 6 – 2.11 jobs/MW (with gradual annual reduction) [Hea 2003] • Can decrease landfill waste • May contribute to increased biodiversity • Biomass can be readily stored and transformed into electricity and heat [Kau 2005] • The technology offer previous coal based power plants a new way to communicate their green image to the consumers • It offers them a source for fuel diversification	**Weaknesses** • Probably cause input price increase on these other markets • Certain energy crops are considered invasive and criticised by nature protection • May cause deterioration in the sustainable forest management in the vicinity of the plant • Monitoring required that the wood originates from sustainable sources (energy plantation not natural forest) • Potential harmful emissions from burning organic materials
External factors	**Opportunities** • Contribution to system adequacy from a RES source • Additional incentive for the forestation and rural development programmes • More efficient if the electricity production is combined with heat recovery	**Threats** • Huge competitive rivalry for the fuel: biofuel production, animal feed, other agricultural use, paper industry, wood industry • Tax incentives for other use may limit the profitability for electricity use

2.5 Market trends

The trend shown in the changes of the merit order is also reflected in the market developments. The examination of the changing positions of the different power technologies in the dimensions of their market share and their market growth makes it possible to build up a strategic assessment of the electricity market.

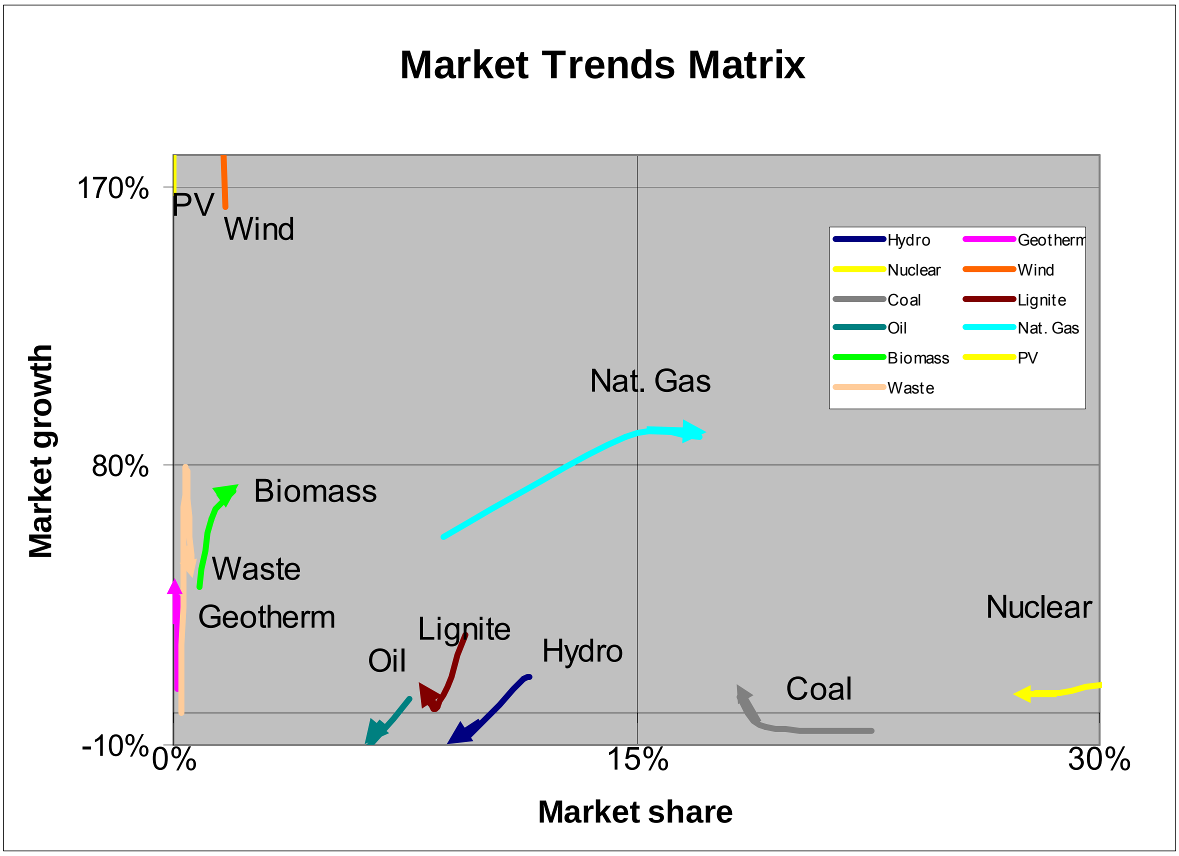


Fig. 2.7: Market Trend in Electricity Generation

Fig. 2.7 shows the changes of the relative position of different fuels between 1995-2004 in the electricity generation mix in the dimensions of market shares and market growth. On this basis the so called "**Boston Matrix**"can be composed (Fig. 2.8).

The Boston Matrix analyses the opportunities of a product based on market growth and market shares of all competing products in the given market. The names of the four sections of the matrix are self-explanatory, however, some further description may be useful.

In the **"Cash Cow"** quadrant power production technologies can be found that have a well established market share, however they cannot increase it significantly. The ruling strategy of these players is to realise the profit margins without huge investment and without further huge R&D spending. However some fundamental modification can change the position of these technologies and then they can progress to the "Star" position.

Technologies in the **"Star"** quadrant attract new investors: besides the established market share investments are attracted by the promising growth rates.

For those technologies in the **"Dog"** quadrant it is the opposite. For them it is hardly possible to find new financing for these products/production lines, and existing owners as well try to minimise losses and risk by selling their assets.

The **"Question Marks"** quadrant is the most ambiguous of all the four. A strict selection process decides which pathways these technologies follow: a strong market penetration or disappearance (represented by the two arrows in the diagram). The "first mover" who gets a hint first which of these products/technologies break-through to higher market penetration can acquire large market shares cheaply. That is why the venture capital funds invest in these products/technologies first: while the portfolio is riskier it offers higher than average returns.

Boston matrix		**Market share** Low	**Market share** High
Market Growth	High	**"Question Marks"** Photovoltaics Wind Generators New coal (gasified, fluidised bed) Biomass Geothermal	**"Stars"** Plants fuelled by natural gas: Combined Cycle Gas Turbines, Combined Heat & Power, Gas motors
	Low	**"Dogs"** Plants fuelled by oil	**"Cash Cows"** Nuclear Power Plants, Conventional Coal Plants, Lignite Power Plants

Fig. 2.8: Boston-Matrix of the different power technologies

The Boston matrix suggests that among the RES electricity sources wind generation is on the very edge of substantial market penetration, the PV demonstrates unprecedented growths while the other technologies are still in the embryonic phase.

2.6 Conclusions

The determination of the optimal RES portfolio within the overall electricity generation system is a very complex task. The shape of the load curve, the cost structure of the generation units, their adjustability and their economies of scale as well as the market concentration play an important role in it. It is also a dynamic system and the system operation also has a major influence on these input factors themselves (i.e. more investment in certain production unit may decrease its capital costs, which in turn justifies higher share in the portfolio). The introduction on economic approaches highlighted the most relevant aspects of the determination of the production level for the different portfolio elements.

One major conclusions of this economic theory part is the RES sources could already have much higher share in the production portfolio if in the present market concentration the incumbent generators would not be able to exercise their market power to block new entries in the market. It also points out that the size of the incumbent operators and the market concentration are at least as important from the reserve requirement point of view as the variability of certain technologies on the reserve requirement. Therefore, the additional reserve requirements which are most often requested for variable sources is strongly debatable.

More market participants, smaller market shares of the incumbent operators, stricter bidding rules play at least as important part in the system reliability as the limited share of capacities with variable output.

The aim of the SWOT analysis was on one hand to identify those strategic segments of the market where the renewable sources can further enhance their advantages to increase their market share by achieve synergies, and on the other hand to find the vulnerable components that have to be supplemented by designing new policies, instruments or requires additional lobbying.

The market strategy has to focus on five advantageous fields:

- In the policies more emphasis should be put on the low or zero volatility of fuel prices which enhances the security;
- Diversification on two levels;
    - increasing the range of fuel sources used;
    - potential of decreasing transmission losses by diminishing the distance between the production and the consumption of energy;
- By the diverse ownership RES decrease the adverse effects of monopolies;
- The positive public acceptance because of their green attributes: low or zero emission (in case of wind some additional campaign may required);
- The huge potential of capital cost reduction which was sustained in the last decade.

The variability of output level (often referred as "intermittency") requires some assistance that can alleviate the acceptance from system operators. More publicity and training should be provided in new system management techniques. This has to be combined with the following strategy:

- All discriminations have to be prevented between the reserves needed because of the changing output level and the reserves required for the possible failures of large units.
- Emphasis on the improvements achieved in balance of system services by RES sources;
- Make the progress in predictability known by the all stakeholders: the increase in the reliability of forecast helps to include the RES in the system operation;
- Prevent the image that the increase in RES electricity sources are the main cause of system failures by pointing out the real causes, which are the low maintenance and the bottleneck prolonged in grids and interconnections.

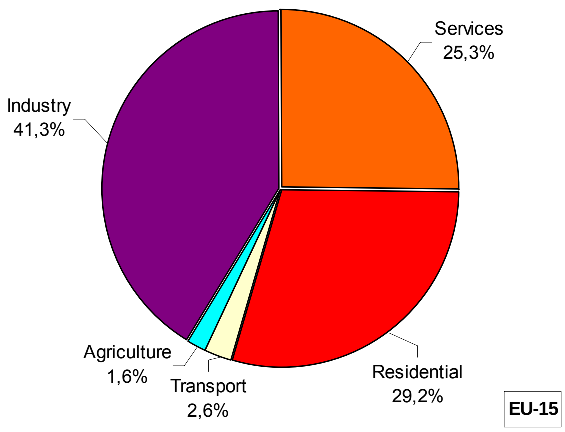
Chapter 3

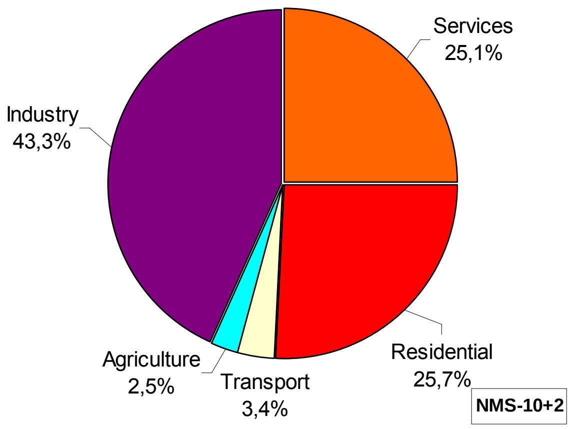
ELECTRICITY CONSUMPTION AND EFFICIENCY IN THE RESIDENTIAL, TERTIARY AND INDUSTRIAL SECTORS

Bogdan Atanasiu and Paolo Bertoldi

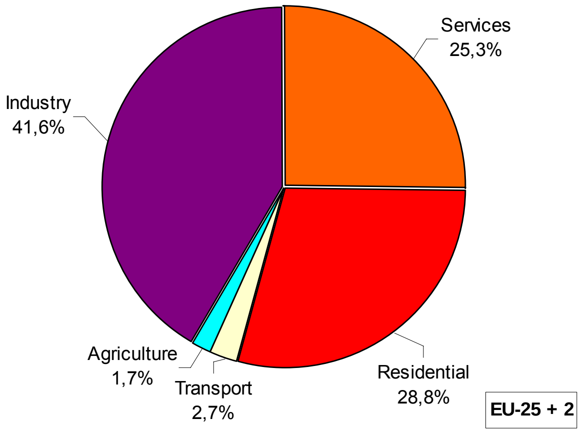
3.1 Electricity end-use in the residential sector

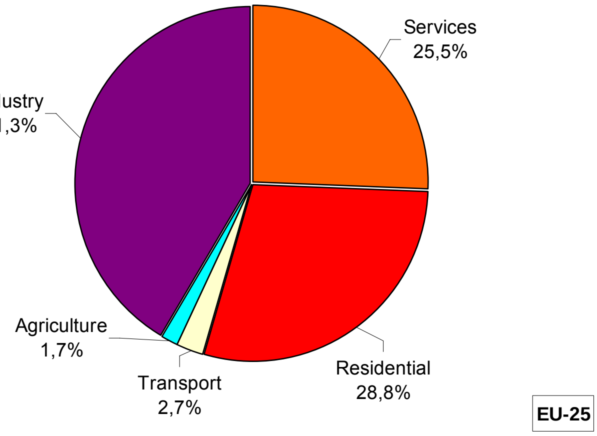
Gas and electricity consumption in the EU-25 Member States, Candidate and Accession Countries continued to grow in the last years despite the introduction of several energy efficiency policy measures and programmes at EU and national level.





a) Electricity consumption: EU-15 b) Electricity consumption: NMS-10+2





c) Electricity consumption: EU-25+2 d) Electricity consumption: EU-25

Fig. 3.1: a), b), c), d): Breakdown of electricity consumption between economic sectors in 2004 (source Eurostat and JRC survey)

The gas consumption of the residential sector has continued to grow in the period 1999 to 2004 in the EU-25 from 4,721 PJ to 5,399 PJ, a total increase of 14%, while the yearly growth rate from 2003 to 2004 has been 2.2%. In the same period, the total EU-25 electricity consumption in the residential sector grew by 10.8%, from 690 TWh to 765 TWh with a growth rate of 1.8% from 2003 to 2004. It can be observed that electricity use grows at almost the same rate as the economy (GDP). Increasing electricity demand is due to many different factors, including:

- More penetration of traditional appliances (e.g. dishwashers, tumble driers, air-conditioners, personal computers, which are all still far away from saturation levels); introduction of new appliances and devices, mainly consumer electronics and information and communication technology (ICT) equipment (Set Top boxes, DVD players, broadband equipment, cordless telephones, etc.), many with standby losses.
- Increased use of "traditional" equipment, i.e. more hours of watching TV, more hours of use of personal computer (driven by some tele-working, and increased used of internet), more washing and use of hot water.
- Increased number of the same appliances in one household, mainly TVs, refrigerators and freezers.
- More single family houses, each with some basic appliances, as well as larger houses and apartments (more lighting, more heating and cooling). Last but not

least, a higher share of older population demanding higher indoor temperatures and all-day heating in winter and cooling in summer, as well as spending more time at home.

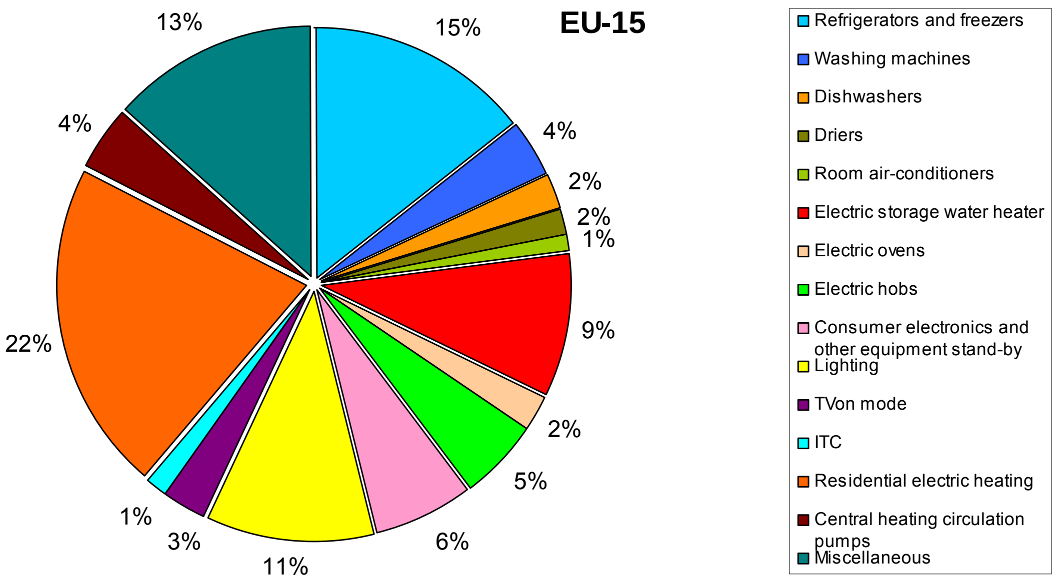


Fig. 3.2: Breakdown of electricity consumption among residential end-use equipment for EU-15 in 2004 (source JRC and [IEA 2003], [Wai 2004, Wai2004a])

Some types of electrical equipment (e.g. electric storage water heater, room air-conditioners, electric direct resistance heating, electric hobs) are present only in a limited number of dwellings. Space heating, although present only in a limited number of households and in particular in some countries, still represents the largest single electricity end-use equipment in the residential sector (about 20% of the total electricity consumption in the residential sector), followed by refrigerators and freezers, lighting and water heating. Direct resistance heating, electric and storage water heating are however decreasing their market share due to strong competition from gas.

Table 1.1: Breakdown of residential electricity consumption in EU-15 [TWh] (source JRC and [IEA 2003], [Wai 2004], [Wai2004a])

	TWh
Refrigerators and freezers	102
Washing machines	26
Dishwashers	14
Driers	13
Room air-conditioners	7
Electric storage water heater	65
Electric ovens	15
Electric hobs	37
Consumer electronics and other equipment stand-by	45
Lighting	76

TV-on mode	20
Office equipment	10
Residential electric heating	150
Central heating circulation pumps	30
Miscellaneous	94
Total	**704**

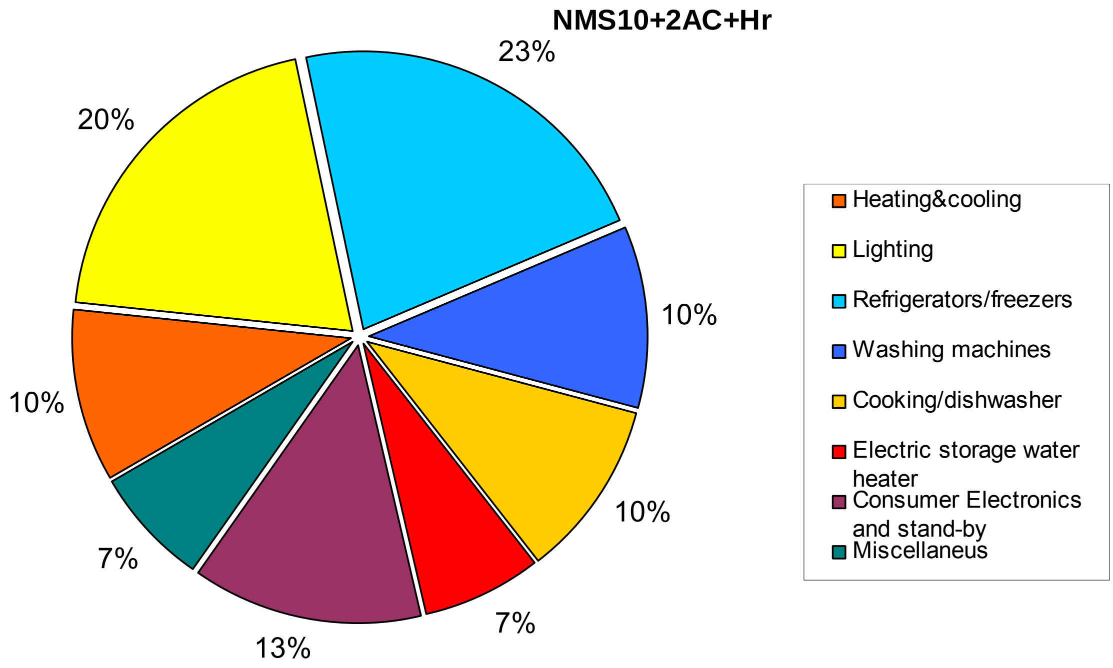


Fig. 3.3: Breakdown of electricity consumption among residential end-use equipment in NMS 10 + 2 AC + Hr for 2004 (source JRC and [Ata2004])

Table 1.2: Breakdown of residential electricity consumption in NMS 10 + 2 AC + Hr [TWh]
(source JRC and [Ata 2004])

	TWh
Heating & Cooling	8.61
Lighting	17.32
Refrigerators/freezers	19.09
Washing machines	9.08
Cooking/dishwasher	8.90
Electric storage water heaters	6.06
Consumer electronics and stand-by	11.36
Miscellaneous	6.11
Total	**86.53**

Table 1.3 EU Residential Sector Electricity Consumption (source: Eurostat, JRC)

	Residential [TWh]			
	Eurostat data			JRC survey
	2003	2004	Growth rate from 2004 to 2003 [%]	2004
EU-25	754.67	767.85	1.75	746.44
EU-15	692.17	704.57	1.79	683.22
NMS-10	62.50	63.29	1.26	63.22
NMS-10+2	80.05	80.10	0.06	80.33
EU-25 + 2	772.22	784.67	1.61	763.55

Electricity consumption per appliance in households in "real" situation has not yet been very well documented. Some average measurements of household electricity consumption in Italy and Denmark (without the space and water heating uses) are 3,358 kWh/year for Denmark and 3,157 kWh/year for Italy [Pag2003]. In France, average electricity consumption excluding water and space heating, is about 2,500 kWh/year. Moreover, in France the observed mean electricity consumption, of electric water heaters amounts to 2,364 kWh/year [Sid 2006]. The average consumption in the EU-15 (total electricity consumption of the residential sector divided the number of households) is 4,343 kWh/year.

3.2 Air-conditioning appliances

One of the main drivers in electricity consumption, and more important to electricity peak demand in the 'southern' countries (IT, ES, PT, EL and Southern FR), is a fast penetration of small residential air-conditioners (all products with less then 12 kW electrical power) and their extensive use during the summer months.

At European level the penetration of small air-conditioners is still small (about 4% of residential space). However, in 2005 the penetration of small air-conditioners in some countries, such as Italy and Spain, reached penetration levels similar to the US with 20%. In 2005, the total 'residential air-conditioners' electricity consumption in EU-25 was estimated to be between 7 – 10 TWh.

For room air-conditioners (up to 12 kW output power), the Labelling Directive has been adopted by the European Commission and was published in March 2002 [EU 2002]. Although the full mandatory application of this Directive was fixed for 30 June 2003, the relevant test standard needed to serve as the reference document was missing. The new revised standard EN 14511, covering all products in the scope of the Directive, was not finalised before May 2004.

3.3 Major Household appliances

In 2005, sales of major domestic appliances (MDAs) (i.e. refrigerators, freezers, washing machines, dishwashers, tumble driers, ovens, cookers and hobs) in the EU-15 were about stable compared to 2004 [Sor2006].

Table 1.4: Sizes and trends in Major Domestic Appliances[2] in Europe [Sor 2006a]

	10 countries	6 countries from	Russia and

[2] Major domestic Appliances (MDA) means: washing machines, tumble dryers, dishwashers, cooling, freezers, cooking, hobs, cooker hoods

	from EU-15[3]	NMS-10 & CC[4]	Ukraine
Size (thousand units)	**5,2716**	**6,817**	**4,732**
Market trend	**0.2 %**	**2.0 %**	**24.8 %**

- **Refrigerators and freezers**

Efficiency improvements for refrigerators and freezers continued. For domestic refrigerators, the energy efficiency index (EEI)[5] was defined in the "Cold Appliances" labelling Directive, (EEI was set at 102 for the average model on the market in year 1992).

Among the combined refrigerator-freezer, the best models on the market in the year 2005 were models rated A++ with an EEI below 30. For example: A A++ model with a 215 l fresh food volume and 60 l freezer (4*) volume has an annual consumption of 137.0 kWh/year compared to 522 kWh/year for the same size class C model. Just meeting the efficiency requirements would reduce the energy by a factor four! Until now there are only a limited number of models in A++ class (EEI below 30) – and still difficult to find in shops, while there are already several models in A+ class. Fig. 3.3 shows the improvement of the EEI from year 1992 to 2005.

It is interesting to notice that new cold appliances sales in NMS and CC are almost identical to the EU-15 in term of efficiency.

CECED calculated the following values as part of their Unilateral Commitment [Cec 2005] reporting mechanism.

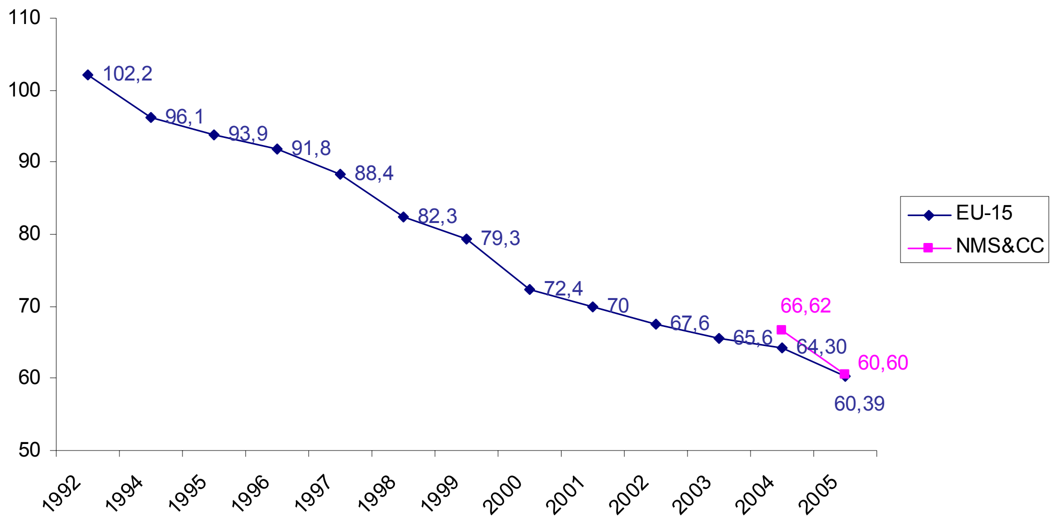


Fig. 3.4: Evolution of the EEI (new model sale weighted average) for cold appliances (source: JRC, [Wai 2004a])

3 10 countries from EU-15: Se, UK, Be, Nl, De, At, Fr, It, Es, Pt

4 6 countries from NMS-10 & CC: Pl, Cz, Hu, Bg, Ro, Hr

5 The EEI is defined as the ratio between the energy consumption of the sold appliance compared to the one of reference appliance as defined in Directive 94/2/EC.

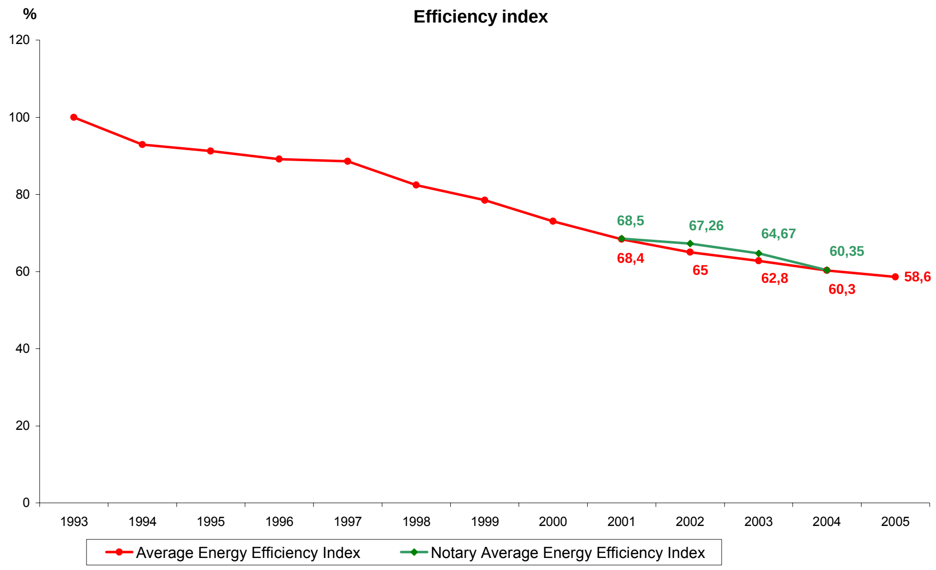


Fig. 3.5: Evolution of the EEI (new model sale weighted average) for cold appliances according to CECED notaries system [Cec 2005]

The 2005 sales data for cold appliances show that in some markets like in Germany the A+ appliances are starting to have an important market share (13.3 %), while at European level the share of A class has reached 60 % of the sales. In all countries the share of A and A+ appliances has strongly increased in 2005 compared with previous years. Large differences still exist between countries due to different national and regional policies and programmes. The lowest share of sales of A class appliances in the west European countries, covered by the GfK panel in 2004, were found in Spain (36.1%) and the highest share in the Netherlands (71.1% plus 19.2% in A+). This remarkably high share is due to incentives for very high efficient appliances. Also worth noticing is that the share of A class refrigerators in new sales is higher in the New Member States (again comparing only among the countries covered by the GfK panel).

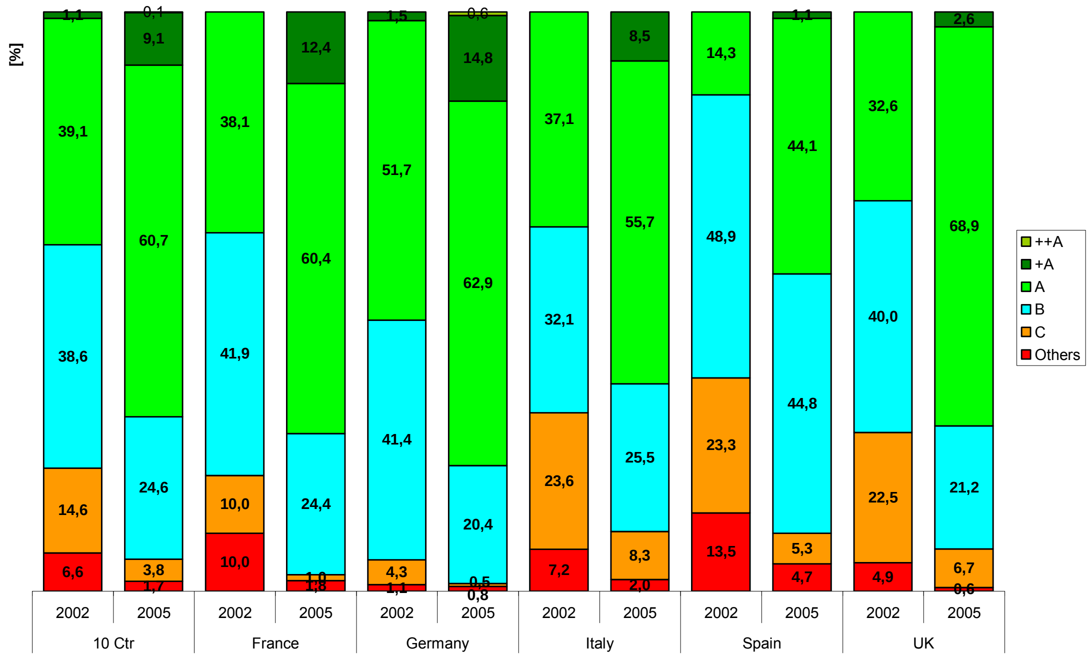


Fig. 1.6: Sales of cooling appliances: comparison for the 5 big countries in 2002-05 by energy class (Source GfK, [GfK 2004, Sor 2005])

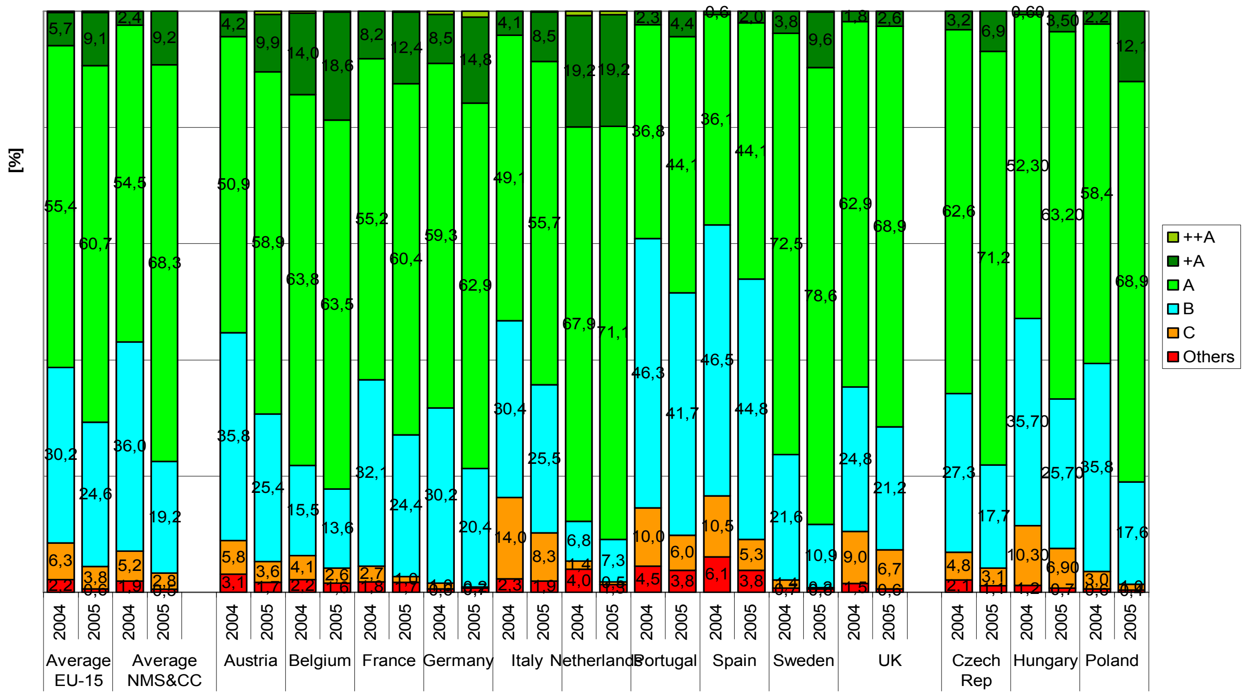


Fig. 1.7: Sales of refrigerators: comparison between 2004-05 by energy class (Source GfK, [Sor 2005])

Freezers are the only main appliance for which low efficiency classes (B, C and D) are still predominant.

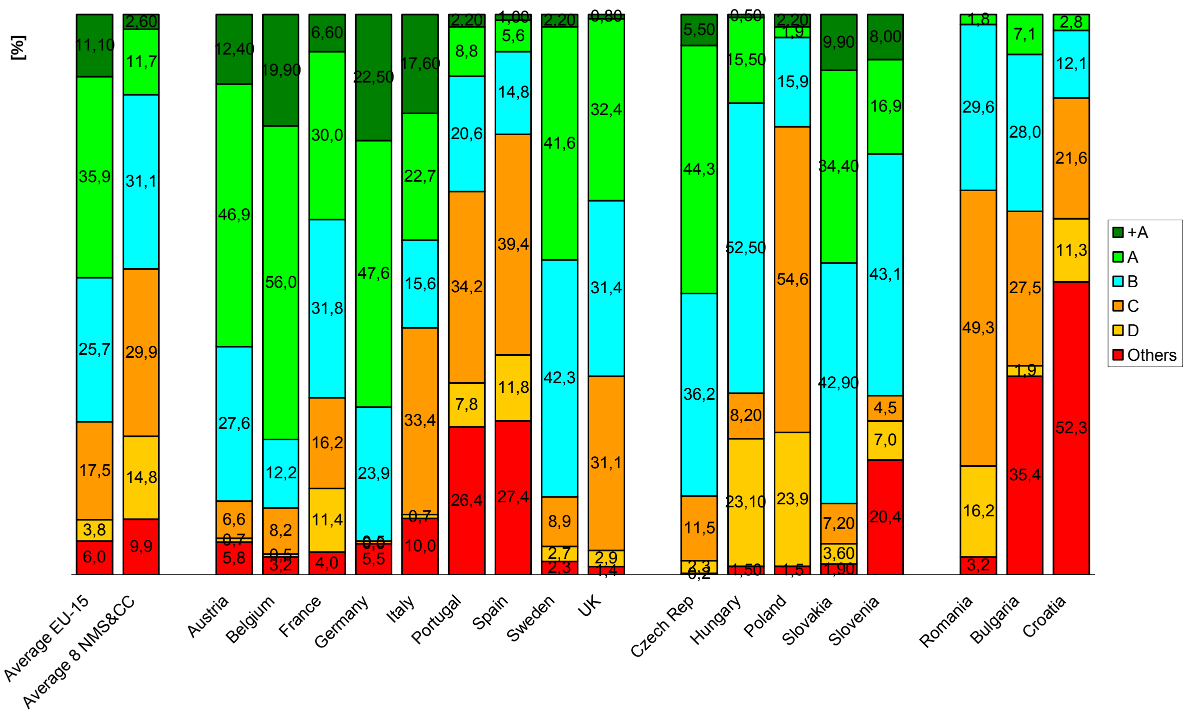


Fig. 3.8: Sales of freezers in 2004 by energy class (Source GfK, [Sor2005])

The major European policy measures already in place are the mandatory energy labelling, with A+ and A++ classes [EU 2003], and the CECED unilateral agreement [Cec 2005].

The CECED unilateral agreement contains the following commitments: participating manufacturers have stopped producing for, and importing in, the Community Market electric compressor-based household refrigerating appliances having an energy efficiency index 75 (corresponding to energy label class C) and above (except for chest freezers), and for electric compressor-based chest freezers having an energy efficiency index 90 (corresponding to energy label class D) and above, by 31st December 2004.

The agreement also includes a ”fleet target”: Each participant will reduce its own production - weighted average energy efficiency index- to a value of 55 for production and importation into the EU market by the year 2006. [Arn 2006]

- **Washing machines**

As far as the sales of washing machines are concerned, the share of A class appliances was already above 50% in 2002, in 2005 in some Member States (Germany, the Netherlands, and Belgium) there is a large penetration of A+ appliances (not defined in the Labelling Directive but agreed among manufacturers), and the combination of A and A+ in these markets is approaching the 100% marker. The most remarkable market change from 2002 for refrigerators and washing machines has happened in the UK thanks to the Energy Efficiency Commitment. It is also interesting to note that class B has almost disappeared from the market, but there is an increased share of appliances not labelled.

In 2005 there was not a significant improvement in the share of sales of A and A+ washing machines in the EU-15 (only countries covered by GfK), while in the New Member Sates the combined share of A and A+ models continues to grow.

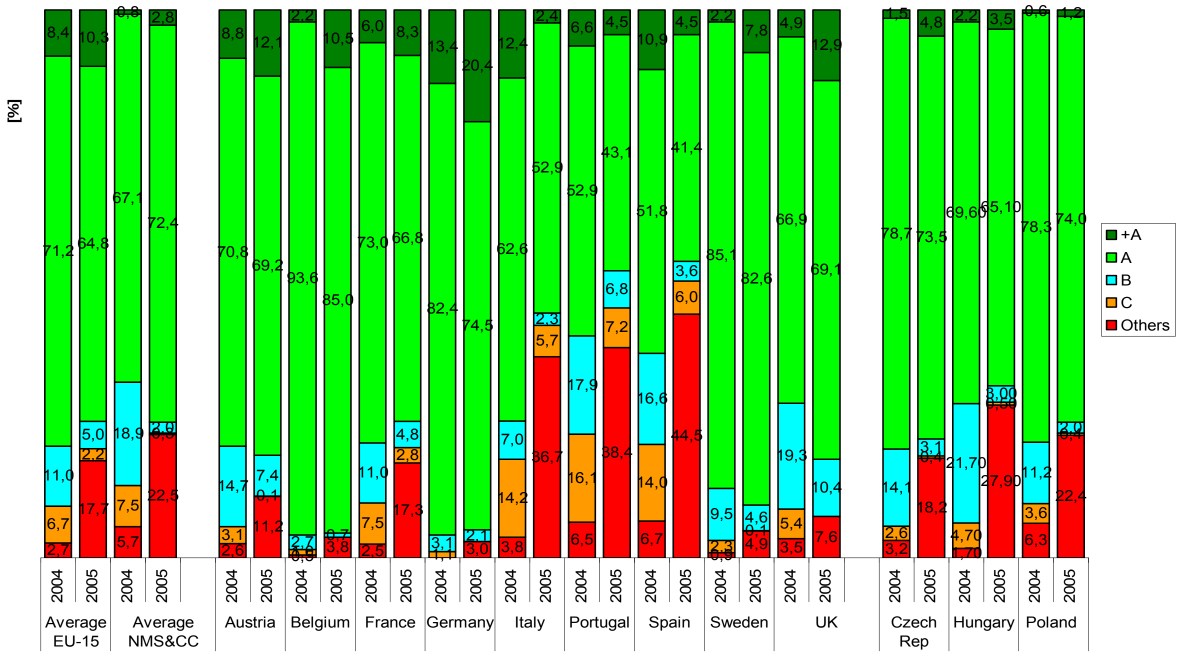


Fig. 3.9: Sales of washing machines: comparison for 2004-2005 sales, by energy class (Source GfK, [Sor 2005])

The production weighted average consumption of washing machines corresponded to 0.95 kWh/kg in the year 2004. The best model on the market (already for several years) has an EEI[6] of 0.85 kWh per wash for a 5 kg cotton load at 60ºC cycle. This indicates that even with the present technology there is a large energy saving potential of about 12% between the average models and the best model.

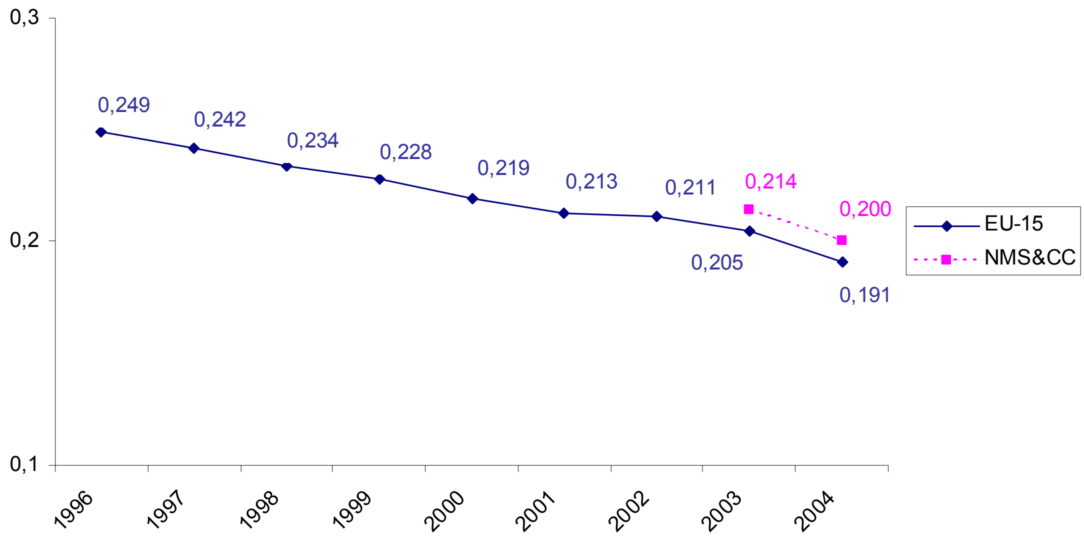


Fig. 3.10: EU-15 and NMS&CC washing machines energy efficiency index progress (in kWh/kg), based on production weighted average (source [Cec 2004] and JRC)

The major European policy measures already in place are the mandatory energy labelling [EU 1996] and the CECED Unilateral commitment [Cec 2004]. The central element in the 2nd CECED commitment is a reduction of the fleet energy consumption (this is the production weighted mean value of the energy consumption of all washing machines produced by the participants). The commitment calls for achieving a European production weighted average of 0.20 kWh/kg for the year 2008 (however already reached by 2004!) [Cec 2004]. On 31 December 2003 the participant manufacturers stopped the production and the imports of washing machines into the Community Market belonging to energy efficiency class D.

- **Dishwashers**

Dishwashers showed only limited efficiency progress between 2001 and 2005. In the year 2003 the average consumption per test cycle wash of a 12 place setting dishwasher was 1.197 kWh, down 10% from the average consumption in 2001. The best model on the market (already for some years) has an EEI of 1.05 kWh per wash cycle. This indicates that even with the present technology there is no significant energy saving potential (this also means that there is no A+ class).

Remarkable progress in energy efficiency of new sale models took place between 2002 and 2005 in all EU-15 countries, especially in the UK and Italy. Also very impressive is the high A class market share in some of the New Member States.

[6] For washing machines the EEI is expressed as the energy used per kg of soiled clothes in a 60ºC cotton cycle (kWh/kg).

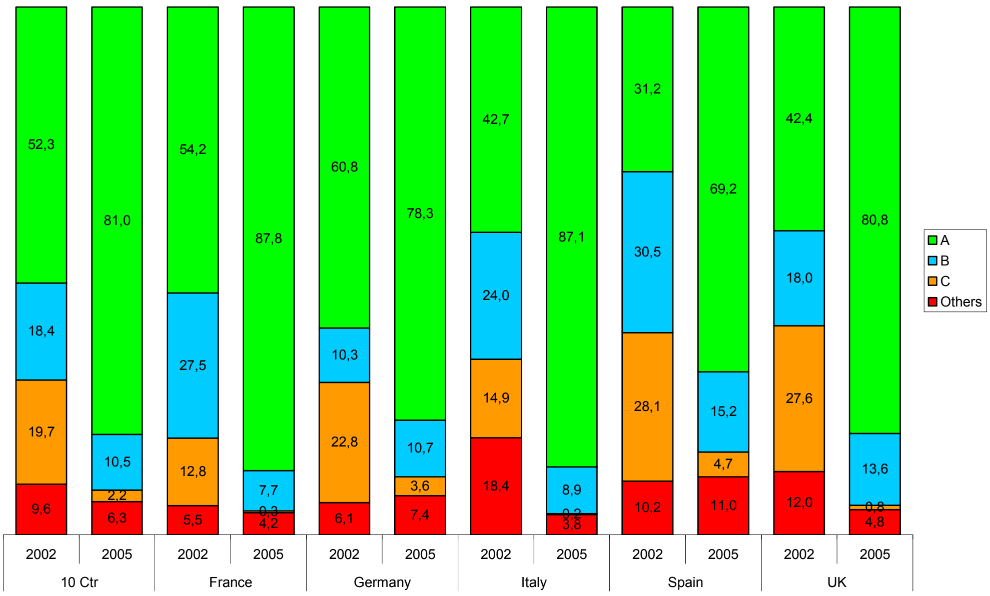


Fig. 3.11: Sales of dishwashers: comparison between 2002-2005 yrs for the 5 major EU-15 countries, by energy class (Source GfK, [GfK 2004, Sor 2004])

The major European policy measures already in place are the mandatory energy labelling [EU 1999] and also the CECED Unilateral Commitment [Cec 2004], which has now expired.

The CECED agreement foresaw that participating manufacturers commonly agreed to stop producing and importing into the EU dishwashers which belong to the energy efficiency class D (for >10 place settings) or E respectively (for <10 place settings) by 31 December 2003.

- **Cooking Appliances**

There is a mandatory energy label only for electric ovens, which represent 97 % of the ovens sales in the EU-15 in 2005, with similar trends in the 10 New Member States. For free standing cookers, for which only the (electric) oven is labelled, the share of electric ones is 34.5 % and for gas ones about 44 %. Interesting to notice is that for hobs, the share in sales among electric and gas is 58.4 % electric and 37.4 % gas models, with almost 100% electric hobs in Germany and Sweden, and almost 100 % gas hobs in Italy. Hobs represent 43% of total sales in the EU-15 and about 20 % in the New Member States, followed by ovens with 26 % and 13 % respectively, and with 26 % and 66 % for free standing cookers. This does not include microwave ovens which have an increasing penetration, but are not yet used to cook major meals. Total electricity consumption for electric cooking is estimated to be 42 TWh (around 37 TWh electric hobs and 15 TWh electric ovens) in EU-15. The impact of the energy labelling is starting to be visible on the market. The best electric oven models on the market just meet the A class level (0.8 kWh for the test cycle), while a typical model has an energy consumption in the test cycle of 1.2 kWh. There is still a long way to go before the class A appliances will dominate the market, as in the case for dishwashers. [Sor 2006]

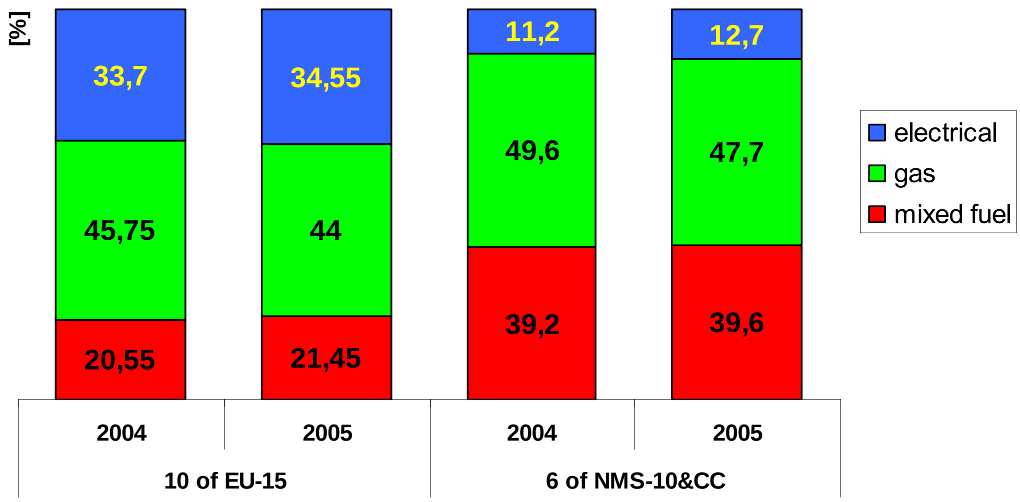


Fig. 3.12: Sales of free standing cookers, by type of fuel; comparison between yrs. 2004 and 2005 (Source GfK, [Sor 2006])

3.4 Consumer Electronics, Information and Communication Equipment

This is the fastest growing energy end-use in the residential sector. It includes more “traditional” equipment such as TVs, and “new” devices such as MP3 players, digital TV decoders etc. The table below show the large increase of equipment sold, considering the general trend of price decrease. CRT TVs and VCRs are also sharply reducing their sales in favour of flat TVs and DVDs.

TVs are the largest electricity consuming appliances in this sector. According to GfK total sales of TV continues to grow, and reached 30 million in 2005. In addition, in 2005 non CRT models gained a considerable market share.

Western Europe	2002	2003	2004	2005	2006	2003/02 %	2004/03 %	2005/04 %	2006/05 %
Cathode ray tube TV	11,957	10,159	8,520	6,041	3,630	–15.0	–16.1	–29.1	–39.9
Advanced TV	3,085	4,821	8,440	12,864	17,410	56.3	75.1	52.4	35.3
Plasma display	955	1,720	2,924	4,097	5,209	80.1	70.0	40.1	27.1
Liquid-crystal display TV	250	1,174	3,515	7,095	10,635	369.6	199.4	101.8	49.9
Rear and front projection TV	1,880	1,927	2,000	1,673	1,566	2.5	3.8	–16.4	–6.4
Digital versatile disks	3,172	4,010	4,290	4,498	4,474	26.4	7.0	4.9	–0.5
Video cassette recorders	1,777	1,089	604	330	182	–38.7	–44.5	–45.4	–44.8
Analogue camcorders	442	263	132	50	19	–40.6	–49.9	–62.1	–62.0
Digital camcorders	2,176	2,270	2,256	2,100	1,938	4.3	–0.6	–6.9	–7.7
Digital still cameras	3,526	5,566	7,299	7,785	7,879	57.9	31.1	6.7	1.2
Analogue set-top boxes and kits	183	162	98	95	42	–11.7	–39.8	–2.6	–55.8
Digital set-top boxes and kits	344	821	1,193	1,674	2,446	138.7	45.3	40.3	46.1
Digital personal audio	1,088	1,300	2,013	3,110	3,426	19.5	54.9	54.5	10.2
MP3-format-based digital personal audio sets	83	320	1,285	2,631	3,097	287.0	301.0	104.8	17.7
Analogue personal audio sets	1,385	1,258	1,145	1,011	899	-9.1	–9.0	–11.7	–11.1
Home cinema systems	1,216	1,572	1,487	1,204	1,115	29.3	–5.4	–19.1	–7.4
Audio home systems	2,273	1,777	1,445	1,199	986	–21.8	–18.7	–17.0	–17.8
Separate Hi-Fi elements	2,108	1,759	1,473	1,306	1,180	–16.5	–16.3	–11.3	–9.6
Game consoles	2,487	2,169	1,767	2,230	3,355	–12.8	–18.5	26.2	50.4
All other categories	6,320	6,715	7,790	9,325	9,783	6.2	16.0	19.7	4.9
Analogue recording media	1,028	822	702	562	408	–20.1	–14.6	–19.9	–27.4
Digital recording media	1,750	2,596	3,751	4,797	5,253	48.3	44.5	27.9	9.5
Total CE	**43,539**	**45,710**	**49,949**	**54,822**	**58,764**	**5.0**	**9.3**	**9.8**	**7.2**

* Western Europe incl. Austria, Belgium, France, Germany, Italy, Netherlands, Spain, Sweden, Switzerland and UK.
Note: These market estimations and forecasts result from GfK-manufacturers' collaboration. Data published for the previous year are as of November, anticipating Christmas trade. As a result GfK revises these data the following March, after data for the previous year have been confirmed.

Fig. 3.13: Western European consumer electronics market, sales in million Euro (source EITO, [Lam 2006])

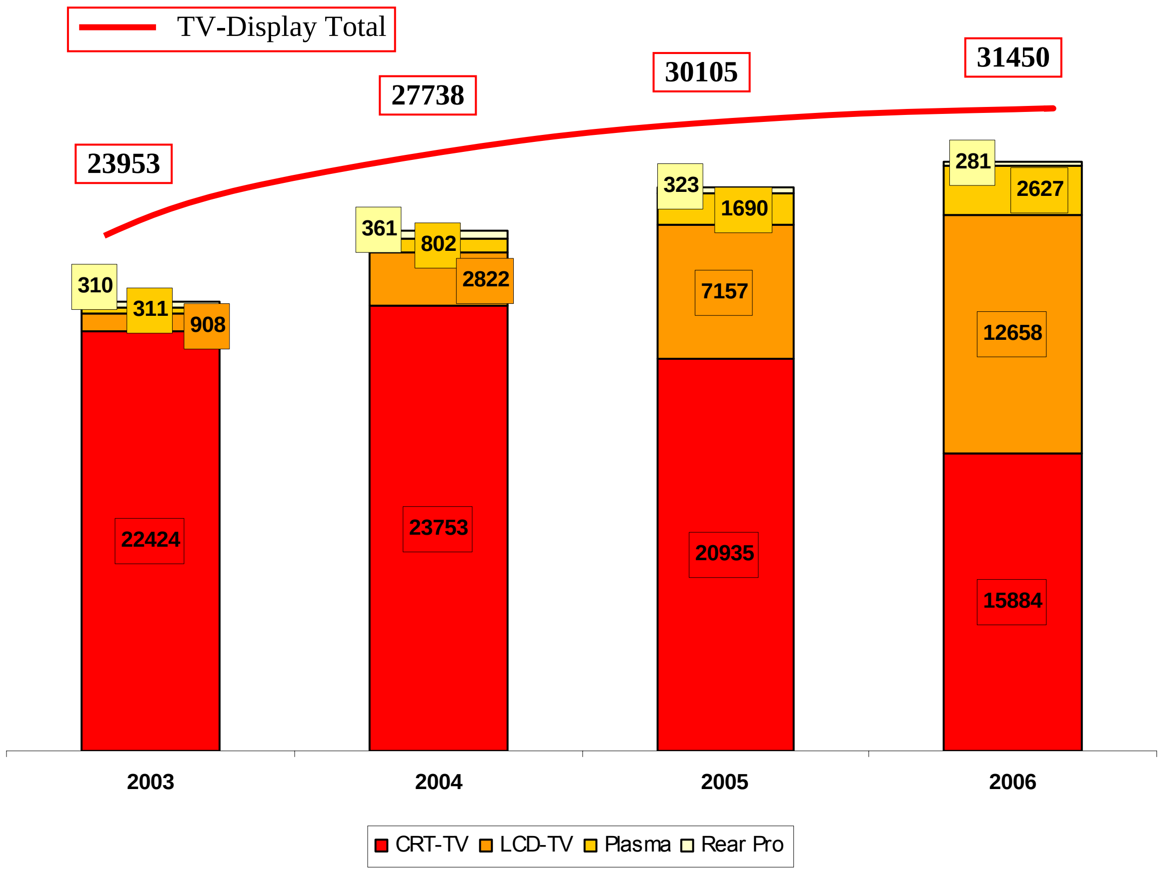


Fig. 3.14: Sales of TVs (source GfK)

EICTA (the European Industry Association for Information Systems, Communication Technologies and Consumer Electronics) submitted in 2003 to the European Commission a Self Commitment (unilateral commitment), signed by the a large number of the their member companies, to reduce the energy consumption of consumer electronics by continuously seeking to improve the energy performance per appliance.

According to the EICTA, unilateral commitment established targets for CRT, non-CRT and DVD' players in order to achieve a considerable reduction of the standby passive power consumption

The sales weighted average stand-by consumption although higher in 2004 (1.867 W) compared to the equivalent 2003 figure (1.75 W), is well below the target set for 2005 of a sales weighted average of 3.0 W standby passive.

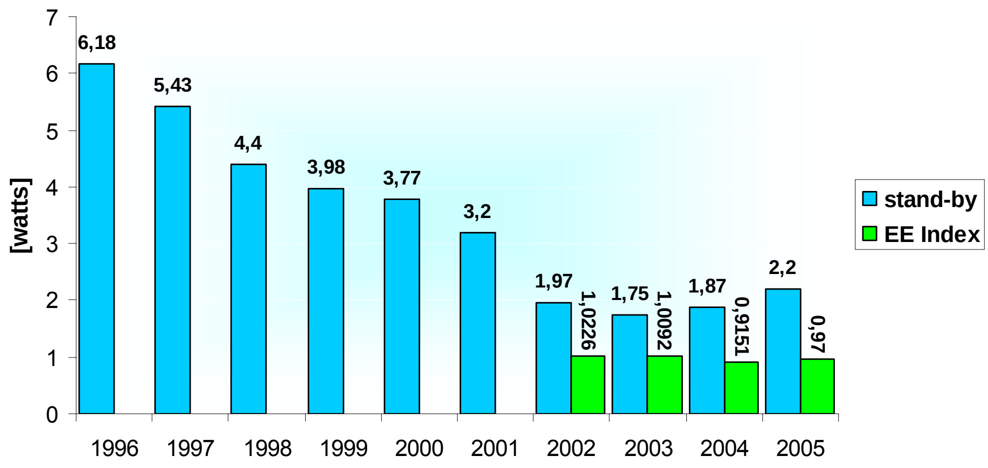


Fig. 3.15: Analogue CRT TV receivers average stand-by power consumption and EE Index (source EICTA, [Eic 2005])

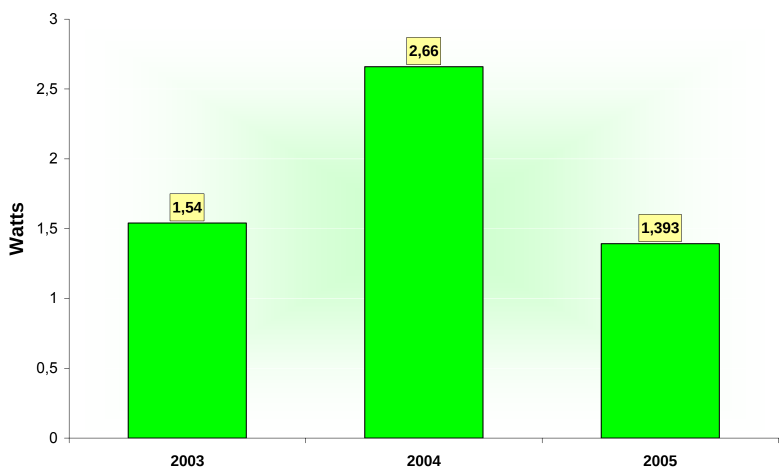


Fig. 3.16: Non CRT TV receivers average stand-by power (source EICTA, [Eic 2005])

Many new TV models have now standby consumption well below 1 W and some companies have introduced a policy to have all their models below 1 W. For VCRs the best appliances have a standby consumption around 1 W (eco-mode) and many have standby consumption around 2 W, however, it must be noted that VCRs sales are decreasing very rapidly. For DVD- players the standby passive of best appliances is below 0.5 W. More recently policy makers' attention has been drawn to the television on-mode consumption, due to the increase in the viewing hours and the size of the TVs. In order to compare on-mode consumption of TVs having the same size and features (TV consumption is strongly related to the size), an EEI has been developed by industry EICTA and experts. As shown in Fig. 3.15 the EEI as reported by EICTA has been slightly improved.

3.4.1 Digital TV services

Another major driver for the increase in electricity consumption is the move to digital TV and broadband communication. The European Union is rapidly moving towards the switch to digital TV and the phase-out of analogue broadcasting. This means that the current stock of analogue TVs will need converter boxes in order to function. At the same time, pay-TV is competing on the market with more sophisticated services and offers, resulting in even more complex set-top boxes, which show a worrying trend in rising energy consumption levels.

In addition to the digital TV services supplied through satellite, terrestrial and cable (fibre or coax), there are new service providers starting to offer digital TV and video-on-demand through the telephone lines with DSL modems or using power line technology. These trends will accelerate the convergence between Information Communication Technology equipment and consumer electronics and have a big impact on energy consumption, because more than one system is always on in each household. In addition, an increasing electricity demand for each device can be observed as it gets more powerful.

According to the Canalys research company, the number of households with digital TV in Western European countries was already over 50 million during the first half of 2005. This high number has been reached through the switch from analogue to digital by pay-TV providers and the seting up of free-to-air services in many Member States. The European Commission has indicated a switchover target of 2010, and the stronger than anticipated success of digital TV in several countries - including France, Germany and Sweden - means that many European countries will meet the target [Til2005].

Subscription for digital satellite TV at the end of 2005 reached about 15 % of Western Europe households [Lmp 2006].

There are different digital technologies in the national markets. Cable is dominating the market in Belgium and Switzerland while satellite is predominant in Austria and Spain.

According to *'European Switchover Strategies'*, a report from market research firm Informa Telecoms & Media, 44.9m European households will have access to DTT (Digital Terrestrial Television) signals on their main TV set by 2011 [Til 2006].

Other recent reports announced that 10 million DTT set-top boxes have been sold in the United Kingdom. Together with cumulative DTT set-top boxes sales in the rest of Europe, it is estimated that over 20 million DDT set-top boxes have now been sold. The number of DTT households in Europe increased from 8.2 million at the end of 2004 to 11.6 million by mid 2005 [Mou 2006].

3.4.2 Policies

In 1997, a European Commission working group identified the digital service system STB as the domestic electronic device with the largest potential to increase energy consumption in European households.

To limit the potential growth in energy consumption a voluntary programme was introduced, the European Code of Conduct for Digital TV Services[7], developed by a working group which includes all the stakeholders. The Code of Conduct sets out the basic principles to be followed by all parties involved in digital TV services, operating in the European Community in respect of energy efficient equipment.

The graph below shows the average power consumption of new Set Top Boxes (STBs) that meet the Code of Conduct requirements.

[7] http://energyefficiency.jrc.cec.eu.int/html/standby_initiative_digital%20tv%20services.htm

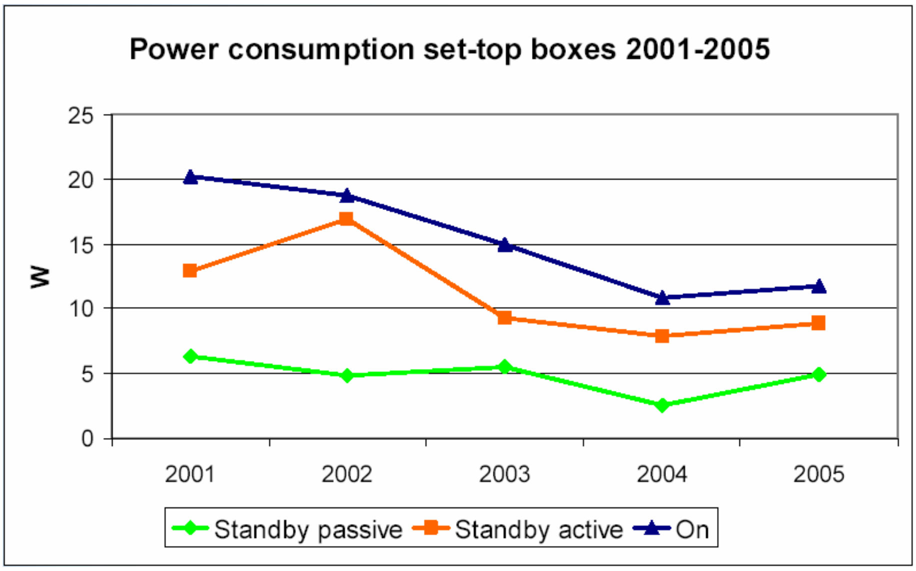


Fig. 3.17: Code of conduct requirements for power consumption for set-top boxes between 2001 and 2005; (source [Har 2006])

Research into proposed development showed that by 2010, the STB could push domestic electronic energy consumption in Europe above that of refrigerators and freezers. Compared to the average electricity consumption of existing set top boxes, two thirds of the consumption could be avoided if all set-top boxes would fulfil the code of conduct agreements. With potentially over 200 million of these boxes across the EU - equivalent to one per household – the necessary annual electricity supply for digital service systems could vary significantly. In 2010, 60 TWh/year would be consumed extrapolating from the current set top boxes in use compared to 20 TWh/year in the case of consequent use of equipment fulfilling the code of conduct requirements.

3.4.3 Broadband Equipment

Another driver in the increase of consumption in households (and in the service sector in the network infrastructure and data centres) has been broadband communication. Detailed data on DSL usage in Europe is still being compiled.

Broadband is one of the fastest among new communication technologies in Europe. The total number of broadband lines in the EU has quadrupled in just three years.

In October 2005, 80 % of broadband subscribers in the 25 Member States of the European Union (EU-25) used DSL to connect to broadband Internet. Cable modems currently account for about 16 % of all broadband connections in the EU-25 [Com 2006].

In January 2006, broadband reached almost 60 million subscribers in the EU-25 and had a penetration rate of about 25 % of households. Growth in broadband use is mainly market-driven and is uneven across Member States [Com 2006].

Current projections show that the predicted uptake of the two key broadband WANs (wide area communication networks), DSL (digital subscriber line) and digital cable, will have a large potential impact on European household energy consumption. Even with the unlikely application of best practice in energy efficiency for all the network and end-user hardware, a simple broadband terminal for, say, 200 million EU households by 2010 would increase annual domestic electricity demand by an estimated 6.6 TWh. This could effectively be doubled by associated LAN equipment.

Figures on energy consumption for DSL modems vary significantly. In the UK, the largest national telecommunication provider, BT, has, through energy efficient procurement policy, provided basic, self-powered external DSL modems with a 4.0W power requirement. More typical devices in the open market and supplied by some other European telecommunication groups have a power requirement of nearer 10 W. With the latter, up to 87 kWh could be added to the individual household's annual energy overheads.

Expectations are that broadband equipment will contribute to the electricity consumption of households in the European Union in the near future. Depending on the penetration level, the specifications of the equipment and the requirements of the service provider, a total European consumption of up to 50 TWh per year can be estimated for the year 2015. With the general principles and actions resulting from the implementation of the new Code of Conduct on energy consumption of broadband equipment the (maximum) electricity consumption could be limited to 25 TWh per year.

To address the issue of energy efficiency whilst avoiding competitive pressures to raise energy consumption of equipment all service providers, network operators, equipment and component manufacturers helped the European Commission to develop the Code of Conduct[8].

The Code of Conduct sets out the basic principles to be followed by all parties involved in broadband equipment, operating in the European Community, in respect of energy efficient equipment.

The Code of Conduct covers, both on the consumer side (end-use equipment) and the network side (network equipment), for services providing a two way data rate of 144 kb/s or above.

3.4.4 External Power Supplies

Another component contributing to the increase of the energy consumption are the external power supplies. These external power supplies are used for many different types of electric and electronic devices, such as mobile telephones (the fast penetration is shown in the table below), digital cameras, cordless phones, notebook PCs, etc.

For external power supplies a European Code of Conduct was introduced in the year 2000 to reduce the no-load losses, and recently also to improve the on-mode efficiency. In the graphs below the results achieved by the participants in the CoC are shown. Before the introduction of the Code of Conducts many external power supplies had a no load power consumption above 1 W, and low efficiency in operational modes.

[8] http://energyefficiency.jrc.cec.eu.int/html/standby_initiative_broadband%20communication.htm

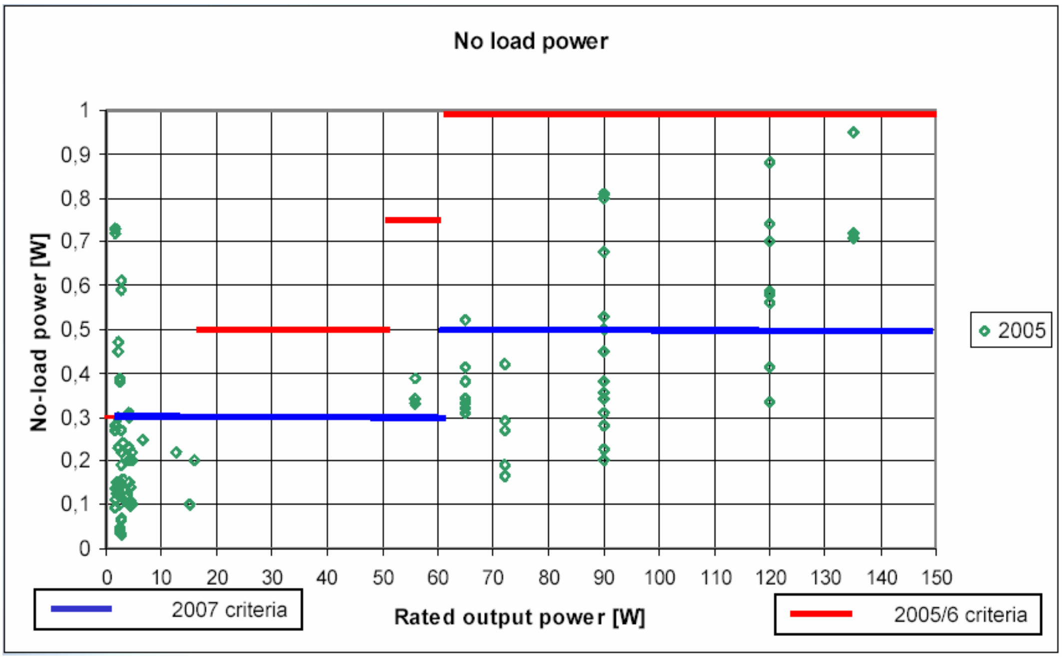


Fig. 3.18: No-load power new criteria for external power supplies and results achieved by participating companies (source [Har 2006])

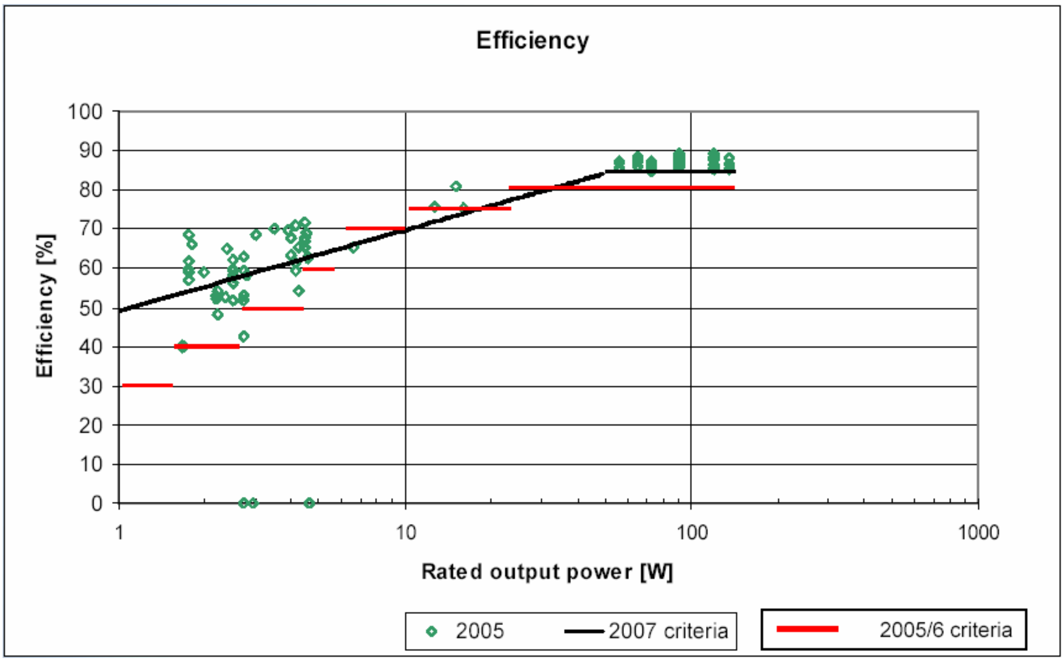


Fig. 3.19: New efficiency criteria for external power supplies and results achieved by participating companies (source [Har 2006])

3.5 Residential Lighting

Compact Fluorescent Lamps (CFLs) represent the most efficient solution available today for the residential market[9]. A suitable 'indicator' of the penetration of efficient lamps is the number of households, which have at least 1 CFL.

Table 1.5: Estimation of the penetration levels in 2004 (source [Ber 2006])

	Number of HH with CFLs [%]	Lighting points/HH	CFL's/HH [including HH without CFLs]
AT	70	26	4
BE	70.5	26	2.5
DK	65	25.4	4.9
FIN	50	23.5	1
FR	52	18.9	2.26
GR	50	7	1
DE	70	32	6.5
EI	38	18	1.5
IT	60	18	0.8
LU	70	20	2
NL	60	40	4
PT	54	11.4	1.7
ES	15	25	2
SE	55	22	2.2
UK	50	20	2
CZ	70	10	2.9
CY	79	16	2
EE	20	6	0.25
HU	60	18	1
LV	18.8	20	0.42
LT	20	6	0.25
MT	50	15	1
PL	50	20	0.5
SK	60	15	1
SI	50	19	1
BG	7	10	0.2
RO	20	10	0.2
HR	39	14	1

The table shows that there are still a large number of households in the EU-15 which do not own a CFL, moreover only a few countries show a number of CFLs close to the cost-effective saturation level (about 25% of lighting points per households using a CFL).

9 CFLs are of two types, with an integral ballast (ballast inside the package) or pin-based. The first type dominates the market for the residential sector. Recently some pin-based CFL luminaires have appeared on the EU market for residential lighting, however, no sales figures are available. Of particular interest are the CFL based "torchieres", which could replace halogen based upright floor lamps, the latter using light sources up to 500W. There is also a certain use of linear fluorescent lamps, especially in some countries, e.g. the UK, and in specific rooms such as kitchens and garages. For the residential sector any linear fluorescent lamps even with a magnetic ballast could be considered an efficient solution if it replaces an incandescent lamp.

However, the recent drop in price had a beneficial impact on sales. In particular, two different types of CFLs are marketed: the short life (average life around 6000 hours) and the professional models (average life around 12000 hours). The first type is mainly marketed for the residential sector. Direct sales comparison between incandescent and CFLs and incandescent is not meaningful as CFLs have a longer life-time (6 times or more). Moreover it is difficult to gain access to sales data, and sales data available includes lamps not destined to the residential sector.

Table 1.6: Sales of CFL lamps (Source [ELC 2004, Str 2004])

Product	Market (million units)					
	2000	**2001**	**2002**	**2003**	**2004**	**2005**
	Western Europe					
CFL-I	101	109	119	131	145	146
CFL-NI	72	78	80	82	87	92
	Central & Eastern Europe					
CFL-I	14	21	27	34	41	
CFL-NI	9	10	12	13	15	

3.6 Tertiary Sector Building Electricity Consumption

The gas consumption of the tertiary sector has continued to grow in the period 1999 to 2004 in the EU-25 from 2,070 PJ to 2,362 PJ with an increase of 14 %, while the yearly growth rate in the period 2003 – 2004 has been 1.9 %. Total electricity consumption for the tertiary sector for the EU-25 was 628 TWh in the year 1999 and 726 TWh in the year 2004. The electricity in the tertiary sector has grown by 15.6 % in the period 1999 – 2004 and by 2.0 % in the period 2003 – 2004.

For the tertiary sector (public sector, services and commerce) there is much less data available for individual electricity end-uses than for the residential sector, and only a few sources attempted to split the total electricity consumption among the different end-uses.

Table 1.7: EU Tertiary Sector Electricity Consumption (source: Eurostat, JRC)

	Services [TWh]		
	2003	**2004**	**2004 vs. 2003 [%]**
EU-25	655.18	670.03	2.27
EU-15	590.24	603.15	2.19
NMS-10	64.94	66.88	2.98
NMS-10+2	75.68	76.29	0.80
EU-25 + 2	665.92	679.44	2.03

In 2000 the ECCP compiled the following breakdown that was endorsed by the all the ECCP experts.

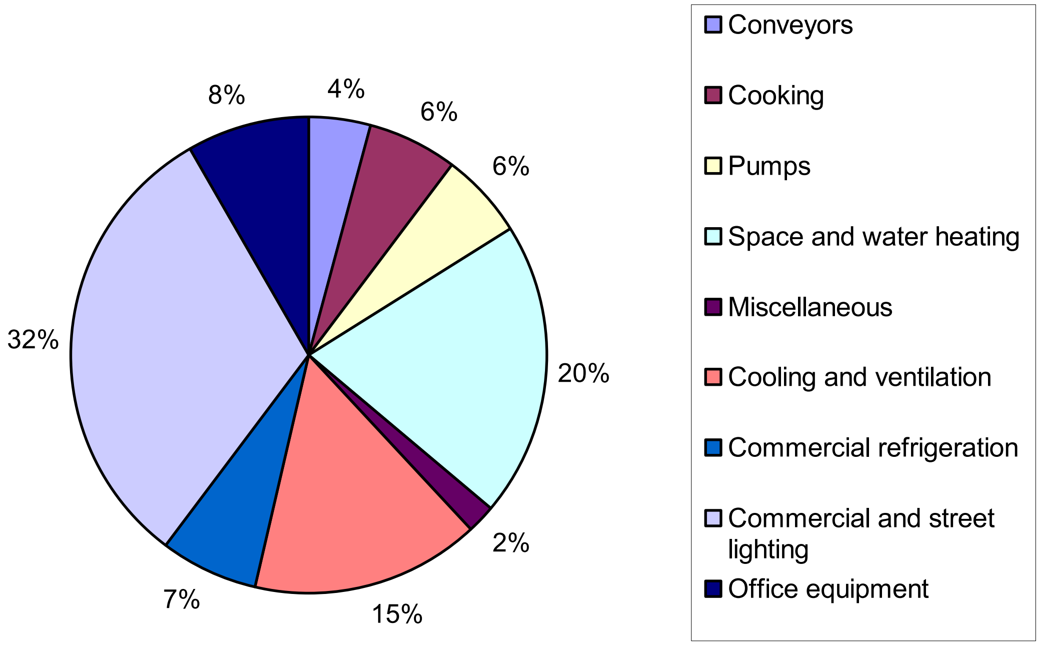


Fig. 3.20: Split of the Tertiary Sector Consumption (Source [ECC 2001])

Not only is there less information available on the end-use equipment and systems' consumption, but also sales data on efficient equipment and/or energy efficiency indexes are difficult to find or missing.

Lighting is by far the major end-use category in tertiary sector consumption, responsible for about 175 TWh or 26 % of total electricity consumption in the tertiary sector (this is lower than the EECP findings in the above figure). As far as non-residential buildings' lighting is concerned, this is dominated in energy terms by linear fluorescent lamps. T12 fluorescent lamps are the oldest technology of fluorescent lamps. These lamps have an efficiency of less than 75 Lumens per Watt. In the majority of cases there exists a T8 lamp that can be retrofitted into the same lighting point. Depending on whether this T8 lamp is a halo phosphor (e.g. TL-D Standard lamp) or a Tri-phosphor (e.g. MASTER TLD Super80 lamp) the lamp efficiency can be improved to between 80 and 90 Lumens per Watt.

The T8 lamp now dominates the linear fluorescent market. The existing mix of lamps is still two-thirds halo phosphate phosphor lamps with the remaining third being three-band rare earth phosphor lamps which are currently increasing their market share year on year. Barrier coat technology has allowed the mercury content in current tri-phosphor lamps to be reduced to below 5mg.

The average lamp wattage for T12 lamps is 65 W. The average energy saving per lamp when switching from T12 to T8 is 12 %. The total annual sales figure for T12 lamps in the European Union is 16 million lamps. This is more or less a stable market. The total sale of linear fluorescents is estimated to be 350 million lamps per year [Str2004]. There is a relatively new technology, T5 which has a higher efficiency and is designed to be fed only by electronic ballasts. However, the market penetration of T5 lamps is still limited, though increasing.

There are about 207 million new installed lamps [Cel 2005], which tend to be of higher efficiency compared to already installed lamps.

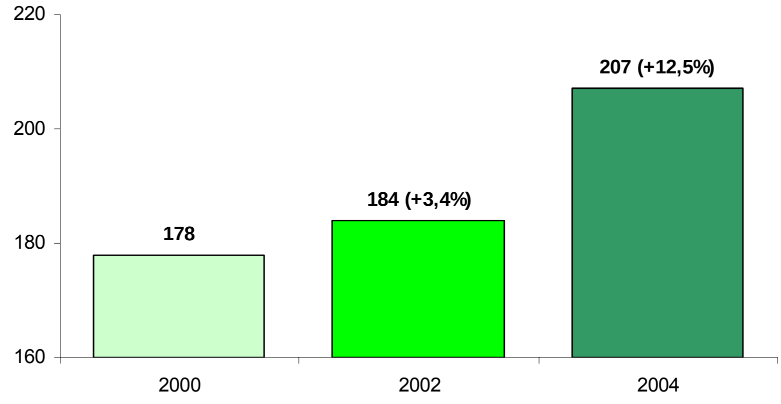


Fig. 3.21: Number of new installed lamps (in millions) [Cel 2005]

Ballasts are needed to run every fluorescent or discharge lamp. There are two very different technologies for ballasts: the magnetic type and the electronic type. The latter has a much lower power loss and also allows operating the lamp at lower wattage for the same light output. There is a voluntary classification scheme for the combination of lamp ballasts introduced in the year 1998 by the lighting equipment manufacturers' trade association, CELMA [Cel 2004]. The classifications scheme[10] together with the minimum efficiency requirements for ballasts Directive 2000/55/EC, which came into effect in 2002, have resulted in a gradual market transformation. The Directive foresees two gradual steps for phasing out low and medium efficiency ballasts. The first steps took place in the year 2002 and phased out low efficiency magnetic ballasts (class D). The second steps took place in November 2005 and phased out Class C ballasts representing the largest share of the market. The EU Directive 2000/55EC aims to reach a market transformation by 31.12.2005 with the following values:

- **class A** ballast 55%,
- **class B and C** (sold until 01.11.2005) ballasts 45%.

At the moment there are, however, no sale data available for the year 2005 to evaluate the impact of the second phase, the graphs below show the ballast market evolution up to the year 2004, when electronic ballasts reached a market share of 31%.

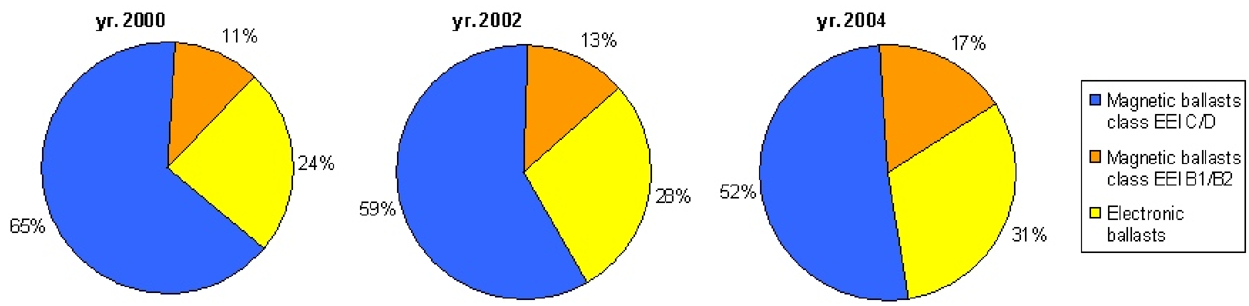


Fig. 3.22: Ballast Sales (Source [Cel 2005])

[10] The classification scheme is available at http://www.celma.org/pdf_files/BallastGuideEN200212.pdf

Lighting equipment efficiency is affecting only partially the total lighting consumption (measure is lm/W), as this is the result of the amount of light provided (measured in lux), and the lighting system's operating hours. Of particular interest is the introduction of technologies to reduce the light quantity (dimming) as function of day lighting, the operating hours in function of the occupancy. There are no data on the present penetration of occupancy sensors, and day-light sensor coupled with dimmable ballasts.

A recent survey by the IEA has identified the following parameters for the OECD Europe [IEA 2006a]:

- Average lighting power density 15.6 W/m^2;
- Average energy consumption 43.1 kWh/m^2 per year;
- Average operating hours 1,781.

Some examples of advanced lighting for office buildings from the Green-Light Programme have reported for office buildings lighting power densities in the range of 7 to 10 W/m^2.

For *other tertiary sector end-use equipment* (e.g. central air conditioners, chillers, commercial refrigeration, pumps, etc.) there is even less information on market penetration of efficient equipment. *Air-conditioners* are estimated to consume about 80 to 90 TWh of electricity.

Eurovent established classification for full load Energy Efficiency Ratio of each type of chillers. The classification follows the A to G approach used in the European Energy Label for household appliances, but the limits between classes have been defined for the existing chillers as listed in the Eurovent Directory [Sah 2006]. It is too early to see the influence of this classification on energy efficiency. However, the distribution shows that 7 % of certified chillers are in Eurovent Class A and in total only 5% of the certified chillers are in Eurovent Class G. Another large share is consumed by *ventilation systems* (including fans), which results in about 114 TWh in the tertiary sector.

For *office equipment* not much data exists on the energy consumption nor on the market share of Energy Star labelled equipment nor on the rate of equipment with the power management features enabled. In the year 2003 a rapid penetration of LCD screens occurred, and was sustained in the years 2004 and 2005, which should have led to a decrease of the total monitor consumption. A German Survey has identified the ICT electricity consumption in the tertiary sector buildings to be 11% of total electricity consumption in this sector [Sch 2006] [Gru 2006]. This is in good accordance with the ECCP finding. The ICT sector is predicted to increase its share of the total electricity consumption (more equipment and more use of the equipment, in particular data centres are large electricity-using buildings). Non-domestic ICT consumption is expected to continue to increase by almost 40% between 2006 and 2020. Risks include expected increases in ICT equipment functionality and networking capabilities and barriers to the ability of the PC to enter low-power consumption modes such as sleep.

For commercial buildings another interesting energy efficiency indicator is the total primary energy consumption (or the specific electricity consumption) per square metre. Although again there are no official statistics, some data have recently been collected by some experts, especially for Germany. From a monitoring exercise carried out in Germany the following data has been compiled [The 2004, Her 2006]. A number of highly efficient office and educational buildings have total primary energy below 100 kWh/m^2 per year, with lighting at about 10 kWh/m^2 and ventilation at 10 kWh/m^2. To reach this low energy consumption values such a building uses natural or passive cooling technologies (including ground loop heat pumps).

Table 1.8: Building Specific Consumption of Primary Energy

Type of building	Primary Energy Consumption [kWh/m^2 gross usable floor space/yr.]
Average old office building constr. before 1990	591
Average office building	502
Average office building constr. after 1990	421
Average new office	400
Best practice	150-100

3.7 Industrial Sector Electricity Consumption

The energy consumption of the industrial sector has continued to grow in the period 1999 to 2004 in the EU-25 from 299 Mtoe to 319 Mtoe with an increase of 6.6 %, while the yearly growth rate in the period 2003 – 2004 has been 1.3 %. Total electricity consumption for the industrial sector for the EU-25 was 792 TWh in 1990 and 1,042 TWh in 2000 [EC 2004] and reached 1,089 TWh in 2004. The electricity in the industrial sectors has grown by 9.5 % in the period 1999 – 2004 and by 1.7 % in the period 2003 – 2004. Of this consumption, 707 TWh, or 65 %, was consumed by motor driven systems [EC 2003a, Eci 2004], which include compressors, refrigerators systems, pumps, ventilations, conveyors and other equipment.

Motor driven systems are present in all types of industries. In particular, with more efficient electric motors the electricity consumption, for the process of converting electrical energy into mechanical energy, could be reduced by 10 to 20 %. Electric motor efficiency has been monitored through the CEMEP unilateral agreement, which has provided sales data for the most recent years on 4 and 2-poles three-phase industrial motors in the power range 1 to 90 kW. These are the motors responsible for the largest share of energy consumption, and are sold in large numbers. The existing CEMEP classification scheme allows for classification of motors into three classes[11]. The European motor manufacturers represented by CEMEP sell about 2 million 4-pole motors and 1 million 2-pole motors per year. Through a unilateral commitment, CEMEP manufacturers have managed to increase the market share of medium efficiency motors (EFF 2) and almost phased out the low efficiency motors (EFF 3).

Another important piece of equipment to save electricity in motor systems is the Variable Speed Drive (VSDs) in all the fluid and motion applications where there is no constant flow or speed. It would be useful to collect sales data for VSDs for future reports.

A report published by the European Copper Institute in 2004 shows the following energy savings for motor systems:

Table 1.9: Energy savings for motor systems (Source [Keu 2004])

	Savings potential (TWh/yr.)					
	EU-15	EU-25	France	Germany	Italy	UK

[11] The European Motor Classification Scheme; http://energyefficiency.jrc.cec.eu.int/motorchallenge/tools.htm

High efficiency motors	24	27	4	6	4	3
Variable speed drives	45	50	8	10	7	6
Application part of the motor systems (pumps, fans, compressors)	112	125	19	26	17	15
Total electricity savings potential	181	202	31	42	28	24

3.8 Conclusions

Energy efficiency policies and programmes (regulatory measures, unilateral agreement by trade associations, utility DSM programmes, incentives, white certificates, etc) implemented at EU and national level have resulted in a market transformation described in the previous sections. These actions are evaluated on the basis of the annual electricity reductions they have delivered and will continue to deliver in the coming years. While the various energy efficiency indicators for end-use equipment are somehow ‘relatively’ easy to evaluate, it is necessary to build a detailed and dynamic stock model in order to evaluate the annual energy reduction. Important information needed to create the stock model is the present stock of installed appliances and equipment, and their energy consumption (in real life conditions not in the energy consumption test mode), the average life of a appliances and equipment, annual replacement rate and any change in ownership penetration, patterns of use, size, together with the key demographic indicators (e.g. number of households, people per household).

Since only a certain percentage of installed equipment is replaced each year, the impact of energy efficiency policies tends to be relatively slow and modest at the beginning, though continually increasing over time. However, in a time span of 10 to 15 years, when almost the whole stock has been replaced and the full effect of the policy measure is visible, annual electricity reduction in the order of tens of TWh will be achieved for several types of appliances and equipment. The annual electricity demand reduction potentials resulting from each individual policy are calculated against the Business as Usual (BaU) scenario, which correspond to the most likely trend in consumption, if additional policies are not introduced. The BaU scenario includes the natural efficiency improvements (due to the autonomous market and technology developments), and the autonomous trends in sales.

One of the possible policy actions is to accelerate the *replacement rate* of “old” installed equipment, thus reducing the time for the complete turnover of the installed stock. CECED in a recent report [Cec 2005a, Rud 2006] claims that by replacing the 188 million appliances in use which are older than 10 years, with the best on the market 44 TWh could be saved. Of course attention must be paid to old appliances being withdrawn from household and “scrapped”, as well as appliances being replaced with models of the same size.

For some appliances, although there is a positive impact thanks to the policy action resulting in energy savings compared to the BaU scenario, there could still be a net increase in the electricity consumption, due to a larger penetration rate (this is the case for example for residential room air-conditioners, dishwashers, dryers). Another element to evaluate the result from a given policy is the possible competition between gas and electricity, and possible energy savings in terms of primary energy or CO_2 emission reduction. For example electric storage water heaters are decreasing their total electricity consumption, due to the fact that they are being replaced by instantaneous gas, thus resulting in primary energy CO_2 emission savings. Similar benefits could be achieved by replacing electric hobs (resistive type) with efficiency gas hobs, and replacing conventional driers with gas models.

Standby energy consumption in entertainment electronic and ICT equipment is growing at a worrying rate. This is because a lot of new equipment is added to the present stock (STBs, DVD players new TVs and surround sound systems, mobile telephones, broadband communication including home network). In addition, some old replaced equipment may still stay in use in different locations in houses (e.g. older TVs moving to children's bedrooms, together with the old VCRs). Some equipment which did not "traditionally" have any standby consumption such as traditional white goods, start to have AC/DC converters, displays, modems, microprocessors, all devices that are likely to be always on and to add a few watts of standby consumption. While these additional features may be desirable and even useful to save energy in the operation modes, every step during the design phase has to be taken by designers and manufacturers to make sure that while in standby the added electronic devices draw as little power as possible and power management is always implemented to use as little electricity as possible and to switch off all the devices not needed. Moreover, although new TVs use significantly less standby power than older models as a result of the EICTA unilateral voluntary agreement introduced first in 1997, the simple number of appliances with standby power mode continues to increase. The net effect of these trends is likely to be a continuing increase in standby power use.

TV reception platforms are rapidly moving towards digital broadcasting technology. As a result, set-top boxes (STBs) will be the source of significant new standby and on-mode power demand in the near future. Some STBs introduced on the market stay in on-mode all the time, consuming up to 20–30 W of power (this consumption tends to increase as more functionality is added to STBs). With the assumption of about 50 million advanced STBs (accessing pay per view services with recording and time shift capabilities) in households by 2010, this is an additional electricity consumption of **10 TWh** per year in the EU-25. In addition, with the phase out of the analogue TV signal, simple converter boxes will be required by the legacy of the old analogue TVs. Converter boxes now on the market tend to consume about 10 W all the time. With the assumption of one converter box per household this will result in an additional **16 TWh** per year. The EU Code of Conduct for Digital TV Systems, if successfully implemented halves this predicted consumption and will thus deliver about **13 TWh** of annual electricity savings by 2010 compared to the business as usual scenario.

A similar trend is also observed for broadband communication (mainly through DSL, but could also be implemented through cable and satellite STB, G3 mobile phones, and PLC) a number of new devices, such as modems, routers, switches, are being introduced and are often always on. Depending on the penetration level, the specifications of the equipment and the requirements of the service provider, a total European Union consumption of up to 50 TWh per year can be estimated for the year 2015. With the general principles and actions resulting from the implementation of new Code of Conduct the electricity consumption could be limited to 25 TWh per year, i.e. a demand reduction of **25 TWh** against the BaU scenario.

As far as the traditional white goods and other residential sector appliances and equipment are concerned electricity demand reductions per year in the order of **24 TWh** to **30 TWh** have been achieved in the last decade (CECED in the same period estimate an energy demand reduction of 34 TWh). In particular it is worth noticing that the demand will be reduced by **65 TWh** to **75 TWh** per year in **2010 compared to 1995** in total by the current polices already in place (appliances labelling, efficiency requirements, unilateral voluntary agreements, Code of Conducts, etc.). It is important to highlight that there is still a huge saving potential available if further cost-effective[12] measures are implemented. In particular, larger saving potentials exist for reducing **stand-by losses** (20 TWh), which is also the sector with the highest consumption growth with the current polices (+50%). A large demand reduction potential is also available in residential **refrigeration appliances** (16 TWh), and **residential lighting** (10 to 20 TWh) With the current policies there will be a consumption increase for lighting of about 10%. The cost-effective technology CFLs is already on the market, but not yet used in all the cost-effective lighting points in households.

Equally important to mention is the fact that with a prompt introduction of additional policies based on least-life cycle cost and accelerated replacement of additional appliances and lighting, the electricity of the residential sector could be reduced by an additional **60 TWh** to **90 TWh** per year by the year 2015 compared to the current policies' scenario.

Another important piece of equipment for electricity consumption and potential savings is the **electric motor**, in particular the three phase industrial motor. Through the CEMEP unilateral agreement started in 1999 about **2 TWh** was already been saved by 2005. The electricity reduction potential of the current agreement, when most of the motor stock is replaced (around 2012), will be about 6 TWh. The economic saving potential is still much larger and estimated to be at about **20 TWh** by 2015. To achieve this cost-effective potential, a new policy action to phase out motors in efficiency classes EFF 2 is needed. The recent report [Eci 2004] has calculated the total electricity cost-effective savings in motor systems to **200 TWh**, this will be achieved with the optimisation of the whole system.

The "Ballast" Directive will deliver electricity savings of about **5TWh** by the year 2010, while the economic potential for **non-residential lighting** will be at least **20 TWh,** if the whole lighting system is considered. The European GreenLight Programme (www.eu-greenlight.org) is promoting this concept and has already achieved remarkable savings (in the order of 100 – 200 GWh) [Gre 2004]. Other important electricity savings in the non-residential building sector are in office equipment (hence the need of a more effective implementation of the Energy Star Programme), and in the cooling and ventilation systems (through the use of natural ventilation, and free cooling, as well the introduction of energy-efficient compressor based cooling and tri-generation).

The results are summarised in the following table, which shows the potential electricity demand reduction up until 2015. The table compares two different reduction potential scenarios based on JRC estimates with the BaU scenario.

Table 1.10: Potential Electricity Demand Reduction up until 2015

	Electricity Consumption 2005	Realistic Demand Reduction Potential by 2015 compared to the	Ambitious Demand Reduction Potential by 2015 compared to the

[12] Most of the energy efficiency measures are cost-effective. This means that they will result in net money savings for the users, as the reduced electricity cost over the life time of the appliances will be bigger than any additional purchasing cost for the more efficient model. In many cases there is an increase in manufacturing costs to manufacturers, which can be passed onto the users or can be compensated by productivity gains (and in many case will decrease over time when the most efficient components are mass produced). Over the last ten years the EU white goods manufacturers have become more profitable, appliances cost less, and the efficiency has improved, this despite fears by manufacturers that the policy action introduced in the nineties could have had a negative impact. Therefore, it can be concluded that energy efficiency measures, and in particular standards and labels, are cost effective for society and reduce CO_2 emissions at a negative cost.

	[TWh/year]	BaU Scenario [TWh/year]	BaU Scenario [TWh/year]
DESWH [13]	**65**	**3**	**20**
Office Equipment	**60**	**10**	**20**
Standby	**44**	**20**	**30**
Residential Lighting	**95**	**16**	**33**
Main Domestic appliances	**165**	**44**	**60**
Electric motor systems	**707**	**60**	**200**
Commercial lighting	**185**	**36**	**72**
Total	**1,321**	**189**	**435**

[13] Domestic Electric Storage Water Heaters (DESWH), the saving potential indicated is only related to the reduction of the thermal stand-by losses due to thicker insulation. Additional saving will come from control strategy (thermostat and timer). Even larger electricity saving will be achieved by introducing solar thermal panels.

Chapter 4

BIOMASS

Robert Edwards, Marcel Šúri, Thomas Huld,
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4.1 Well – to – Wheels Analysis of Biofuels

Robert Edwards

The Renewable Energies Unit was responsible for the biofuels part of a Well-to-Wheels (WTW) analysis of alternative transport fuels produced in collaboration with CONCAWE (EU petrochemical industry collaboration on environmental and safety research) and EUCAR (EU car industry technical collaboration) [Edw 2006]. Also, Vincent Mahieu of IES-TAQ worked on the TTW (tank to wheel) and WTW integration aspects.

Many institutions have published conflicting life-cycle analyses or WTW studies of biofuels, and the original intention was to compare existing studies. However, this proved impossible, due to the lack of transparency of most studies (regarding the input data used, the methodological assumptions) and incorrect methodology. Therefore, it was decided to make a fresh study, which both uses a rigorous methodology, and specifies all assumptions and input data, with references. Thus stakeholders are invited to examine the input data and contribute updates and corrections, rather than simply comment on the results. In this way the study continuously evolves and is attaining the status of a reference, being used by the European Commission and IEA studies.

Wherever possible, primary data from industry sources were used. The study evolves by stakeholders reviewing the input data and suggesting improvements and updates. The last major WTW revision was made in March 2006 [Edw 2006], with new availability and cost sections as well as a wider range of biofuels.

For every alternative fuel and power train, the difference in GHG emissions, fossil fuel use and cost-to-EU has been estimated between two realistic scenarios: expanded alternative fuel use and “business as usual”. The study also estimates how much biomass from EU sources could be converted to different biofuels at a given cost.

The study considers all routes to alternative road transport fuels with a significant potential in 2010-2020.

The main limitation to the introduction of biofuels is cost. As a first step for comparing the advantages of biofuels produced by different routes, the results of the study are expressed in terms of two figures-of-merit, representing the cost of replacing a certain quantity of fossil fuel, and the cost of avoiding a certain quantity of greenhouse gas.

A Well-to-Wheels (WTW) analysis is a life-cycle analysis restricted to quantitatively well-defined aspects. Thus it excludes such factors as employment and effects on macro-economic domestic product. However, more complex factors, such as effect on local employment and economy, soil and water protection, ecological effects, implications for innovation and trade also need to be considered when formulating biofuels policy.

4.1.1 Method

For every alternative fuel and power train, the JEC study estimates the difference in GHG emissions, fossil fuel use and cost-to-EU between two realistic scenarios:

- Scenario with expanded alternative fuel use,
- Reference "business as usual" scenario.

These scenarios must only differ in fuel use and production. Thus by-products from biofuels (e.g. rapeseed cake from biodiesel) must be balanced by an equivalent product in the reference scenario, representing the product they substitute (e.g. soybean meal). This subtraction results in a credit representing the fossil energy use, GHG emissions and cost of substituting the product by the by-product.

4.1.2 Results and discussion

In Fig. 4.1, the vertical axis shows the cost of replacing fossil fuel, using various processes for making biofuels. The costs are compared to a 2012-technology gasoline car, which lies at the origin. The horizontal axis shows what this means in terms of the cost of avoiding GHG emissions.

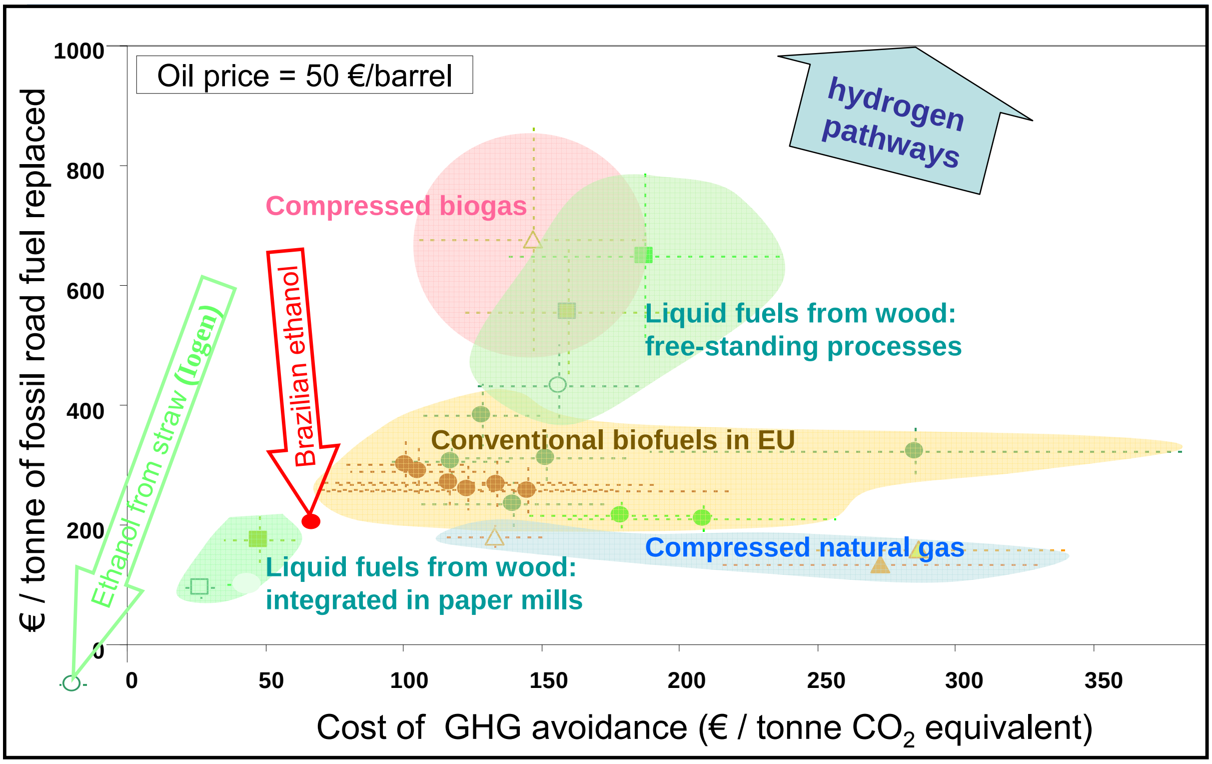


Fig. 4.1: Vertical axis: cost-to-EU of substituting diesel and gasoline with various alternatives. Horizontal axis: the associated cost of GHG avoidance
(50 €/barrel = ~64 $/barrel at Sept 2006 rate = 384 €/tonne)

The assumptions were the following:

- The cost-to-EU (removing subsidies and tax concessions),
- No knock-on economic costs/benefits (employment, innovation etc.),
- Oil price is 50 Euro/barrel,

- Inclusion of the annualised cost of maintaining the distribution infrastructure,
- Inclusion of annualised cost of any vehicle modifications,
- 2012 technology,
- “Learning curve” for costs assuming 5.75% market share for new fuels.

We see that only some of the routes to “advanced” biofuels offer cost savings compared to existing “conventional” biofuels, although they compete better in terms of GHG saving. Hydrogen pathways are expensive because of the high cost of distribution and vehicles in 2010-2020 scenario (5.75% market share assumed for costs). Ethanol from the straw-to-ethanol process appears to be already cheaper than fossil gasoline at an oil price of 50€/barrel. However, this point is faded to show our uncertainty on the costs of this process, which is not yet in commercial operation. Although we used yield and process input data from the constructors of a pilot plant, we were forced to estimate plant cost by scaling from a study on a different plant, for wood-to-ethanol [Woo 1999].

Each spot on the graph represents a way of making biofuel: the differences are in the use of by-products and how processes are heated (e.g. natural gas or straw, with or without cogeneration of electricity).

4.1.3 Conclusions

- Burning of biomass for electricity (and/or heat), saves more GHG per tonne of biomass (or per hectare) than does conversion to transport fuels. It also works out cheaper, because of simpler plant.
- The limited (and uncorroborated) data available on straw-to-ethanol indicate that this might be an economic option. Advanced biofuels from woody material would be cheaper than conventional biofuels if produced in a wood-pulp mill, but more expensive if one has to build a separate plant.
- Bio-hydrogen is an extremely expensive option due to the high cost of compression and distribution.
- Biogas from anaerobic digestion can be compressed as a transport fuel. This gives fewer greenhouse gas emissions than conventional biofuels, but is more expensive if one includes the cost of maintaining the distribution infrastructure. Biogas is more effectively used to replace natural gas.
- Readers are invited to download the JEC study [3], to review the input data and assumptions, and to suggest updates or corrections. In this way the study evolves.

Acknowedgements:
The main authors of the WTT section of the JRC study are R. Edwards (JRC), and J-F Larivé (CONCAWE), with technical assistance from W. Weindorf at L-B Systemtechnik GmbH. A full list of authors and collaborators is on the website[14].

[14] http://ies.jrc.ec.europa.eu/WTW

4.2 Availability of Biofuels from EU Production

Robert Edwards

The Well to Wheel study also estimates how much biomass from EU sources could be converted to different biofuels at a given cost. In the North of Europe, ploughing up grassland to grow more crops for biofuels would result in a large release of carbon from the oil, and should be avoided. In the South, agricultural production is mostly limited by the availability of water. Therefore crops for biofuels are restricted to the existing EU arable area. The effects of biofuels on imports and agricultural prices are also assessed.

As a baseline we used a DG-AGRI projection for agricultural production and markets up to 2012, assuming biofuels production remain at 2005 levels, as well as a constant demand for food crops, we then considered the possibilities and consequences of increasing biofuels production at the 2012 horizon.

Considering land as the primary resource leads to difficulties because of the large variations in land quality and therefore potential yields. Instead we used cereal production as a proxy for yield postulating a constant ratio between the yield of cereal and the yield of other crops.

The availability of waste biomass for energy is much higher than that for conversion to road fuels. This is because of the economic scale of the plants: heat and combined-heat-and power applications are economic on a small scale, and can exploit dispersed resources. In contrast, plants for converting waste to biofuels are complex and expensive: to be economic, they must be large to benefit from the economies of scale (100-200MWth at the least). Therefore the amount of biomass which could be converted to biofuels is much less than that which could be burnt for heat and/or electricity.

4.2.1 Conventional ethanol and bio-diesel

The scenario for maximum possible production in the EU of conventionally produced ethanol and bio-diesel is summarised in the table below. The scenario assumes a production of 230 PJ/a of ethanol corresponding to 5.75% of the gasoline demand on an energy content basis (the EU Commission's target for 2010). This can be achieved with the sugar beet surplus (10.0 Mt/a) plus just under half of the surplus cereal production potential (26.4 Mt/a) (Table 4.1).

The remaining notional cereal surplus of 29.2 Mt/a from the balance of the set-asides, the net land released by the sugar reform and yield improvements, is available for bio-diesel production. If the land corresponding to this cereal surplus were used for oil seeds production, 13.0 Mt/a of rape seeds and 3.5 Mt/a sunflower seeds could be produced (assuming a 80/20 land use ratio). The total oil seeds potential, including the 5.6 Mt/a of oil seeds already used today for bio-diesel production, corresponds to 311 PJ/a of bio-diesel equivalent to 3.5% of the total diesel fuel market including personal cars, commercial and heavy duty vehicles. It must be realised that this estimate assumes no change in the amount of oilseeds imported for food use.

Overall, around 4.2% of the road fuels market can be covered by these conventional bio-fuels (in energy terms), equivalent to the substitution of 12.5 Mt/a of fossil fuels. Note that the net fossil energy saved is only 2.3% and the GHG savings only 2.1% because these fuels are only partly renewable.

The estimated cost for replacing fossil fuels with biofuels with the realistic grain/oilseed trading scenario is 409 and 231 € per ton and the cost of CO_2 avoided is 228 and 129 € per ton for the low and high oil price scenario respectively. This is the additional cost above that of the fossil fuel in the base-case.

This scenario is, however, unlikely to happen, because it would require between two and three times more fraction of arable land devoted to oilseeds, leading to rotations which are more frequent than optimal, and/or growing rapeseed in rather unsuitable areas, driving up costs (a simple estimate based on linear supply flexibility indicates all-EU production at this level would increase rapeseed prices by 76 %!). Therefore, new import barriers would be needed to prevent imports undercutting EU-produced oilseeds and these are probably not compatible with existing trade agreements. Anyway, it would be cheaper for the EU to import oilseeds in exchange for cereals exports. The fundamental reason is that Europe is climatically better suited to cereals production than oilseeds (that is why EU already imports almost half its present oilseed requirements).

Table 4.1 Potential for production of conventional ethanol and bio-diesel in EU-25

	Crop		Ethanol	Bio-diesel	Fossil fuels replaced		WTW avoidance				Cost @25 €/bbl			Cost @50 €/bbl		
							WTW Fossil energy		WTW CO_{2eq}		€/ t conv fuel	G€/a	€/ t CO2 av	€/ t conv fuel	G€/a	€/ t CO2 av
	Mt/a	PJ/a	PJ/a	PJ/a	PJ/a	Mt/a	MJ/MJ	PJ/a	g/MJ	Mt/a						
Surplus sugar beet	10.0	38	20			0.5	0.27	5	28.4	0.6	413	0.19	342	250	0.12	207
Surplus expressed as wheat grain																
From set-asides	31.0															
From net land released by sugar reform	7.6															
From improved yields	16.9															
Total surplus	55.6															
To ethanol	26.4	390	209			4.8	0.46	97	36.4	7.6	359	1.74	243	216	1.05	148
To oil seeds	*29.2*															
Equivalent oil seeds[(1)]	⇩															
Rape	13.0	310		181		4.2	0.72	130	45.1	8.2	437	1.84	230	235	0.99	123
Sunflower	3.5	83		52		1.2	0.83	43	67.4	3.5	467	0.57	169	260	0.32	94
Existing oil seeds for energy																
Rape	5.6	133		78		1.8	0.72	56	45.1	3.5	437	0.79	230	235	0.42	123
Total			**230**	**311**	**541**	**12.5**		**333**		**23.4**	**409**	**5.13**	228	**231**	**2.89**	129
Gasoline/diesel market coverage			**5.75%**	**3.5%**												
Total road fuel market coverage			**4.2%**													
WTW avoidance, % of fossil fuels base case								**2.3%**		**2.1%**						

(1) Assumes 80/20 rape/sunflower

Several studies have quoted the percentage of arable land which would be needed to reach the Biofuels Directive targets. The vast difference in yields between different types of land makes a "% of land" meaningless. According to our figures, the extra crops required to bring about the required increase in biofuel production (assuming 5.75% replacement of diesel by bio-diesel and 5.75% of gasoline by ethanol on an energy basis) would replace 27% of projected EU 2012 cereals production, or roughly 22% of total arable capacity (not including set-asides) or roughly 19% of arable capacity including set-asides.

- The EU does not have enough arable capacity on the existing arable land area + set-asides to reach this target in 2012 without increasing food imports (elimination of potential cereals exports is already included in our figures).

4.2.2 "Advanced" biofuels

This includes ethanol from cellulosic material and synthetic fuels produced by biomass gasification and syngas-based synthesis processes. "Wood" is short for "lignocellulose resources largest potential sources being farmed wood, perennial grasses and wood waste from forestry.

The potential for farmed wood (short rotation forestry or SRF) was estimated on the basis of the cereal surplus discussed above, assuming a substitution mass ratio of 1.57 t of wood per t of cereal (Table 4.2). The land producing the estimated 56 Mt/a surplus cereals could potentially produce 88 Mt/a of wood instead, with an additional 15.8 Mt/a from substitution of existing oil seeds.

Wood waste availability was estimated on the basis of a recent detailed study of wood (mostly forest residuals) for energy. About one quarter of the total would be available cheaply (2.8 €/GJ) at pulp mills suitable for using the black-liquor biofuels route. Of the rest, we estimated that only 1/3 would be logistically available to other plants for making biofuels and then the price would rise to that of farmed wood, i.e. 4.1 €/GJ. That means a total of about half the energy-wood is available for making biofuels: about 26 Mt/a. This brings the total wood availability to just under 130 Mt/a.

Wheat straw is the most concentrated source of cellulosic material. We used a GIS-based study which considered regional straw yields (see 4.3).

Table 4.2 Potential for production of advanced biofuels in EU-25

Resource	Mt/a	PJ/a	Ethanol PJ/a	Syn-diesel PJ/a	*(Naphtha)* PJ/a	DME PJ/a	Hydrogen PJ/a
Surplus sugar beet	10.0	38.4	20				
Wheat straw	15.9	230	97				
Surplus wheat grain							
Set-asides	*31.0*						
From net land released by sugar reform	*7.6*						
Improved yields	*16.9*		←		Or		→
	⇩						
As farmed wood	87.3	1571	539	491	*164*	802	980
Existing oil seeds for energy	*5.6*						
	⇩						
As farmed wood	15.8	284	97	89	*30*	145	177
Waste wood	26.2	471	162	167	*56*	274	332

Assumptions for all scenarios:
Marginal sugar beet still grown
Straw only used for ethanol production
50% of waste wood used though black liquor route

4.2.3 Biogas

Although there is a lot suitable biomass feed around, the problem is to estimate what proportion of the total available could be used, and at what cost. Biogas plants are capital-intensive relative to their output, particularly when upgraded gas is required e.g. for use as CBG. These plants cannot support high feedstock costs such as may be associated with long-distance transport. In Denmark, the EU country where the biogas industry is the most developed and where intensive agriculture and short distances provide a favourable environment, even fairly large scale plants can only be economic when co-processing waste from fisheries, slaughterhouses and dairies, for which they actually get paid.

We chose the most economic example of biogas production for our availability scenario, on the basis that this would be how the industry is most likely to develop in the next 10 – 20 years. This requires co-feeding of slurry and organic waste (either food industry waste or municipal waste). The potential road fuel production from this type of plant is limited to less than 100 PJ/a in EU-25 by the simultaneous availability of organic waste and large quantities of animal slurry.

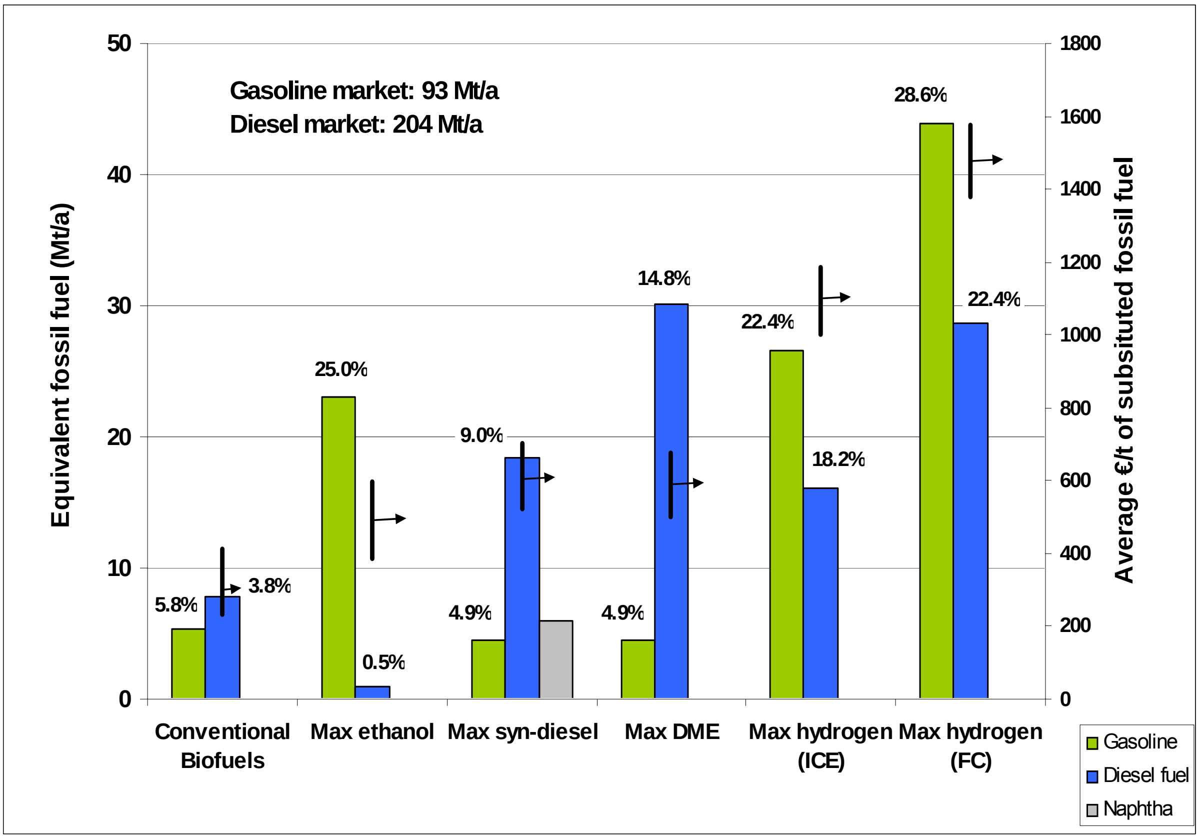
Farmed crops can also potentially be used to produce biogas. However the high cost of such feedstocks is likely to make this option uneconomic compared to other alternatives. We have therefore elected not to consider it.

Table 4.3 Fossil energy and GHG emissions avoidance potential from biogas in EU-25

Scenario	Total	Road fuels		Avoidance						Cost					
	Alt fuels	market coverage		WTW fossil energy			WTW CO_{2eq}		Fossil fuels	Oil @ 25 €/bbl			Oil @ 50 €/bbl		
	PJ/a	Gasoline	Diesel	MJ/MJ	PJ/a	% of total for fossil fuels	g/MJ	Mt/a	Mt/a	€/ t fossil fuel	G€/a	€/ t CO_2 av	€/ t fossil fuel	G€/a	€/ t CO_2 av
Biogas	200	2.8%	0.9%	0.99	198	1.3%	140.4	28.1	4.5	824	3.7	130	646	2.9	102

4.2.4 Overview of biofuel potential from EU biomass

Figure 4.2 shows columns representing the amount of biofuels which could be produced from EU resources with different types of biofuels. Compressed biogas is not included. The numbers give the corresponding percentage of the expected 2012 gasoline and diesel consumption.



Left axis: coloured columns represent how much biofuel can be produced from EU resources, limited by economics and logistics. Also shown in figures is % replacement of gasoline or diesel fuel in 2012. (Naphtha is a co-product of syn-diesel production which could be used as transport fuel or, more likely, as chemical feedstock.)
Right axis: corresponding average cost of substituting fossil fuel.

Fig. 2.4: Potential and average cost of EU transport fuel substitution with different biofuels scenarios.

The second group of columns shows the result of maximising ethanol production, including "advanced" processing of wood and straw as well as cereals. In the "max diesel" scenario, straw is used for ethanol, whilst the rest of the spare agricultural capacity is used for short-rotation forestry. Together with wood chips from the forestry sector, this is used for producing synthetic diesel via gasification. Making DME (dimethyl ether; a diesel fuel with physical properties similar to propane) is more efficient, allowing more replacement at similar cost.

- The target of 5.75% replacement of EU transport fuels by biofuels cannot be reached from EU resources using “conventional” biofuels, if one is to avoid the loss of soil carbon caused by increasing ploughed area.
- “Advanced” biofuels made from lignocellulose would allow replacement of biofuels from EU resources, but generally at higher cost
- bio-hydrogen maximises the transport-km from given biomass resource, but is extremely expensive on a WTW basis

4.2.5 Expert Workshop to review availabilities data

In order to review and improve the work of JRC on biofuels availability and cost in the frame of the JEC WTW study, a workshop was organized by R. Edwards and V. Mahieu (IES Emissions and Health Unit), with help from other partners in the study. Apart from representatives of the study partners, there were 18 experts on various aspects of biofuels availabilities and 14 participants from Brussels DGs. The Proceedings are available on the WTW web-page [Edw 2006]

The title of the workshop was Availability and Cost of Biomass for Road Fuels in EU. It was held 3-4 May 2006, at the Borschette Centre, Brussels. In advance, R. Edwards prepared a detailed agenda which identified the critical points which limit the accuracy of estimates of biofuels availability. This included quantifying aspects of the following topics:

- Soil carbon effects
- Bio-energy Crops (SRF, switch grass, miscanthus, herbaceous)
- Forest Residuals
- Straw and other Agricultural Waste
- Agricultural Crop Potential, Prices, Market / Imports Effects
- By-products Issues
- Compressed Biogas: Manure and Organic Waste

Although some people were initially surprised by the availability and cost figures, there was very little disagreement when the input assumptions were examined. Differences between studies are mostly due to the different scenarios which were being studied: including or not including existing uses, time-frame, point on the cost-supply curve, use for biofuel or bioenergy/heat. In the case of biogas, the differences result from JEC study considering the whole WTW pathway (including distribution and use in the car) and not just biogas production.

Advice from the experts was that obtaining definite figures in many areas of data uncertainty would be very difficult. No-one could improve directly on the input data from that used in the JEC study, although there were helpful suggestions for literature to be followed up.

4.3 Spatial Analysis of Straw Availability in the EU

Robert Edwards, Marcel Šúri, Thomas Huld and J-F Dallemand

The IES Renewable Energies Unit is carrying out activities of spatial analysis in the field of bioenergy resource assessment. The amount of biomass available for energy use depends not only on the total resource, but also upon how much can be economically and logistically delivered to processing plants. Geographical Information Systems (GIS) have already proven their capability to contribute to the resolution of spatially-determined issues, and in the field of bioenergy the use of map-based assessments is emerging rapidly.

At this stage of our activities, the module on the assessment of cereals straw resources for bioelectricity at European level is the more advanced in our group and an overview of the first results is discussed in the following text. Another module aiming at a harmonised comparison of European Union regions in terms of bioenergy (present use and potential for transport, heat and electricity) is under way. A module on Short Rotation Forestry is at planning stage (present use, acreage and yield per species, land suitability per crop, support schemes, installation/maintenance/harvesting/transport costs, etc.).

There are several pathways of conversion of straw to energy – it can be burned for electricity and/or heat, or it can be converted to ethanol or other transport fuels. In our study we have focused on localisation of large electricity power plants as these are supposed to be the most economically effective. Starting from existing data and taking into account agronomic/environmental constraints related to straw harvesting, competitive use of straw and industrial/logistic constraints, the possibility to replicate "Ely clones" (from the Ely power plant experience in UK which uses approximately 200,000 tons of straw per year) in regions of the EU has been quantified and discussed.

4.3.1 Data

We have applied the existing European-wide statistical and GIS data (Eurostat production figures for wheat and barley CORINE Land Cover etc.) in order to assess the technical potential of straw from wheat and barley in the 25 European Union countries and 2 Accession States (Bulgaria and Romania). Besides Eurostat and GIS data we have collected a wide range of studies on straw-for-energy, including papers, national reports, regional case studies and direct communication with research and regional authorities. The support information was collected from the following countries and regions: Bulgaria, Czech Republic, Denmark, France, Germany, Hungary, Ireland, Italy, Lithuania, Poland, Romania, Slovakia, Spain, and England. We focused on extracting the information on agrotechnical and environmental aspects of straw collection, competitive use of straw, technology options, transport costs and data from existing installations.

4.3.2 Methods

First the straw production was calculated on Eurostat NUTS level 2, taking into account variations in yield. Not all produced straw is available for bioenergy. The first two constraints are environmental limitations and the competitive use of straw.

The environmental constraints should prevent collection of straw from fields where there are unfavourable soil conditions: low organic matter content, risk of degradation processes, limited water resources, and extremes of climate. However, as effects of systematic straw collection on environmentally sensitive soils are not well known yet, we have not considered them so far.

There are several uses for straw which compete in some regions with energy applications. The main competitive use is cattle bedding/litter. Significant amounts of straw are also used in horticulture, mushroom production or for industrial processes. However the information published in various studies is inconsistent, and often based on an expert guess with lacking documentation of the methodology and terminology. It is generally accepted that cattle raising is the most important competitive use of straw. Based on the scattered data of available studies we have estimated the straw used per head of cattle from total straw produced per head of cattle in each of NUTS level 2 region and subtracting this estimation of competitive use resulted in a map of the net surplus of straw at the level of regions.

In the next step, we used the CORINE Land Cover (CLC) data to spatially disaggregate this information onto a regular grid with a cell resolution of 5x5 km so that spatial analysis can be performed (Fig. 4.3). The area of wheat and barley was estimated in each 5x5 km grid cell, assuming that it is distributed uniformly on the fraction of the cell devoted to the CLC category 211 (arable land).

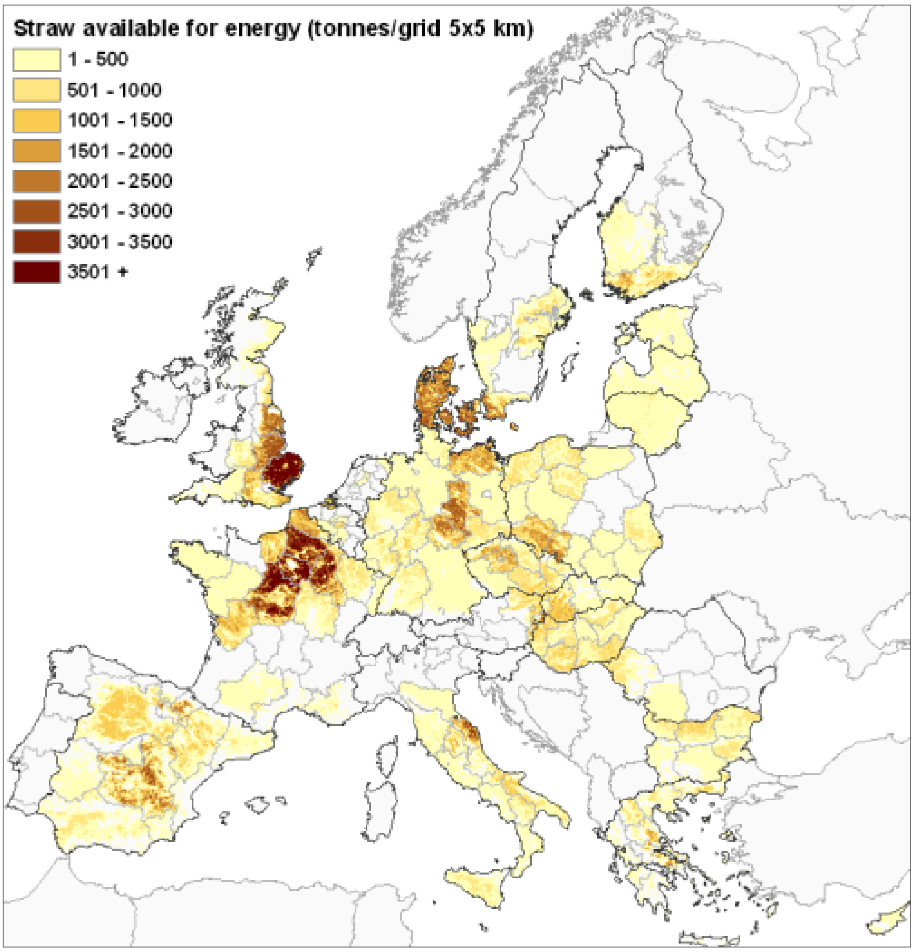


Fig. 4.3: Net availability of straw (tonnes per 5 × 5 km grid cell), estimated by disaggregating the net straw availability per region using CLC data (category arable land).

Another constraint on the availability of straw-for-energy is how much straw can be made economically and logistically available at the conversion plants. This requires knowledge of the optimum size of such a power plant. Then suitable locations for the plants can be hypothesized on the basis of the maximum transport distance, which depends on the net available straw density. The specific capital cost of a straw-burning power plant decreases as it is made bigger, but the cost of straw transport increases. The generating costs show a minimum with increasing plant size. Therefore the spatial density of net straw availability in the capture area of the plant affects the optimum plant size, and the cost of the electricity produced. Due to the logistics limitation, we decided to consider size of the world's biggest power plant that is in operation in Ely (UK). More information about the economical consideration can be found in the paper by Edwards et al. [Edw 2005].

4.3.3 Results

We chose the highest resource density to locate the first 120 MW_{th} (38 MW_{el}) power station (see Fig. 4.3), then proceeded to find optimal locations of further power stations until their straw supply radius exceeded 50 km. The resulting map (Fig. 4.4) shows that in the region studied one could theoretically build about 67 Ely-sized power plants (most of them in France, UK and Denmark) with total capacity of 2.5 GW. Using this capacity the straw energy utilised would be 230 PJ (LHV thermal) (out of a total net straw availability of 820 PJ) generating about 21 TWh electricity per year. The generating costs for the locations identified for power stations were estimated to rise from 68 to 73 €/MWh as straw transport distance increased (Fig. 4.4).

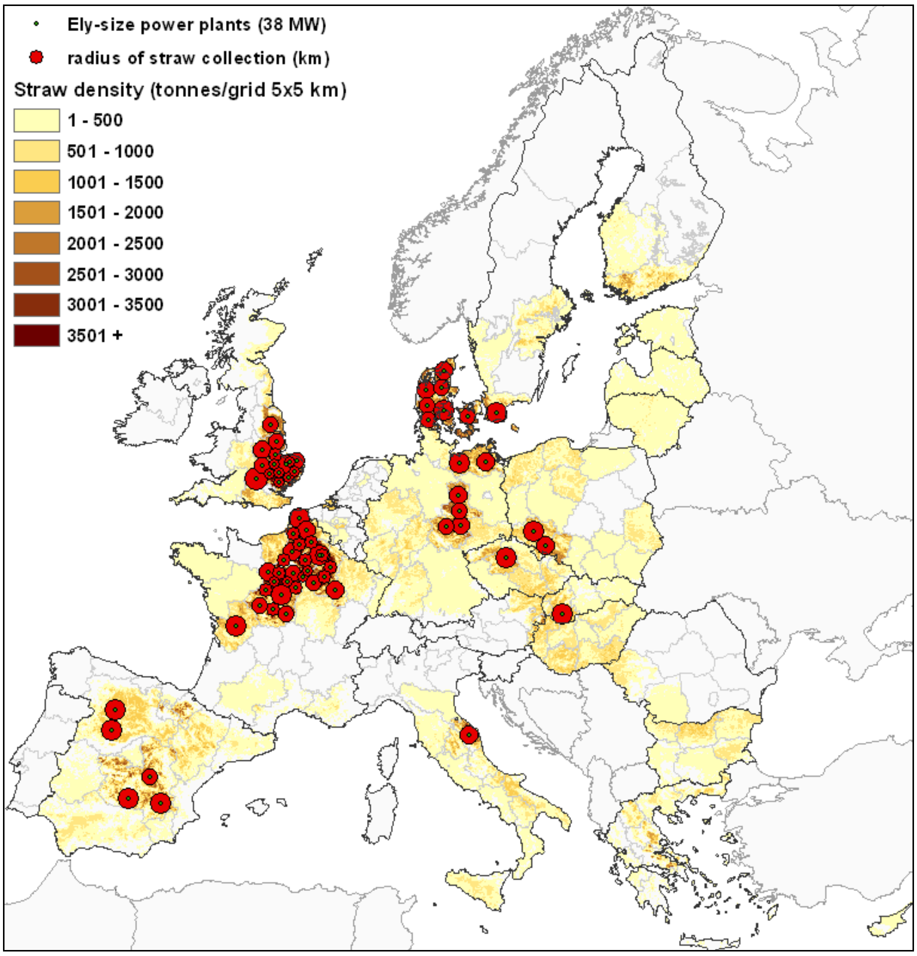


Fig. 4.4: Theoretical localisation of ELY-size (38 MW) electricity generation power plants in the EU25+2 countries.

4.3.4 Conclusions and discussion

It should be noted that this example of the spatial analysis – at this scale – has only the scope to find the maximum number of power stations, not to propose particular sites, which would require much more detailed local assessments of logistics. In this case we ignore the fact that some straw is already used by the existing power plants in the UK (1 installation) and in Denmark (11 installations).

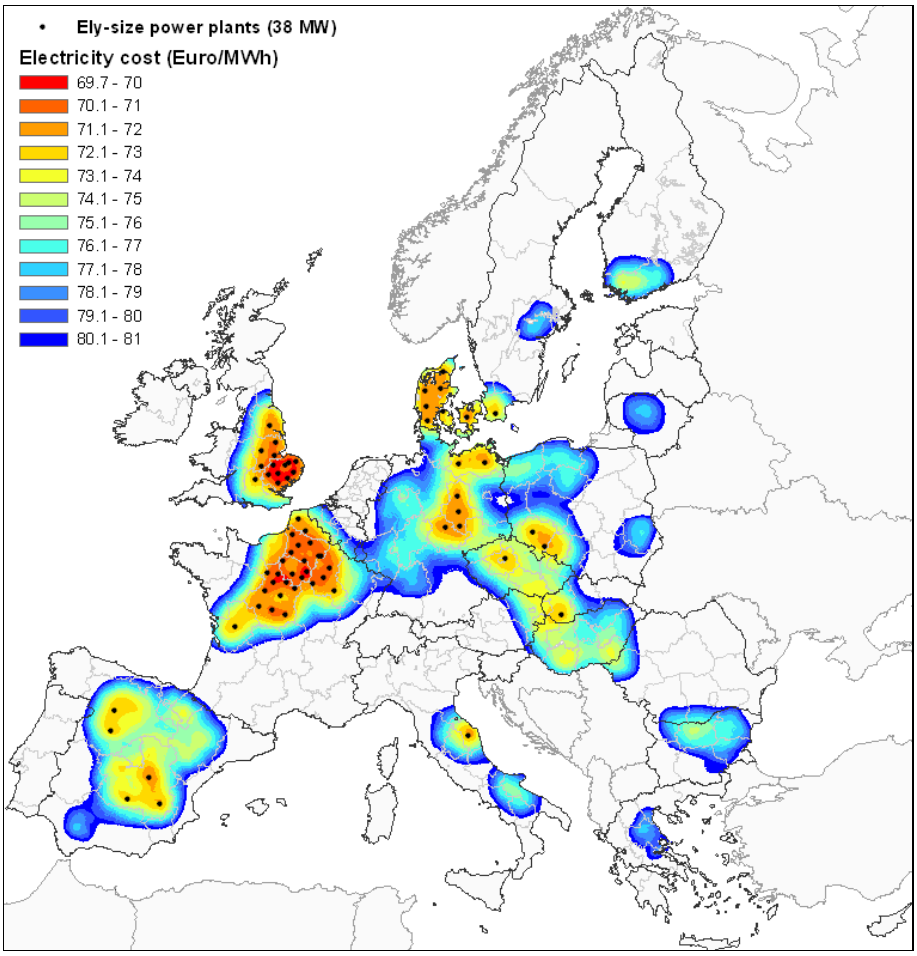


Fig. 4.5: Effect of resource density on electricity cost, assuming theoretical location of 38 MW electricity generation power plants.

The most significant limitation for building big straw-electricity capacities (>50 MWel) is logistics imposed by the daily traffic of heavy trucks shipping straw close to the power station. In our study the 67 electricity-generation power stations have still left out 72 % of straw for small-scale applications. There is a range of smaller applications that could be considered further in the analysis. More of the available straw could be used in smaller CHP plants which can be economic where there is an existing need for the heat, or in heating boilers. There is still potential for technological improvements in converting straw to pellets/briquettes that would allow much wider use in small-scale applications.

4.4 European Biomass Data Collection

J.F. Dallemand, M. Szabo, N. Scarlat

The IES Renewable Energies Unit is engaged in activities of scientific and technical networking within the framework of the activities of the Scientific and Technical Reference System on Renewable Energies and Energy End-Use Efficiency[15]. Since bioenergy is a multi-disciplinary field based on a wide range of different technical expertise, scientific and technical networking is a key issue to discuss various options and build consensus at European level. An example of such activities is the JRC-EEA-CENER-CIEMAT Expert consultation on "Sustainable bioenergy cropping systems for the Mediterranean" (Madrid, February 2006) [JRC 2006] where experts discussed bioenergy development in the South of Europe with regard to agro-environment, water supply, biodiversity and costs competitiveness.

The Mediterranean region has specific environmental and farming characteristics, such as an arid climate, risk of soil erosion and a high climatic variability over the years. All of these might become more pronounced as an effect of climate change. On the other hand, this region has a high share of extensive farmland with a high nature value, that will need to be protected from intensification on the one hand, and from abandonment on the other. Bioenergy production will need to fit into this framework. At the same time, the requirements for energy crops are different to those for food crops (energy vs. nutrient value) which implies that other crops may be needed. It is not only high yields but also energy content and energy balance which should be considered. Agroenergy involves a whole system approach and evaluation of all the potential products (energy, biofuels, fertilisers, industrial products, etc.).

Historically, biomass has not been produced for energy as it has been for food, so there is scarce information on yield figures, adaptability, varieties, etc. The identification of the most suitable bioenergy crops for the Mediterranean is thus a complicated issue and needs much further research as well as practical implementation in existing farming systems. Currently there are significant yield differences between experimental fields and practical applications by farmers at either small or larger scale. There is also still much RTD needed on plant breeding, selection of crops, and varieties which may improve the characteristics of crops suitable to arid Mediterranean conditions. A GIS approach would be useful for incorporating detailed pedo-climatic and socio-economic conditions and determining the most suitable crop mixes for each local situation.

For oil production, traditional crops might be used as a first option, but novel biomass crops are promising, including: *Cynara*, *Carinata*, Castor bean, oil palm, and *Jatropha*. For these new crops whole crop usage favours the economics of the whole biomass chain.

Regarding ethanol crops, the energy balance of some conventional crop-conversion routes is sometimes not favorable. New crops with high water use efficiency have to be considered. Examples of these novel crops are the Jerusalem artichoke, sweet sorghum, prickly pear and wild tobacco.

Lignocellulosic crops were seen as crops that may be well suited to the climatic conditions, while still providing a high yield. However, for some crops, irrigation may be needed. There is a wide variety of short rotation forestry and herbs that can be used for bioenergy production. Compared to conventional systems, perennials can offer

[15] http://streference.jrc.cec.eu.int

some advantages, such as reduced soil erosion, less need for fertilisation and pesticides, while increasing the carbon sink and organic matter.

It was found that in general, there is a variety of biomass options for electricity/heat generation, but there are far fewer options to sustainably produce bioenergy crops as feedstock for liquid biofuels. This may change with the introduction of advanced biofuel conversion technologies. However, for many crops irrigation is a key factor for long-term stable yields, and the resilience of plantations of perennial crops. The optimal trade-offs between the quantity of water use, the time of irrigation and the yield will still have to be found out. This is crucial for bioenergy production in the Mediterranean. There is much research needed on finding measures to improve efficiency in relation to the input-output ratio of water and nutrients in the cropping phase, and the energy efficiency throughout the full chain, including the conversion step from biomass to energy. Overall there is a need to get an integrated picture of all environmental considerations in relation to the cropping systems, and the whole energy production chain.

Today biomass subsidies are not linked to “sustainability standards” (greenhouse-gas emissions, biodiversity, security of supply, rural economy, etc). More research is needed on what is sustainable, as well as how to measure and to certify it. From a broader sustainability perspective, costs and logistics of biomass production, collection, transportation and conversion will have to be considered. Important factors are the limited availability of land, the higher costs of bioenergy crops compared to residues, and the high variations in crop yields between years. Overall, combinations of suitable bioenergy crops and biomass residues might have to be used, i.e. bioenergy crops and by-products might well be complementary.

Improvements in the logistics have to be studied, but they also need to be implemented in practice taking into account the area-specific circumstances. This implies an involvement of the appropriate stakeholders and of industry. In addition, detailed economic fact-finding studies need to be carried out, especially in relation to quantifying externalities.

Overall, it was agreed that sustainable bioenergy chains can only be developed if interactions between sectors are taken into account. For sustainable bioenergy crop production in the Mediterranean, agro-environmental perspectives identified during the workshop were:

- Firstly, to use productive, irrigated land for new energy crops as an alternative to intensive food production, instead of converting high nature value farmland to intensively-used arable land for bioenergy production.
- Secondly, to help reducing water and other input use wherever possible; reduce the risk of soil erosion. This also includes the selection of the crops with low environmental impacts.
- Thirdly, to develop biomass extraction as a complement to fire prevention measures on forest and scrubland.
- Fourthly, evaluation and planning at different geographical levels is needed, taking into account a range of environmental aspects (biodiversity, water use, inputs, etc.), and the different farm and environmental realities.
- Finally, co-operation between different sectorial authorities is crucial to integrate energy, environmental, and agricultural issues.

Other activities in preparation include an Expert Consultation on "Cereals straw for bioenergy in the European Union" which was held at Pamplona (CENER, Spain in October 2006). The main topics discussed will be the agro-environmental impact of straw harvesting, the competitive uses of straw and the logistic/industrial constraints related to the use of straw for bioenergy in Europe. In France, according to INRA [Gos 2005], the national resource of cereals straw is estimated between 22 and 25 million tons. Assuming a yield per hectare of 3.5 tons, after deduction of competitive use, 8 million tons are still available for new uses. With a 50% abatement to preserve the soil fertility, this leads to an INRA estimation of 4 million tons available for bioenergy.

In the case of Lithuania, according to the Lithuanian Institute of Agricultural Engineering [Kat 2006], if the present use of straw for energy is very limited, about 40% of straw yield (i.e. 400-500 000 tons at country level) is unused and could possibly be used for energy purposes. With 15% left on the soil, the competitive uses are estimated as: bedding, 40%, fodder 4%, and 1-2% for gardening, mushroom cultivation and other purposes. One of the objectives of the expert consultation in preparation is to collect, discuss and analyse regional figures in order to improve European/national estimates.

Within the framework of the STRS RE and EEE activities, specific attention is paid to the collection of data and information leading to harmonised bioenergy data profiles, especially for the New Member States of the European Union. In 2006, the STRS on RE and EEE launched studies on methodological improvement of statistical data collection regarding biomass availability and use in the 10 New EU Member States. In the first stage the two reports have been prepared by the teams of Estonia [Soo 2006] and Lithuania [Kat 2006]. The core bioenergy indicators are presented below in Figures 4.6 to 4.9.

4.4.1 Estonia

In Estonia, the main energy and biomass related policy documents are the Electricity Sector Development Plan, the Long-term National Development Plan for the Fuel and Energy Sector, the National Environmental Strategy and the Forestry Development Plan. For the country including 15 counties, 109 rural municipalities and 33 cities, the data on energy production are collected annually by the Statistical Office from all enterprises producing primary or secondary energy. Data are also collected from auto-producers of heat and electricity. Data on energy and fuel consumption are collected by a sample survey leading to yearly energy balance sheets. The present potential of biomass from agriculture can be estimated from the agricultural statistics collected by the Statistical Office (13 surveys conducted in 2004 including data on land use, sown area, production etc.). The national reporting system includes a public database of statistics available via Internet[16]. For Eurostat reporting, the statistics on biomass as energy source are presented in the Energy Questionnaire on Renewables and Wastes.

In Estonia, the share of renewable energy sources in the total primary energy supply is relatively high i.e. 12.2% in 2004. Traditional forest biomass is the major source of renewable energy utilised in Estonia with a share of 11.6% (corresponding to 95% of the renewables). Black liquor constitutes 4.4% of renewables and other renewables (biogas, hydro and wind) 0.7% only. Firewood corresponds to the major share of wood fuels utilised in Estonia. The share of refined wood fuels, such as briquettes and

[16] www.stat.ee

pellets, is still marginal (below 1%), in spite of the quite large production capacity. Black liquor is utilised in one pulp plant only.

Regarding wood utilised as fuel, a great part of available volumes of traditional wood biomass is already used for energy production. The availability of wood fuel has thus become a main problem for new bioenergy projects. At short-term, an option could be a wider use of harvesting residues not used presently. At longer-term, energy crops, short rotation forests, straw and reed could be utilised.

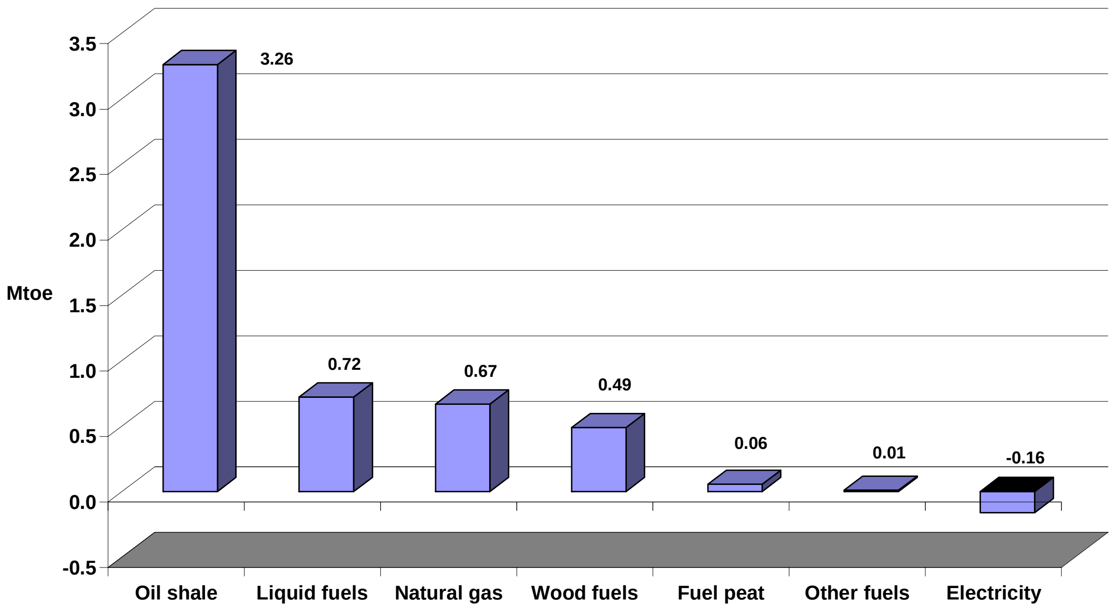


Fig. 4.6: Structure of primary energy supply, Estonia (Source: Tallinn University of Technology)

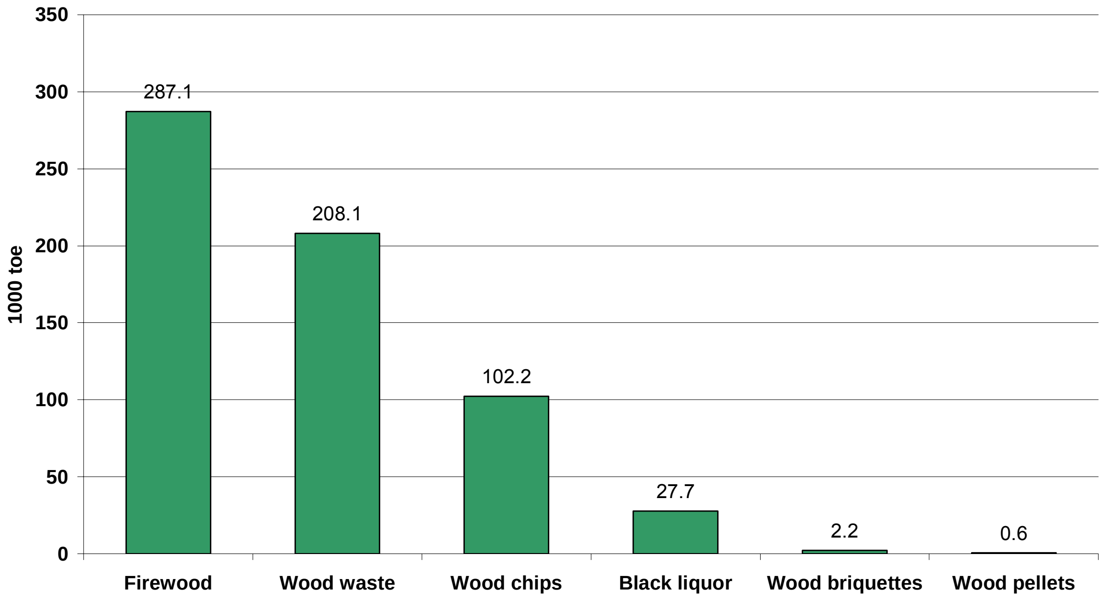


Fig. 4.7: Energy market (Estonia), Current energy use of biomass (2004) (Source Tallinn University of Technology)

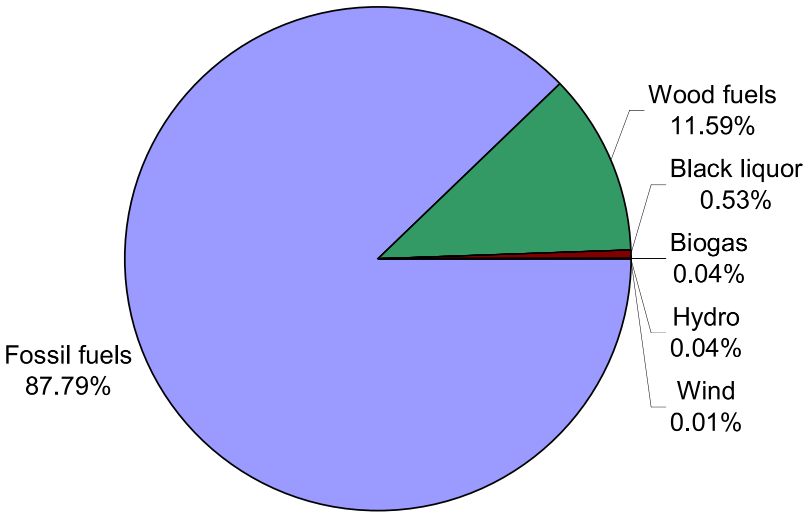


Fig. 4.8: Share of renewable energy in gross inland energy consumption (Estonia, 2004) (Source Tallinn University of Technology)

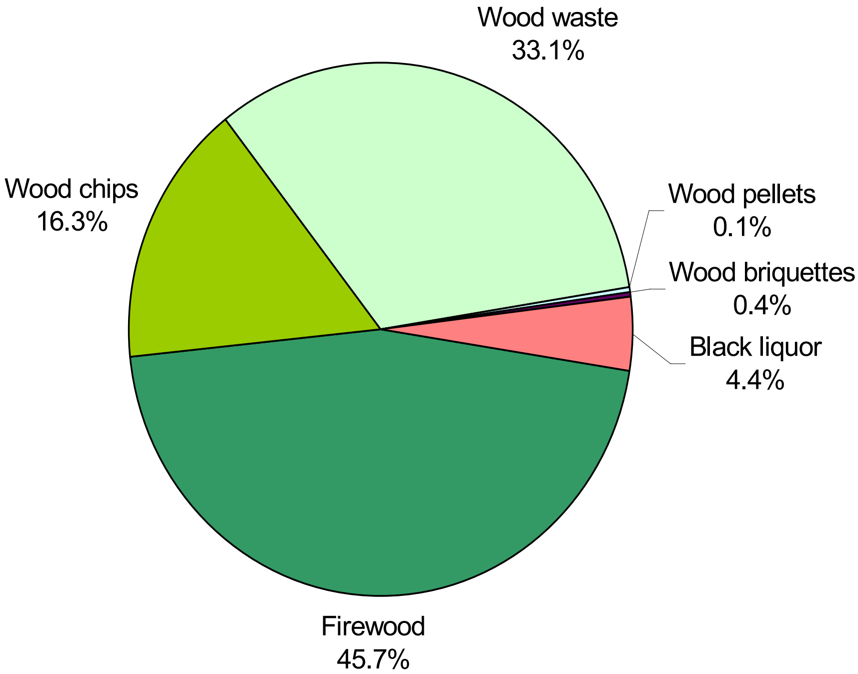


Fig. 4.9: Share of sources in biomass consumption (2004) (Source Tallinn University of Technology)

4.4.2 Lithuania

In Lithuania, the size of the biomass market is increasing and the use of biomass for energy production increased from 284.7 toe in 1990 to 699.6 ktoe in 2004, which corresponds to 6.76 % of the national primary energy consumption.

In 2004, RES amounted to 8% from primary energy consumption, with biomass corresponding to 94% of RES. The present total installed thermal capacity of biomass burning boilers is 427 MW_{th}, with a large part of wood fuel consumed in households (62.9% in 2004, i.e. 433.4 ktoe). The total capacity of biogas plants (from animal manure, organic waste of food industry and sewage sludge of wastewater treatment plants) is 2 $MW_{el.}$

4.4.3 Bioenergy Regional Profiles

Even if large quantities of data on bioenergy are available in Europe at regional level, these data are difficult to collect and compare since based on different terminologies or methodologies. For this reason, the Renewable Energies Unit started in 2006 a new activity of regional assessment of bioenergy production and potential. This activity is still at an early phase of methodological development. Among the objectives, we find the regional characterisation of the crops or crops associations feasible for energetic conversion as well as the assessment of the bioenergy potential in selected European regions. Specific attention will also be paid to the documentation of the bioenergy support schemes. The data collection will start with one region per EU Member State.

The preliminary list of biomass resources for the Regional Biomass Resource Assessment Questionnaire can be found in the Annex.

Chapter 5
HEAT FROM RENEWABLE ENERGIES

J.J. Bloem

5.1 Introduction

The European Community aims to promote renewable energies, in order to improve the security of energy supply, improving competitiveness and promoting research and industrial development in Europe as well as improving our environment.

As referred to in the recent Green Paper "A European Strategy for Sustainable, Competitive and Secure Energy”, the international energy situation and Europe’s dependence on imported energy remind us of the urgency to increase the production and use of alternative energies, including renewable energies [EC 2006]. Since 1997, the Commission is working towards the objective of 12% of renewable energies in the EU energy balance by 2010.

While the EU has set legislation on the promotion of electricity generation from renewable energy sources (with an objective of the share of electricity produced by renewable energy of 21% by 2010) and for the promotion of biofuels (with an objective of 5.75% by 2010), the production of heating and cooling from renewable energy has so far not been the subject of specific EU legislation. Fossil fuels are dominating the market of heating of buildings and air-to-air heat pumps dominating the market of cooling of buildings.

However in February 2006, the European Parliament adopted, with an overwhelming majority, a resolution and a report with recommendations by Mrs. Mechthild Rothe (MEP) asking the European Commission to table a Directive proposal to promote Heating and Cooling from renewable energy sources. A draft of this Directive might become available during the winter of 2006-2007.

Although renewable energies heat technologies have been known for centuries, even before the industrial revolution, it has become of political interest again after the oil crisis in the 70s. The technologies presented below for application in the built environment are distinguished based on the primary energy source, e.g. solar radiation, the heat from the earth and the heat from burning biomass. In addition, each technology is characterised by its application (system or plant) size and technology, ranging from small domestic systems to large industrial or commercial systems for combined heat and power energy production. It is therefore often difficult to present data in a coherent way.

The European Renewable Energy Council (EREC) recently drafted a resolution, the RES-H Joint Declaration, which calls for a more proactive approach and a policy framework by the European Commission [Ere 2006]. The main message is that 25 %[17] of the EU heating and cooling supply could be provided by renewable energies in 2020, if the EU sets the right policy framework in due time.

In May 2006, the European Energy Commissioner Mr Piebalgs gave his strong political support to the launch of the European Solar Thermal Technology Platform, which he called “vital to secure the competitiveness of our industry”.

17 EREC is adjusting this number to 20% as the target for the year 2020.

5.2 Data on heat from renewable energies.

Some basic knowledge on heat energy is needed to put the RES heat in the right perspective. According to Eurostat in 2003 the total end use of net heat and electricity was 32.1 EJ in Europe 32 – approximately 55% of the total energy use of 57.3 EJ (Fig. 5.1). For the same year the heat demand alone was estimated to be 21.7 EJ. Heat dominates energy end use. Despite its relevant share in the total heat demand, the domestic hot water consumption remains an unknown factor, as no recent and reliable survey regarding this consumption exists. A detailed assessment of this parameter at national and European level would contribute to a better understanding of the heat market.

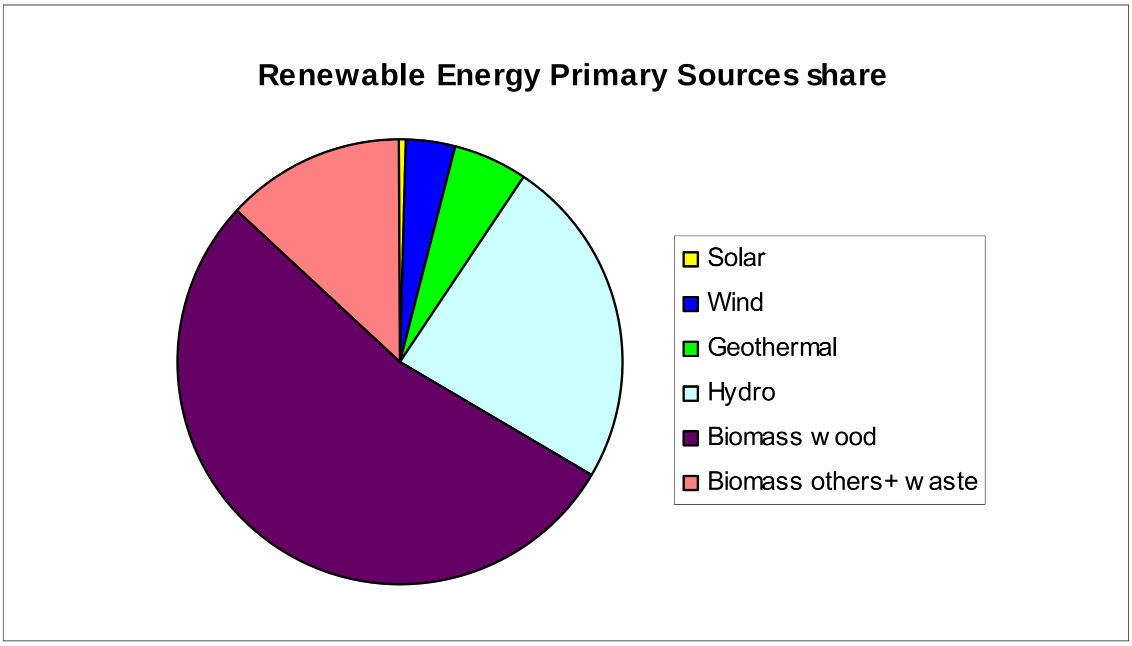


Fig. 5.1: About 50% of the RE share is to produce heat.
Data Source: Elaborated data from Eurostat

One of the major problems for statistics is that measured data on heat in the building sector are hardly available. Most of the information about domestic thermal energy is derived from empirical methods. Because of this lack of data and knowledge, heating from renewable energy has several barriers to overcome. Two running EC projects, K4RES-H and THERRA are trying to compile and assess more up-to-date information on renewable energies heat production and consumption.

In addition the ECOHEATCOOL project uses databases of the International Energy Agency (IEA) and Eurostat as information sources. The comparison with national and/or Euroheat & Power statistics show that national information about district heat is not always properly transferred to international statistics, because of overlapping or restricted definitions. For example, district heat deliveries in Germany, France and Italy are not properly reported to the EUROSTAT database. As a result, the heat deliveries in the target area are substantially underestimated – by approximately one fourth (the domestic heat sector in the three countries accounts for 120 TWh out of a total of approx 550 TWh).

A frequently referred database is EurObeserv'ER[18], where data are collected from different sources, e.g. national agencies, industry associations and national statistics offices. The data in this chapter uses most recent data from the different industry associations.

5.3 Renewable Energies - Heat technologies

In order to describe the different specific technologies clear definitions are required. An introduction how to measure heat is given in the Annex.

5.3.1 Definitions

The term "Renewable Heat" covers all heat that is the result of a conversion process of renewable resources or that contain renewable resources (waste or hybrid power plants).

It is important to describe the conversion processes or systems, including the conversion efficiency and the renewable energy input resource. A schematic impression of the conversion chain is given in Figure 5.2. Note that the auxiliary energy on the input side might have its origin from different resources as will become clear at a later stage.

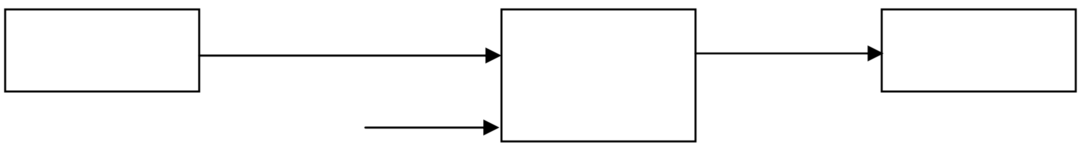


Fig. 5.2: Schematic conversion chain

The following heat resources are defined as renewable: solar thermal, geothermal, biomass (solid, liquid and gas and the bio-degradable part of municipal or industrial waste). A more detailed discussion on the renewable heat resources will be under the specific sections. Each of these technologies has specific conversion systems that might differ in size, conversion efficiency, etc.

An important issue is the definition of the renewable heat on the output side that will be used for statistical purposes. Considered under renewable heat is the heat produced after the first conversion, thus not considering distribution or storage of heat. This is somewhat in analogy to electricity production in which case the useful fraction or distribution losses are not taken into account as well. Distribution losses might be reported separately.

It has to be noted that Eurostat and IEA report only the figures on renewable energy heat from the input side.

In the built environment one may distinguish, based on the resource, three technologies:

[18] http://www.energies-renouvelables.org/

- **Solar Thermal**, the heat from the sun. In the context of this document passive solar or solar cooling applications are not considered. Solar heat can be applied to domestic or industrial applications for the production of hot water, space heating, industrial processes like drying, cleaning, etc.
- **Geothermal**, deep geothermal and shallow geothermal to exploit the heat from the earth. Renewable heat from geothermal systems is converted from the heat that is stored under the solid surface of the earth. Heat pumps are conversion systems often used in geothermal systems and will be addressed more in detail in the specific section.
- **Biomass** heat from wood pellets, chips or logs and in some minor cases from biogas. Liquid forms are not considered in this document.

In addition one may consider waste as a separate resource:

- **Waste**: The biodegradable part of municipal or industrial waste is taken into account, although not all countries consider this form as renewable as being electricity or heat.

Table 5.1 Application areas for RES – Heat in the built environment

	Residential (small size plants)	Tertiary (large size plants)	District and CHP (very large plants)
Solar Thermal	X	X	-
Geo Thermal	-	X	X
Biomass	X	X	X

In the following sections the technologies are briefly presented and recent data available are given.

5.3.2 *Solar Energy*

Solar energy technologies may be distinguished in:

- Passive technology, e.g. building design, urban planning.
- Active technologies e.g. solar thermal (and photovoltaics; out of the scope of this chapter).

Passive solar energy technology by definition does not need auxiliary energy to perform and is related to careful design taking into consideration the location, climate and level of solar radiation. Already centuries ago buildings were constructed in such a way that thermal mass and solar radiation were matching the need for a comfortable environment to live and work in. It is during the last half century that an energy-careful design has received less importance due to the availability of appliances that provide and control a comfortable indoor environment. Note that electricity consumption for air conditioning units and hot water systems is increasing rapidly despite rising energy costs.

Although a very important aspect of energy saving using solar radiation as primary energy resource, the passive solar technology is in general not considered as a renewable energy technology.

Concerning solar thermal systems the market is doing very well. Solar thermal systems in the built environment are used for:

- Domestic Hot Water systems (DHW), being the major application.

- Space Heating, mainly in Northern Europe
- Space Cooling in the Mediterranean area

The applied solar thermal technology can be distinguished in:

- Flat glazed thermo-siphon systems of about 2 – 3 m^2 can be found mostly in Southern Europe.
- Flat glazed forced circulation systems of about 2 – 6 m^2 are installed in Mid- and Northern Europe.
- Evacuated Tube Collectors which have about 15% higher efficiency than the flat plate collector in south Europe and about 30% in northern Europe.
- Unglazed collectors.

Evacuated Tube Collectors take about 10% of the total collector sales in 2005 and are expected to become more popular. By far, most of the systems are used for Domestic Hot Water (90%). Other applications are space heating (in almost all cases these are combination systems) and pool water heating (mostly by unglazed collectors).

Solar thermal data (Fig. 5.3 and 5.4) are available from the European Solar Thermal Industry Federation[19] (ESTIF) and are usually expressed in square metres (m^2) sold or installed area. The International Energy Agency's Solar Heating & Cooling Programme, together with ESTIF and other major solar thermal trade associations, have decided to publish future statistics in MW_{th} (Megawatt thermal) and have agreed to use a factor of 0.7 kW_{th}/m^2 to convert square meters of collector area into MW_{th}

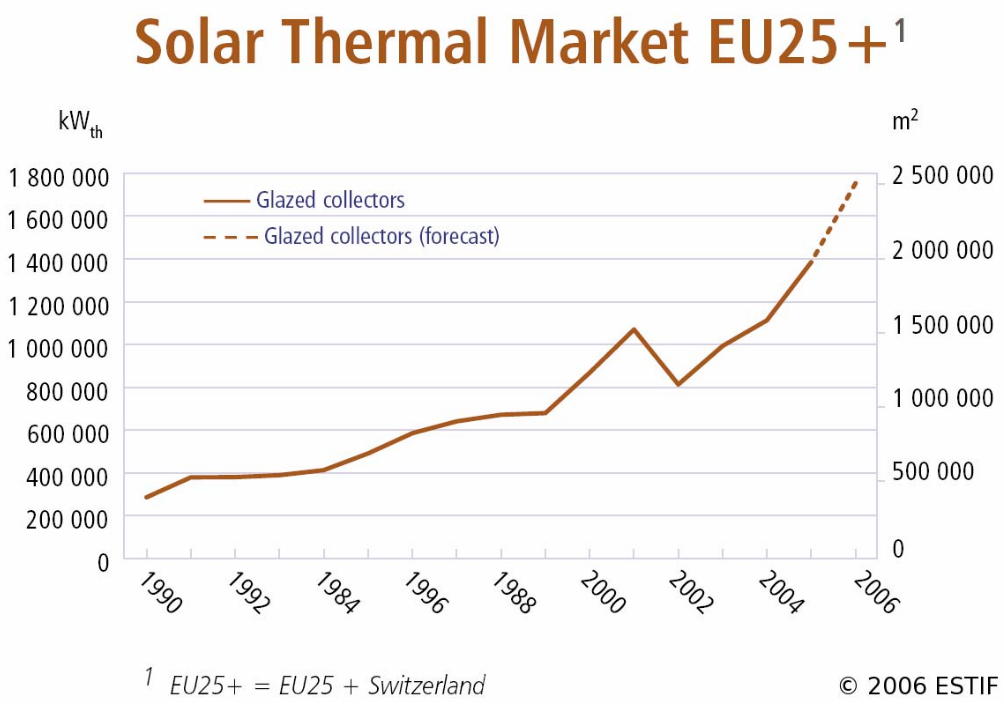


Fig. 5.3 Solar thermal capacity in 2005. Source ESTIF

In 2005, almost 1,400 MW_{th} of solar thermal capacity (2 million m^2 of collector area) was newly installed in Europe – 26% more than in the previous year. The traditional lead markets Germany, Austria and Greece, are responsible for about ¾ of the operational capacity in Europe and have all performed well in 2005. Some very good developments in several of the high-potential markets like France and Spain can

19 www.estif.org

be noted. At the end of 2005, the total capacity in operation in the EU and Switzerland was 11,175 MWth ($15.9 \cdot 10^6$ m^2 of collector area) [Est 2006].

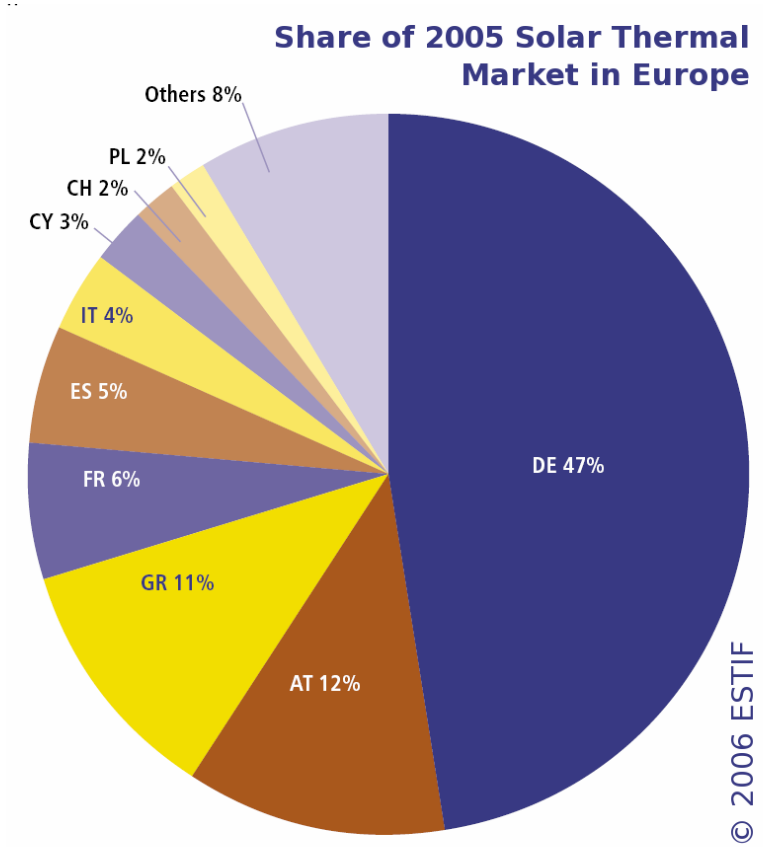


Fig. 5.4 Share of solar thermal market in 2005. Source ESTIF

The Spanish implementation of the EC Directive on the Energy Performance of Buildings [EU 2002a], with the new technical building code (CTE) [CTE 2006] includes an obligation to cover 30-70% of the Domestic Hot Water (DHW) demand with solar thermal energy. It is expected that this will support the boom in the solar collector market in Europe. In addition the European certification scheme, the Solar Keymark [Est 2005] for solar thermal collectors (EN 12975) and factory made systems (EN 12976) is more and more accepted, both by the industry and by public authorities.

5.3.3 Geothermal Energy

Renewable heat from geothermal systems is converted from the heat that is stored under the solid surface of the earth. Heat pumps are conversion systems often used in geothermal systems.

The technological developments of recent years have opened new ways to use the heat in the interior of our planet. The results achieved by scientists working on the European Hot-Dry-Rock research projects raise the expectation that electric power will soon be produced from geothermal energy throughout Europe at economically and ecologically acceptable conditions, not only in regions known for high ground temperatures.

In some regions of Europe geothermal power plants already contribute substantially to an environmentally friendly and sustainable energy supply, using existing technologies exploiting steam and hot water reservoirs. These sites are mainly in Italy, the Azores, other islands of volcanic origin in Europe and Iceland. In Iceland geothermal energy will be one of the two pillars upon which will be built a fully renewable energy supply. In South-East Europe, Turkey and the Caucasian region further huge, yet chiefly unexploited reservoirs may contribute to a sustainable energy supply. New ideas and technologies will secure a dependable supply of clean drinking water. Deep and hot aquifers can be used as a supply for energy and drinking water as well.

Heat supply from geothermal energy in Europe is primarily realised by using hot water from:

- Deep aquifers with temperatures up to 150 ºC for district heating, etc., or
- Small to medium shallow, low temperature geothermal plants using heat pumps.

Shallow geothermal also supports the use of solar energy for heating, through underground storage of solar heat from summertime until its use in winter, and offers many other opportunities of long-term thermal energy storage.

In total, only a minuscule portion of the potential of geothermal energy is as yet explored and in use in Europe. Targets for a geothermal energy development are given in Table 5.2. Often these plants produce heat and power. For this reason data is given for heat and electricity.

Table 5.2 Heat and electricity from geothermal. Source EGEC[20]

	1998	**2010**	**2020**
Heat*	920,000 dwellings 5,200 MW_{th}	3,000,000 dwellings 15,000 MW_{th}	12,000,000 dwellings 48,000 MW_{th}
Electricity**	940 MW_{el} 4,300 GWh/y	2,000 MW_{el} 16,000 GWh/y	without support: 3,000 MW_{el} 24,000 GWh/y ecologically driven: 8,000 MW_{el} 64,000 GWh/y

*Deep and shallow resources
** incl. engineered geothermal systems

The geothermal technology requires in most cases a heatpump to convert the heat from the renewable resource into renewable heat. Geothermal heat pumps, or Ground Coupled Heat Pumps (GCHP), are systems combining a heat pump with a ground heat exchanger (closed loop systems) or fed by ground water from a well (open loop systems). The ground heat exchanger may either be a horizontal pipe placed within a ditch or a vertical pipe placed within a borehole. The latter is termed as a Borehole Heat Exchanger (BHE*)*. These systems use the earth as a heat source when operating in heating mode, with a fluid (usually water or a water-antifreeze-mixture) as the media transferring the heat from the earth to the evaporator of the heat pump, utilizing

[20] European Geothermal Energy Council www.egec.org

in that way geothermal energy. In the cooling mode, they use the earth as a heat sink. For each kWh of heating or cooling output, they currently require 0.22 – 0.35 kWh electricity, which is 30%-50% less than the seasonal power consumption of air-to-air heat pumps, which use the atmosphere as a heat source/sink [Gro 2006].

Note that the electricity required can have different resources too, which might be renewable, like in Scandinavian countries. Since the auxiliary consumption is more than 5% of the produced energy it needs to be reported.

The European Heat Pump Association[21] (EHPA) represents the interests of the European heat pump industry. The introduction of ground coupled heat pumps in the built environment is investigated and stimulated through the EC - GROUNDREACH project [Ehp 2006]

The ratio of useful energy over electricity consumption of a heat pump at given operating conditions is defined as the "Coefficient of Performance" (COP). The COP or energy efficiency of a heat pump depends on the temperature of the input water from the ground circuit, which depends on geological conditions (thermal and hydraulic parameters of the underground, climatic setting) and technical parameters (length and type of ground heat exchanger, material, type and quality of grouting, etc.). Other factors that affect the COP of a heat pump are the heating/cooling load, the type of the building heating/cooling system and the relevant supply temperatures.

Table 5.3 EU Geothermal Heat Production (2005). Source EGEC

Country	Capacity MWt	Use TJ/yr	Use GWh/yr
Sweden	3,840.0	36,000.0	10,000.8
Hungary	694.2	7,939.8	2,205.7
Italy	606.6	7,554.0	2,098.5
France	308.0	5,195.7	1,443.4
Denmark	821.2	4,360.0	1,211.2
Slovak Republic	187.7	3,034.0	842.8
Germany	504.6	2,909.8	808.3
Austria	352.0	2,229.9	619.0
Finland	260.0	1,950.0	541.7
Czech Republic	204.5	1,220.0	338.9
Poland	170.9	838.3	232.9
Slovenia	48.6	712.5	197.9
Netherlands	253.5	685.0	190.3
Greece	74.8	567.2	157.6
Belgium	63.9	431.2	119.8
Portugal	30.6	385.3	10.07
Spain	22.3	347.2	96.5
Ireland	20.0	104.1	28.9
United Kingdom	10.2	45.6	12.7

[21] www.ehpa.org

GRAND TOTAL	8,473.6	7,509.6	21,253.9

Due to the fact that at depths below 8 metres the ground temperature is constant throughout the year (depending upon prevailing weather conditions or ambient temperature) and increases slightly with depth beneath the ground surface, BHE show better performance and energy efficiency than horizontal ground heat exchangers.

With BHE as a heat source or sink, geothermal heat pumps can offer both heating and cooling at any location, with great flexibility to meet any demand. More than 20 years of R&D focusing on BHE in Europe resulted in a well-established concept of sustainability for this technology, as well as sound design and installation criteria. Use of geothermal heat pumps in Europe is limited to operation for heating mainly, corresponding to only a fraction of total residential heating demand. Sweden is market leader of the geothermal heat pump technology.

Table 5.4 EU Geothermal Electricity Production (2004). Source EGEC

Country	Installed Capacity [MW]	Running Capacity [MW]	Annual Produced Energy [GWh/y]	Number of Units
EU-15				
Austria	1.0	1.0	3.2	2
France	15.0	15.0	102.0	2
Germany	0.2	0.2	1.5	1
Italy	790.0	699.0	5,340.0	32
Portugal	16.0	13.0	90.0	5
total EU-15	822.2	728.2	5536.7	42

It is interesting to note that Italy is producing about 1% of its national electricity production by geothermal and takes the major part of the European figure.

5.3.4 Heat from Biomass

Heat from biomass is receiving renewed attention as a domestic, renewable resource that may help reduce dependence on fossil fuels. However biomass is a complex matter. As another source of indirect solar energy biomass is plant biomass (i.e. wood, residuals, processed waste, processed fuel) or animal biomass. Plants use solar energy during photosynthesis, and store it as organic material as they grow. Burning or gasifying biomass reverses the process and releases the energy, which can then be used to generate heat or electricity, or can provide fuel for transportation.

One may distinguish solid, liquid and gaseous forms of biomass. In several countries municipal or industrial waste is considered under the biomass technologies, other countries treat it as a separate item in their statistics.

Biomass includes wood-fuels, agricultural energy crops and residues, municipal waste, black liquor, commercial and non-commercial, liquid and gaseous biofuels. Woodfuels include fuelwood, forestry and mill residues, energy plantations like willow, poplar, eucalyptus etc. and charcoal and pellets made from such woodfuels.

Agricultural energy crops and residues include herbaceous and perennial plants like miscantus, reed grass, rapeseed, bagasse, straw, stalks, husks and dung and pellets made thereof. Biogas comprises an estimate of all commercial and non-commercial sources directly used or supplied to pipelines, fuel cells stations etc. Its calorific value is part of total biomass. Biogas includes landfill and sludge gas, digester gas, gasified biomass, etc. as sub-products of total biomass.

There are several processes by which biomass is converted into a usable energy. The simplest, fairly inefficient and widely utilized in the developing world, is for the provision of heat, primarily for cooking and as a rudimentary source of lighting. Some of the new cooking-stoves are able to capture over 40% of the potential energy in wood, compared to the less than 10% conversion rate of traditional models. In colder climates especially in Scandinavia, Germany and Austria, domestic biomass fired heating systems are used fairly extensively. Some of these can achieve efficiencies of up to 70% with strongly reduced atmospheric emissions - considerable efficiencies over open fireplaces with chimneys due to the heat losses associated with chimneys.

The Biomass Action Plan [EC 2005] recognises the importance of Combined Heat and Power (CHP) plants and district heating and cooling as an important technology to optimise the use of biomass. The heat produced is considered as an inevitable by-product of electricity production. CHP plants run on biomass, others on fossil fuel, with the common thread being increased efficiency. These cogeneration plants typically burn a fuel to create electricity but rather than just venting the "waste" heat into the environment they hold onto it and use it to heat buildings and water. Some industrial plants like paper mills can use the residual steam, after it has turned a turbine, instead of boiling water with an entirely different system. Cogeneration plants can be tailored to a variety of sizes, from micro-single farm operations to standard electric utilities that supply heat to a whole town.

Table 5.5 Heat production and consumption in 2003.
Source IEA Energy statistics.

	EU-25 TJ	EU-15 TJ	Germany TJ
Heat			
Produced	1,923,331	1,175,418	390,583
Distribution losses	142,288	93,809	30,313
Consumption	1,683,405	1,074,058	353,735
Renewable Energy Source			
Biomass	166,958	149,165	0
Waste	124,196	119,884	26,565
Geothermal	1,377	919	410
Solar thermal	51	51	0
Sector			
residential	938,383	566,683	307,103
tertiary	255,076	165,748	0

To achieve the RES 12% target 74 Mtoe more are needed by 2010. Each sector has to contribute the following indicative additional amount of biomass energy: electricity 32 Mtoe, heat 24 Mtoe, and biofuels 18 Mtoe. This would lead to a total biomass accumulated energy production of 130 Mtoe in 2010. [EC 2005]

Data on biomass heat is difficult to assess. An example is given in Table 5.5 for the heat production and consumption in 2003 in Europe and for individual countries. The data shows that Germany does not report heat from biomass or solar thermal, but only from geothermal and waste. The reasons may be manifold. Larger plants are often CHP plants connected to district heat networks. Smaller and often residential plants are seldom measured while data, if available, have to be estimated from fuel sales figures.

According to Eurostat data [EST 2006a] about 10% of electricity and heat is produced by CHP from renewable energies, mostly biomass. According to the European Biomass Industry Association[22] (EUBIA), 98% of RES heat in Europe is produced from bioenergy. The wood energy barometer applied by EurObserver presents primary energy figures from wood energy but does not distinguish between electricity and heat. However the increased development of CHP plants is mentioned.

For 2004 the international association for bio-energy professionals[23] (ITEBE) reports a wood energy production in EU-25 of 55.4 Mtoe (or 3.2% of the primary energy consumption), divided into 80.6 % for heating and 19.4% for electricity production. It is expected that by 2020 the biomass heat production might reach 100Mtoe, roughly double the 2005 figures. This remains, however, far behind the estimated target of 100 Mtoe in 2010, based on the White Paper target. The objective of the Biomass Action Plan [EC 2005] for heat from biomass is set at 75 Mtoe and more realistic.

From some countries detailed data are available like Austria. The Austrian Energy Agency GmbH[24] reports that around 70% of Austria's domestically produced power came from renewable sources in 2005. About 11.2% of Austria's total primary energy supply came from biomass and 21% of heat production, according to International Energy Agency statistics. Europe's largest wood-fired power plant is situated in Vienna, supplying 5,000 households with electricity and 12,000 with heat.

5.4 Conclusion

Moreover discrepancies in the use of definitions and reporting procedures when it comes to data collection at European level appear. The resulting misinterpretations are carried forward in energy modelling exercises which might lead to wrong conclusions and development of inappropriate tools for implementing targeted policies. The conclusion is that international heat statistics must be improved urgently.

[22] www.eubia.org
[23] http://www.itebe.org
[24] www.energyagency.at

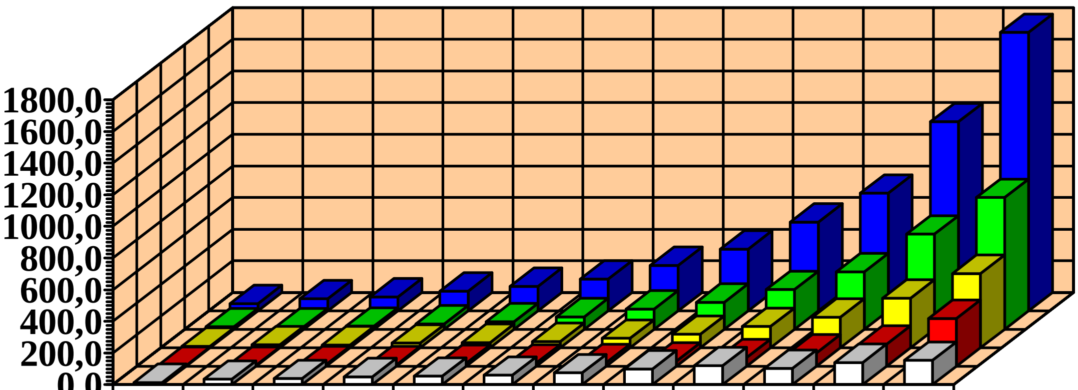
Chapter 6

PHOTOVOLTAIC SOLAR ELECTRICITY

Arnulf Jäger-Waldau

6.1 Introduction

In 2005, the photovoltaic industry continued its impressive growth and delivered world-wide some 1,700 MWp [Pvn 2006] of photovoltaic generators (Fig. 6.1). In the past 5 years, the average annual world growth rate was above 40%, making the further increase of production facilities an attractive investment for industry. An investment report published in 2004 by Credit Lyonnais Security Asia forecasts that the photovoltaics sector has a realistic potential to expand from € 5.6 billion[25] in 2004 to € 24 billion in 2010, corresponding to 5.3 GWp in annual sales [Rog 2004]. In the meantime the bank analyst Mr. Rogol estimates that even 10 GW of annual sales with a € 40 billion turnover of the sector could be reached in 2010 [Rog 2006].



	1990	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
United States	14,8	34,8	38,9	51,0	53,7	60,8	75,0	100,0	120,6	103,0	140	154
Rest of World	4,7	6,4	9,8	9,4	18,7	20,5	23,4	32,6	55,5	83,8	139	302
Europe	10,2	20,1	18,8	30,4	33,5	40,0	60,7	86,4	135,1	193,4	314	470
Japan	16,8	16,4	21,2	35,0	49,0	80,0	128,6	171,2	251,1	363,9	602	833
Total	46,5	77,6	88,6	125,8	154,9	201,3	287,7	390,2	561,8	744,1	1195	1759

Fig. 6.1: World PV Cell/Module Production from 1990 to 2005 (data source: PV News [Pvn 2006])

The IEA Photovoltaic Power Systems Programme reported in October 2005, that by the end of 2004 *"Total direct employment in the sector in the reporting countries may now exceed 50,000 persons, with rapid growth indicated in Germany and the USA"* [IEA 2005]. If the growth of Photovoltaics in the IEA PVPS reporting countries, as well as others like China and India are taken into account it is very likely that in 2005 the world-wide solar electricity industry already provided employment for over 70,000 people, about double the number estimated by the European Photovoltaic Industry Association (EPIA) in 2003 [Epi 2004].

[25] Exchange rate used: $ 1.25 = € 1

Photovoltaic companies are attracting a growing number of private and institutional investors. The number of market studies and investment opportunities has considerably increased in the last few years and business analysts are very confident that despite raising interest rates the photovoltaics sector is in a healthy condition. 2005 and early 2006 saw an increasing number of very successful Initial Public Offerings (IPO) of solar companies. The 30 companies listed in the PPVX[26] (Photon Pholtovoltaic stock index) together have a market capitalisation of more than € 20 billion at the end of August 2006.

The current solar cell technologies are well-established and provide a reliable product, with sufficient efficiency and energy output for at least 20 years of lifetime. This reliability, the increasing potential of electricity interruption due to grid overloads, as well as the rise of electricity prices from conventional energy sources, add to the attractiveness of Photovoltaic systems.

About 90% of the current production uses wafer-based crystalline silicon technology. The top advantage of this technology is that complete production lines can be bought, installed and be up and producing within a relatively short time-frame. This predictable production start-up scenario constitutes a low-risk placement with high expectations for return on investments.

The current temporary shortage in silicon feedstock was triggered by the extremely high growth rates of the photovoltaics industry over the last years, which was not followed by the silicon producers. Three developments can be observed at the moment:

- Silicon producers have now reacted and are in the process of increasing their production capacities, which will ease the pressure on the supply side within the next two to three years. This indicates that they have recognised PV as a fully fledged industry that provides a stable business segment for the silicon industry, as opposed to being strongly dependent on the demand cycles of the microelectronics industry.
- PV companies accelerate the move to thinner silicon wafers and higher efficient solar cells in order to save on the silicon demand per Wp.
- Significant expansions of production capacities of existing manufacturers are under way and a large number of new thin film manufacturers try to enter the market to supply the growing demand for PV modules. Compared to 2004 thin film shipments increased by over 50% to 108 MW in 2005. In 2010 EPIA forecasts that 20% of the then 5.3 GW module shipments will be thin films [Unz 2005].

Similar to learning curves in other technology areas, new products will enter the market, enabling further cost reduction. After years of research and technology development, thin film production plants with a few hundred MW cumulative production capacities are now under construction. Equally, competitive technologies are amorphous Silicon, CdTe and CI(G)Se thin films. The growth of these technologies is accelerated by the positive development of the PV market as a whole and the current silicon wafer shortage. The expansions for the required scale-up to manufacturing units of 50 MWp annual capacity and more are under way and will now join the wafer silicon devices technology in satisfying demand [Fir 2005/6, Uni 2005/6]. It is interesting to note that not only new players are entering into thin film

[26] The PPVX is a non commercial financial index published by the solar magazine "Photon" and "Öko-Invest". The index started on 1 August 2001 with 1000 points and is calculated weekly using the Euro as reference currency. Only companies which made more than 50% of their sales in the previous year with PV products or services are included [Pho 2006].

production, but also established silicon-based PV cell manufacturers diversify into thin film PV.

If thin film should supply 20% of the photovoltaic devices by 2010, the growth of production capacities must be about double as high as the rest of the industry, assuming that total PV growth continues at a constant of 32% per year, as predicted by the Credit Lyonnais Security Asia study. By then, Silicon wafer technology would deliver about 4,000 MWp per year, requiring 40,000 metric tons of Si-feedstock, about 40% more than today's entire world production capacities of semiconductor silicon (28,000 metric tons). Even the more conservative EPIA scenario of 27% growth would result in a silicon demand of 30,000 metric tons of Si-feedstock [Epi 2004].

These scenarios show that in order to maintain such a high growth rate, different pathways have to be pursued at the same time:

- Drastic increase of solar grade silicon production capacities;
- Accelerated reduction of material consumption per silicon solar cell and Wp, e.g. higher efficiencies, thinner wafers, less wafering losses, etc.;
- Accelerated introduction of thin film solar cell technologies into the market and capacity growth rates above the normal trend.

Further cost reduction will depend not only on the scale-up benefits, but also on the cost of the encapsulation system, if module efficiency remains limited to below 15%, stimulating strong demand for very low area-proportional costs.

6.2 World View

In 2005 the photovoltaic market grew again by more than 45%. Most of the installations were sited in Germany, but additional markets like California, Spain and Italy added to it.

The new industry policy for Photovoltaics in the People's Republic of China, and the ongoing consolidation of the PV industry by merger and acquisition, are hot topics for the market. The current silicon shortage and the related price rise of the wafers forced the solar cell manufacturers to sign long term supply contracts with considerable down payments to finance the capacity expansion. At the same time that new thin film production capacities are under construction, new thin film manufacturers are entering the scene and established silicon-based PV cell manufacturers diversify into thin film PV to reduce their exposure to future consequences of this development.

The Photovoltaic world market grew again by more than 45% in 2005 to 1,759 MW. Like in the case of 2004, Germany was the largest single market with 603 MW followed by Japan with 291 MW and the US with 108 MW [Sys 2006, Jpe 2006, Pvn 2006]. The revised German Feed-in Law [EEG 2004] went into force on 1 August 2004. The transitional arrangement before, and the revision itself resulted in a dramatic increase in PV installations. The German Solar Industry Association estimates that new grid connected systems with a capacity of about 600 MW were installed in 2005. Photon reported systems installations with a total of about 710 MW [Pho 2006]. Even with the more conservative 603 MW installed photovoltaic systems (including off grid installations) Germany accounted for more than 93% of the EU 25.

Despite the fact that the European PV production grew again by 50% and reached 470 MW, the extreme growth of the German market did not change the role of Europe as a net importer of solar cells and/or modules. The ongoing capacity expansions might change this in the future. In February 2006 SolarWorld announced to take over the silicon wafer based solar business of Shell Solar [Sol 2006].

Between 2001 and 2005 PV installations in the European Union increased six-fold to reach almost 1.8 GW cumulative installed capacity at the end of 2005. More than 85% of the total PV installations in the EU were placed in Germany. With a three-year programme from 2002 to 2004, Luxembourg propelled itself to World Champion and leads the statistics in terms of installed PV with 52.4 Wp per capita. Due to a new legal situation, there was no significant addition of PV capacity in 2005. Nevertheless, if the enlarged European Union, as a whole, would have the same PV quota per capita as Luxembourg, 26.4 GWp installed PV or about 26.4 TWh (0.93% of total EU energy consumption in 2002) per year could be achieved.

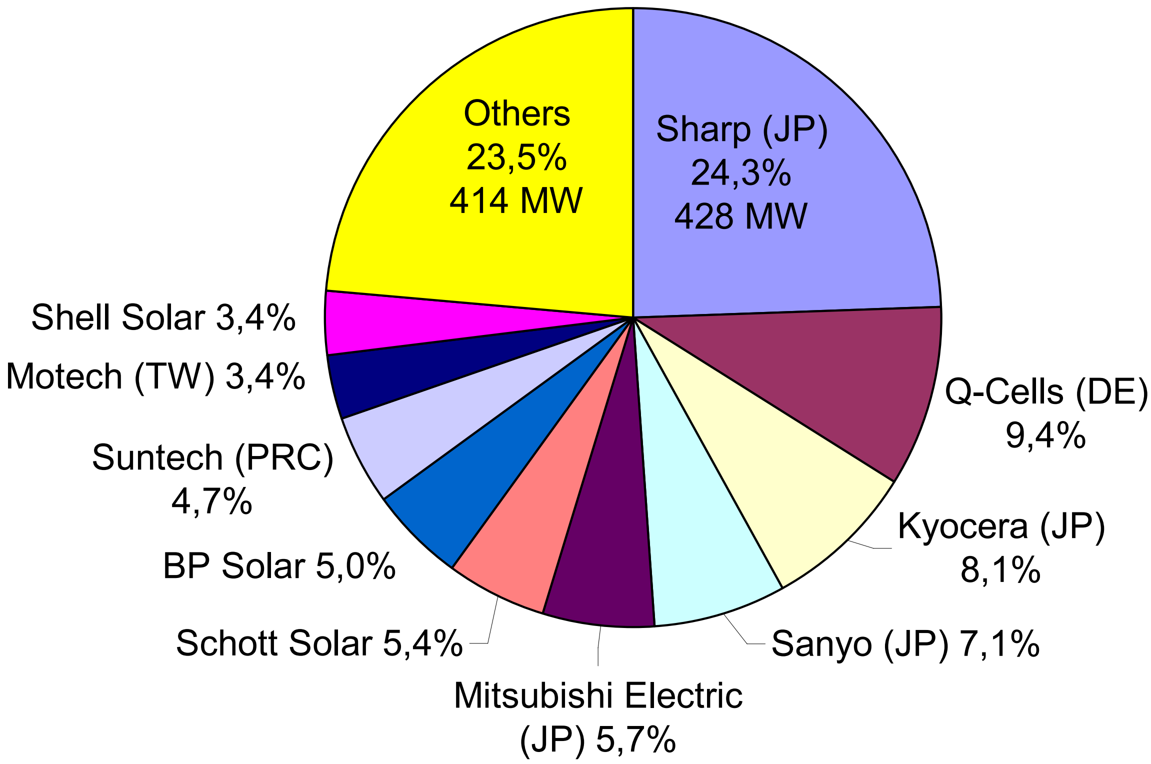


Fig. 6.2: Top 10 Photovoltaic companies in 2005 (total shipments in 2005: 1759 MW) [Pvn 2006]
Please note that BP Solar, Schott Solar and Shell Solar have cell production capacities in more than one country.

The second biggest market with 291.1 MW of new installations was Japan with a 8.3% growth rate compared to 2004. The lower than usual growth rate was mainly due to the completion of the Residential PV System Dissemination Programme in October 2005. This programme had supported the expansion of Japan's PV market for the past 12 years. 89% or 260.4 MW of the new installations were grid connected residential systems bringing the accumulated power of solar systems under the Japanese PV residential programme to 1095 MW out of 1,420 MW total installed PV capacity at the end of FY 2005 [Ikk 2005, Jpe 2006]. At the same time Japanese exports increased by 65% to 528 MW with 386.8 MW being exported to Europe [Jpe 2006]. The world market share of Photovoltaic devices manufactured in Japan decreased slightly by 2.6% to 47.4%, but four of the Top Ten companies are Japanese (Fig. 6.2). For FY 2006 the PV industry is confident that, even without subsidies, the residential market will show an increase due to the trend to fully electrified houses and new Renewable Portfolio Standard with an increased amount of electricity generated from renewable energy sources.

Sharp Corporation continues to dominate the PV scene with more than 24% market share and a production capacity of 500 MW/year in FY 2005, and it can be expected that this will not change in 2006 [Ikk 2006]. In addition, it is interesting to note that Sharp finally announced the start of their large scale thin film production in September 2005 [Sha 2005]. The ten largest PV manufacturers together held 76.5% of the market, whereas the rest was shared by over 30 different companies.

The third largest market was the USA with 108 MW of PV installations, 65 MW grid connected [Pvn 2006a]. California and New Jersey account for 90% of the US grid connected PV market. There is no single market for PV in the United States, but a conglomeration of regional markets and special applications for which PV offers the most cost-effective solution. Until 2002, the US PV market was dominated by off-grid applications, such as remote residential power, industrial applications, telecommunications and infrastructure, such as highway and pipeline lighting or buoys. In 2005 the cumulative installed capacity of grid-connected PV systems surpassed that of off-grid systems. Since 2002 the grid connected market is growing much faster thanks to a wide range of “buy-down” programmes, sponsored either by States or utilities.

After the first Chinese (Taiwan) company MOTECH reached the top 10 list in 2004, Suntech Power (PRC) followed in 2005. On 2 August 2006, Suntech Power signed an agreement to buy the Japanese PV module manufacturer MSK [Msk 2006]. Suntech bought a two third stake in the 3rd quarter of 2006, with the option to buy it completely in 2007. The People’s Republic of China and Taiwan together produced 210 MW in 2005, almost tripling the 75 MW production of 2004 and surpassing the US production of 154 MW. The market in the PRC is still quite small, but is expected to grow drastically within the next few years. The goal is to supply 10% of the total primary energy in 2020 by renewable energy. To reach this goal the build up of a renewable energy and photovoltaics industry is supported by a renewable energy industry policy, as well as a feed-in law for electricity from renewable energy.

Figure 6.3 shows the announced and estimated increase of production capacities by 2007. The figures are taken from press releases [Bps 2004, Kyo 2005, Mit 2004, Qce 2004, Sun 2005], company web-sites, public reports [Ikk 2005, Pvn 2006b] or extrapolated from the production increases of the companies during the last years. It has to be noted that the assessment of all the capacity increases is rather difficult as it is affected by the uncertainties given below.

The announcements of the increase in production capacity in Europe, the US or China often lack the information about completion date compared to Japan. Because of the Japanese mentality where it is felt that a public announcement reflects a commitment, the moral pressure to meet a given time target is higher in Japan than elsewhere where delays are more acceptable. In the case of Sharp, the prediction is probably too low, taking into account their dominating role in the PV industry. Not all companies announce their capacity increases in advance. Therefore, this report might miss out on a major increase if it is well above normal predictions.

Announcements of completion of a capacity increase frequently refer to the installation of the equipment only. It does not mean that the production line is really fully operational. This means, especially with new technologies, that there can be some time delay between installation of the production line and real sales of solar cells. In addition, the production capacities are often announced, taking into account different operation models such as number of shifts, operating hours per year, etc.

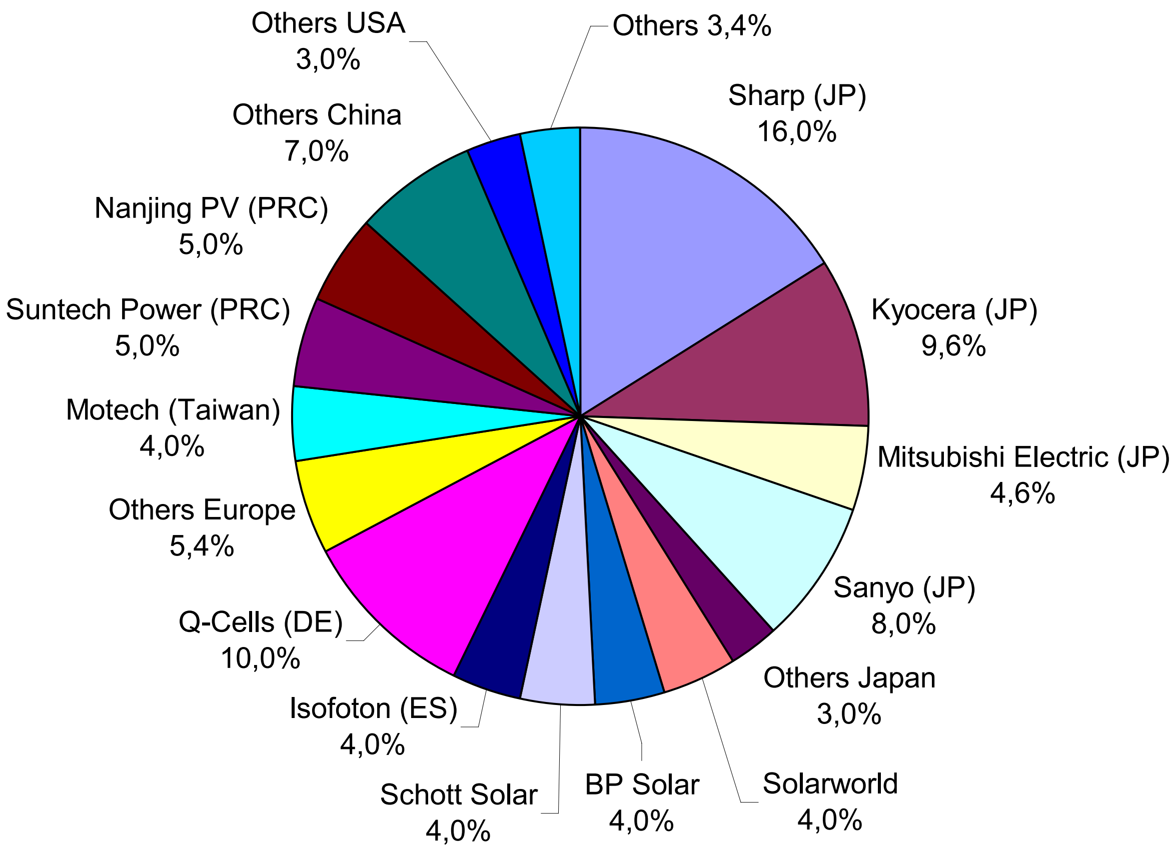


Fig. 6.3: Announced and estimated increase of production capacities world-wide by 2007 (5 GW)

Production capacities are not equal to sales and therefore there is always a noticeable difference between the two figures, which cannot be avoided. The given figure for Sharp is the one most likely to approximate actual production, whereas others might just give the capacity installed in the factory at the end of the year even though it is not yet operational. Despite the fact that only limited comparisons between the different world regions are possible, the planned cell production capacities for 2007 portray some very interesting developments.

First of all, should the announced increases be realised, total production capacities will then stand at 5 GW of which roughly 600 MW could be thin films. The more than doubling of the 2005 silicon production figures has serious implications on the silicon feedstock demand and it is expected that not enough feedstock will be available to guarantee full operation of the 4.4 GW production capacity in 2008.

Secondly, 11 companies have plans to increase their production capacities to 200 MW, or more by the end of 2007. Four companies even plan to have 400 MW and more (Sharp, Kyocera, Sanyo and Q-Cells) compared to only one company (Sharp) at present. It is very interesting to note that three out of the eleven companies aiming for 200 MW and more are from the People's Republic of China and Taiwan.

This leads to a third observation. If the large increase in production capacity is realised in China, the share on the world market would increase from 11.9% in 2005 to about 20 % or 1 GW in 2007. This production capacity would be much more than the 450 MW of cumulative installed solar systems in the People's Republic of China by 2010, as announced at the International Conference for Renewable Energies in Bonn [Bon 2004]. It is obvious that the solar cell manufacturers in China intend to continue the high export rate (90% in 2005) of their production to the growing markets in Europe, the US and developing countries.

Europe is on track to fulfil its targets for 2010, which were however not as ambitious as the Japanese 4.8 GW one. In view of enlargement and the remarkable market growth these targets should be revised upwards. The introduction of the German Feed-in Law in 1999 and its renewal in 2004 [EEG 2004], led to a significant change in the frame conditions for investors and has been one of the major driving forces behind European growth. Since 1999 European PV production has grown on average by 50% per annum and reached about 470 MW in 2005. The European market share rose during the same time from 20% to 26.7%, whereas the US share decreased due to a weak home market and the Japanese share increased and stabilised around 50 ± 3%. The European PV industry has to continue its high growth over the next years in order to maintain that level. This will, however, only be possible if reliable political frame conditions are put in place in the rest of Europe as well to enable a return on investment for the PV industry.

Besides this political issue, a continuous improvement of the solar cell and system technology is required. This leads to the search for new developments with respect to material use and consumption, device design, reliability and production technologies, as well as new concepts to increase overall efficiency.

6.3 Market and Implementation in the European Union

The market conditions for photovoltaics differ substantially from country to country. This is due to different energy policies and public support programmes for renewable energies and especially photovoltaics, as well as the varying grade of liberalisation of domestic electricity markets. A complete list of support schemes for Photovoltaics is given in the Annex. Between 2001 and 2005, installations of Photovoltaic systems in the European Union increased six fold to reach almost 1.8 GW cumulative installed capacity at the end of 2005 (Fig. 6.4) [Sys 2006].

In 2005, like in 2004, Germany was the largest single market with 603 MW, followed by Spain with 20.2 MW and France with a little over 6.3 MW [Sys 2006]. The revised German Feed-in Law [EEG 2004] went into force on 1 August 2004. The transitional arrangement before and the revision itself resulted in a dramatic increase in PV installations. For 2005 the German Solar Industry Association estimates that new grid connected systems with a capacity of about 600 MW were installed. Photon reported systems installations with a total of about 710 MW [Pho 2006]. Even with the more conservative 603 MW installed photovoltaic systems (including off grid installations) Germany accounted for more than 93% of the EU 25 (Fig. 6.4).

Spain almost doubled from 2004, and for 2006 and 2007 projects with about 200 MW are already under construction or planned [Pho 2006a]. On 26 August 2005, the Spanish Government approved the *Plan de Energías Renovables en España* (PER) for 2005 – 2010. The objectives are to cover 12.1% of Spain's overall energy needs and 30.3% of total electricity consumption with renewable energy sources by 2010. The cap on PV of 150 MW set by the Royal Decree 436/2004, dated 12 March 2004, was increased to 400 MW by 2010.

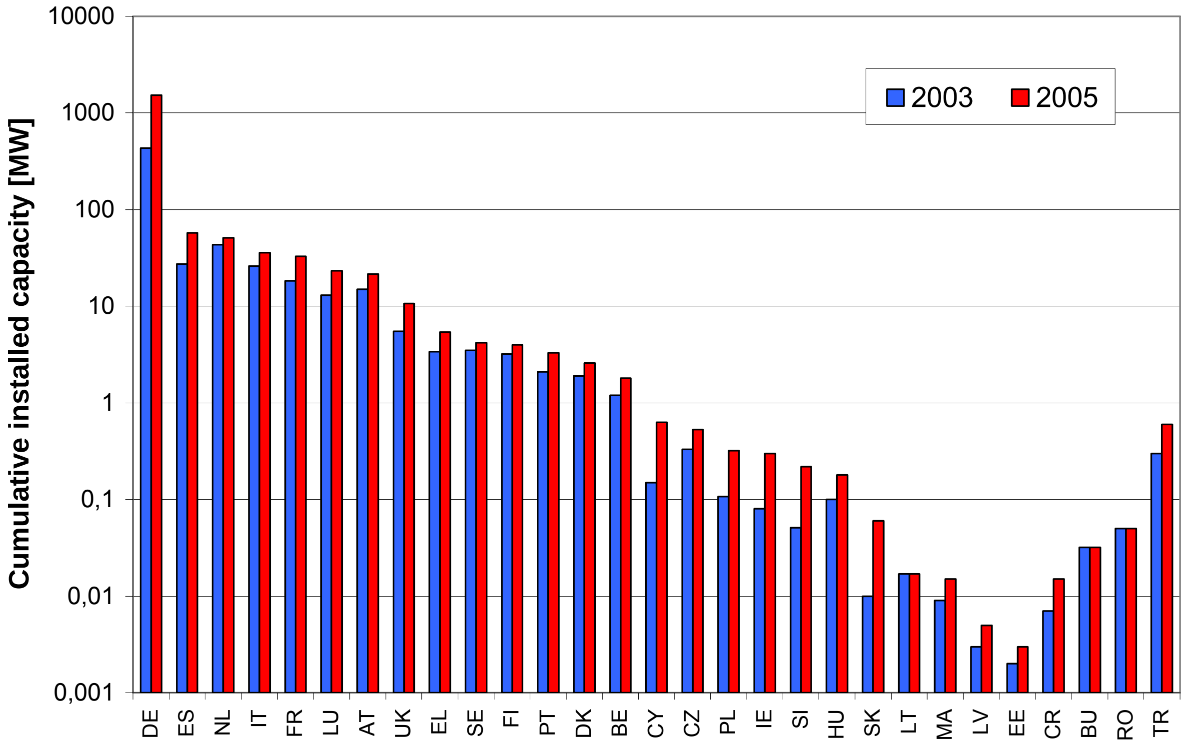


Fig. 6.4: Cumulative installed grid connected PV capacity in EU + CC 2003 and 2005; Note that capacities do not seem to correlate with solar resources

The new Italian feed-in tariffs, agreed on in July 2005, led to a steep rise in applications in the second half of 2005 and the first half of 2006, but no considerable increase in the amount of new systems capacity could be observed in 2005. After the end of the first quarter of 2006, applications with more than 1.3 GW were submitted to the "implementing body" *Gestore del Sistema Elettrico* (GRTN SpA.), 2.6 times more than the 500 MW cap up to 2012, but it is estimated that between 50 and 80 MW might be installed at most this year.

France is the latest of the large European Member States to introduce an attractive and cost competitive feed-in tariff for PV installations integrated in a building. The new feed-in tariffs have been in force since 26 July 2006, but is only valid for new installations. The general tariff is 0.30 €/kWh (0.40 €/kWh in Overseas Departments and Corsica) for 20 years. For building integrated PV installations there is a supplement of 0.25 €/kWh (0.15 €/kWh in Overseas Departments and Corsica). In addition, 50% of the investment costs are tax deductible and a lower VAT of 5.5% on system costs (without labour) is applied. Accelerated depreciation of PV systems is possible for enterprises. Regional support is still possible. The 5% tariff digression for new installations was cancelled. All tariffs (old and new) will be adjusted annually in accordance to the inflation during their duration.

With a three year-programme from 2002 to 2004, Luxembourg propelled itself to World Champion and leads the statistics in terms of installed PV with 52.4 Wp per capita. Due to a new legal situation there was no significant addition of PV capacity in 2005. Nevertheless, if the enlarged European Union as a whole would have the same PV quota per capita as Luxembourg, 26.4 GWp installed PV or about 26.4 TWh (0.93% of total EU energy consumption in 2002) per year could be achieved.

Despite the fact that the European PV production grew again by 50% and reached 470 MW, the extreme growth of the German market did not change the role of Europe as a net importer of solar cells and/or modules. The ongoing capacity expansions might change this in the future. In February 2006 SolarWorld announced it would take over the silicon wafer based solar business of Shell Solar [Sol 2006]. But it has to be noted that the European PV industry is much more fragmented than competitors in the US and Japan (Fig. 6.5).

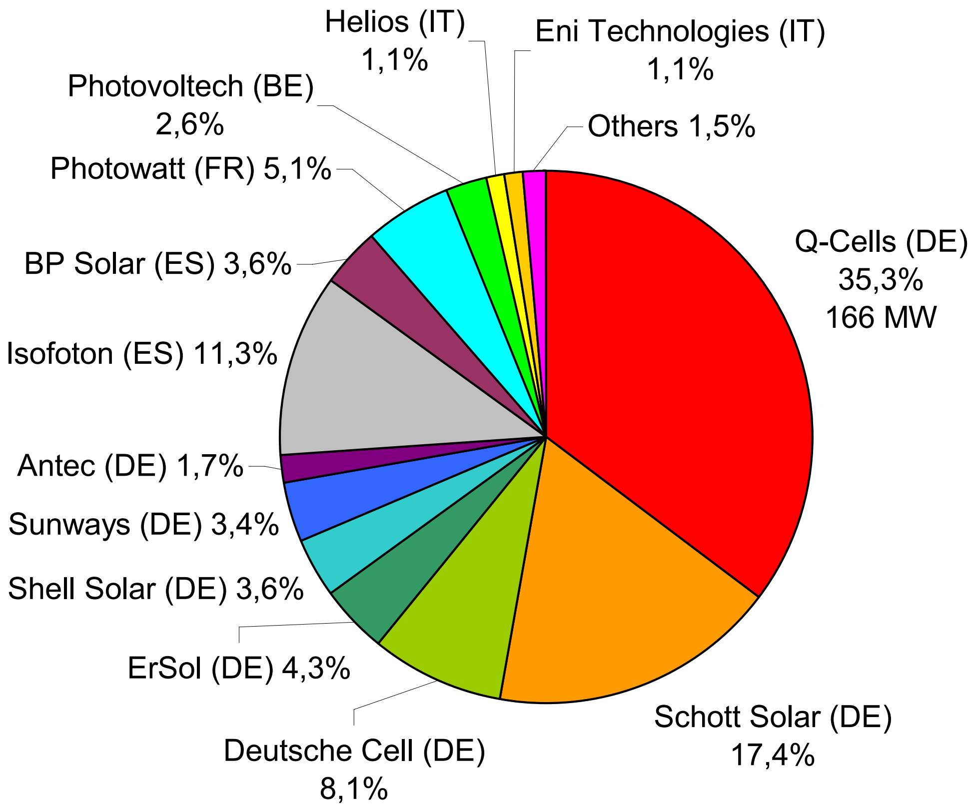


Fig. 6.5: Shares of the European PV companies in European production (2005: 470 MW, this corresponds to 26.7% of the world-wide sales) [Pvn 2006]

The question regarding the number of photovoltaic systems installed where is getting more and more difficult to answer. Already last year the reported figures for the German installations in 2004 varied from an initial 360 MW reported by the German Solar Industry Association (BSW), and then revised to 500 MW, whereas Photon International reported up to 770 MW [Pho 2005].

The problem started with the end of the German interest reduced loan programme in June 2003. No method was in place to register the number of PV systems installed and the dramatic increase of installations after the revision of the German feed-in law, took everybody by surprise. The discrepancies in the reported data arise from the different data collection methods, ranging from installer surveys to grid operator surveys and inverter sales statistics. Unfortunately, the annual statement of the German grid operators (VDN) on the kWhs actually produced cannot be used either, as it is not available before October of the following year and in the last years it was even corrected after that. Therefore, it is difficult to verify the different numbers.

For 2004 VDN reported 556.5 GWh of electricity generated from photovoltaic electricity systems. To calculate the new installation from the actual electricity generated, the following assumptions are made:

1) The average production of a 1 kWp system is 800 kWh (850 kWh) per year.
2) The 2003 figures of 408 MW grid connected are correct.
3) In 2005 the system installations were equally distributed during the year. This means that for the calculation each kWp installed in 2004 contributes with 400 kWh (425 kWh) to the calculation.

The calculation therefore looks as follows:

The 408 MW installed at the end of 2003 produced	326.4 GWh	(346.8 GWh).
The new systems installed in 2004 have produced	230 GWh	(209.7 GWh)
which translates to	575 MW	(494 MW)

of new installations.

This calculation indicates that it is very likely that the revised BSW numbers are close to the actual installations but still have an uncertainty margin.

An updated list of support measures for Photovoltaics in the European Union Member States is listed in the Annex.

As shown in the Annex, 15 out of 25 Member States already have introduced feed-in tariffs. However, the efficiency of this measure to increasingly exploit these countries' PV-potential varies considerably in function of the details in each national regulation. In those States where the tariff does not cover the expenses, impact is very limited. In some other States, there is a motivating tariff, but its effectiveness is limited due to

- too early a fulfilled cap,
- too short a period of validity for the guaranteed increased tariff, or
- administrative requirements being too complicated or even obstructive.

Only in those countries in which the tariff has been high, and a set cap realistic enough, have PV installations increased and competition in production and trade developed substantially. From the socio-economic data at hand, feed-in tariffs should be designed to potentially enable a pay-back of the initial investment within 10 to 12 years and should be combined with a built-in "sun-set". Such a decrease of the guaranteed tariff by a certain percentage each year compensates early technology users, enforces realistic price reductions if well designed, and offers a long-term perspective for investors and producers of solar systems.

The New Member States and Candidate Countries still have much lower installation figures, despite good to very good solar resources, in some States with up to 1,600 kWh/kWp (Cyprus, Malta, Romania, Bulgaria, and South-east Hungary). Even in the Baltic States yearly average values of more than 800 kWh per year are possible for a 1 kWp system, which is comparable to Northern Germany [Sur 2004].

An important advantage for feed-in tariffs comes to light when analysing the effectiveness with which individuals are motivated – i.e. hundreds and thousands of private (domestic) investors, who have relatively easy access to grid connection, standardised accountability and last but not least, neighbourhood pride – an ideal situation for intrinsically decentralised PV-energy. Where local common action (at village or town level) or "locally centralised" investment gives better revenue, the market automatically plays its efficiency-enhancing role. Developments threatening electrical grid stability in terms of demand (e.g., large increase of air conditioning units in the Mediterranean EU) could be compensated much more economically, ecologically and socially balanced by decentralised generation and injection – partly avoiding expensive grid reinforcements. In addition, jobs would be created regionally in installation and maintenance businesses.

Stable political and socio-economically viable frame conditions do not only convince private and commercial investors to install photovoltaic power plants, but also stimulate the investment in new production capacities for solar cells and modules. Especially in Germany and Spain, the most dynamic markets in Europe, the production capacities for solar cells and modules have increased faster than in the other European countries (Fig. 19).

Since the introduction of the feed-in law in Germany, employment in the renewable energy sector has more than doubled compared to 1998. The latest figures given by the German Environment Ministry in May 2006 count more than 157,000 people employed in this sector (including Services and R&D) in 2004 and estimate 170,000 jobs in 2005 [BMU 2006]. The Photovoltaic industry accounted for approximately 30,000 jobs in 2005 [Bsw 2006]. According to an industry survey, amongst renewable energy companies in Germany, every second company plans to increase the number of employees by 30 to 100% within the next 5 years. Photovoltaic companies are amongst the most optimistic ones and in total expect a doubling of employment by 2010. In 2005 Photovoltaics accounted for a turnover in Germany of € 3 billion and 70% of the added value remained inside Germany.

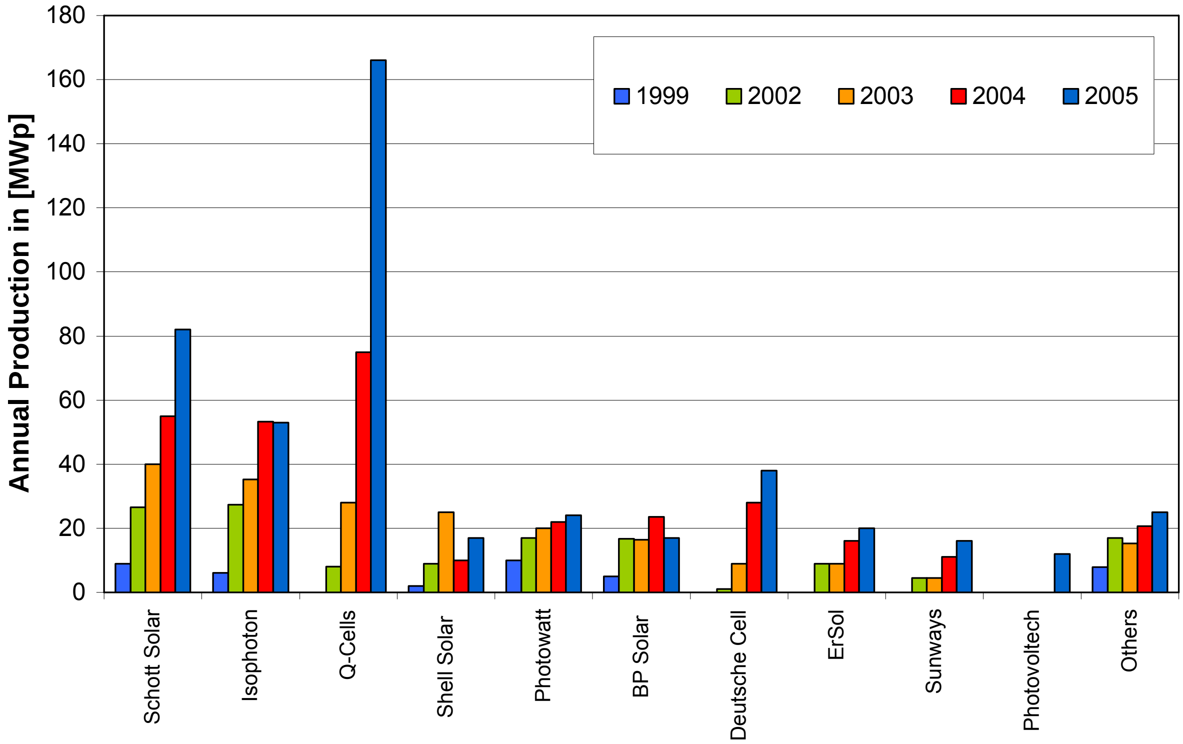


Fig. 6.6: Annual production of the European PV manufacturers with sales larger than 10 MWp in 2005 [Pvn 2006]

It is interesting to note that since 1999, the majority of investments in solar cell production facilities in Europe were made in Germany and Spain – the two countries that offer the most stable and realistic legal framework conditions for citizens investing in a PV system. In 2005 the employment figures in Photovoltaics for the

European Union is estimated to be 40,000 to 42,000. These figures are estimated from the already 30,000 jobs reported for Germany [Bsw 2006] and 6,300 for Spain [IEA 2006b].

In 2005, the European Commission did an impact assessment to evaluate the effectiveness of support measures for renewable energies in the European Union. The results were published in the Communication from the Commission "The support for electricity from renewable energy sources" already states [EC 2005a]:

The renewable energy sector is particularly promising in terms of ***job and local wealth creation****. The sector invests heavily in research and technological innovation and generates employment, which to a very high degree means skilled, high quality jobs. Moreover, the renewable energy sector has a decentralised structure, which leads to employment in the less industrialised areas as well. Unlike other jobs, these jobs cannot be "globalised" to the same extent. Even if a country were to import 100% of its renewable energy technology, a significant number of jobs would be created locally for the sale, installation and maintenance of the systems. A number of studies on the job creation effects have already been published and different estimates have been provided [Epi 2004a, Ere 2004, Ike 2005].*

It is of no surprise that the studies quoted refer to the Photovoltaics industry. The German Solar Industry Association reported that despite the fact that more than 50% of the solar cells installed in PV systems in Germany are imported, 70% of the added value stay within the German economy [Bsw 2006].

Electricity generated with photovoltaic systems has additional positive benefits for the European economy in the long run. First, with increasing installations of photovoltaic systems, the generated electricity can help to reduce the import dependency of the European Union on energy imports. The already quoted impact assessment states:

Rising oil prices and the concomitant general increase in energy prices reveals the vulnerability and dependency on energy imports of most economies. The European Commission's DG ECFIN predicts that a $10/bbl oil price increase from $50 to $60/bbl would cost the EU about 0.3% growth and the US 0.35% [EC 2005b]. For the European Union, the negative GDP effect would be in the order of €41.9 billion from 2005 to 2007. Further price increases would worsen the situation. The European Renewable Energy Council (EREC) estimates that € 140 billion in investment would be required to reach the 2010 goal of 12% renewable energy consumption [Ere 2004]. This would ensure fuel cost savings of €20 billion (not even taking into account the substantial price increases since 2003[27] [IEA 2006b] and reduce external costs by €30 to €77 billion. If we add the employment benefits, the overall costs for society can be estimated to be positive compared to a negative result if no RES were introduced. There are several studies that examine the difficult issue of quantifying the effect of the inclusion of RES in an energy portfolio and the reduction in the portfolio energy price. This is in addition to the economic benefits of avoided fuel costs and external costs (GHG), money which could be spent within the economy and used for local wealth creation [Awe 2003].

Second, electricity from Photovoltaic systems is generally produced during times of peak demand, or economically speaking, when electricity is most expensive. In addition, photovoltaic electricity is produced at its best during those times when in the case of extreme heat and resulting water shortages thermoelectric power plants have to reduce their output due to a lack of cooling water.

[27] Crude oil prices went up from US$26/bbl (June 2003) to over US$60 (August 2005), source: IEA

During the extreme heat wave in July 2006, peak prices paid at the European Electricity Exchange (EEX) spot market exceeded the feed-in tariff paid in Germany.

The continuous expansion of the production capacities for solar cells is of particular importance in light of the export markets for solar systems to the rural areas in Asia, Africa and South America, where about 2 billion people are still without electricity. The Europeans should not lose this future market, also with respect to the possibility it offers for the labour market. In June 2004 the European Photovoltaic Industry Association (EPIA) published its recent photovoltaics roadmap and stated therein: *“Failure to act on the recommendations of this Roadmap will be a huge missed opportunity. Europe will suffer the loss of its current strong market position and potential major industry for the future. The PV industry can be of great importance to Europe in terms of wealth and employment, with 59,000 PV related jobs in the EU in 2010 if the targets are met, and a figure of 100,000 jobs would be realistic if export opportunities are exploited.”*

According to EPIA, new PV production facilities create about 20 jobs per MW of capacity adding about 30 additional jobs per MW installed capacity in the wholesale, retail, installation and maintenance services sector. The later jobs are mostly located on a regional level near to the final customer. The goals set by EPIA in its roadmap are cumulative installed photovoltaic systems with 3.6 GWp electricity generation capacity in Europe by 2010 and the respective job numbers mentioned above would correspond to roughly 1.2 GW per year production capacity of cells and systems in the first case and roughly double in the export case. These figures look quite realistic if the planned expansions of production capacities in the order of 900 MW for 2006/7 in Europe are added to the realised production of 470 MW in 2005.

A prerequisite for all such developments is that parallel to the public market introduction incentives, electricity generated by solar systems can be *freely traded and attain preferential grid access.* As PV systems contribute to the avoidance of climatically harmful greenhouse gases, it has to be ensured that electricity generated from solar systems be exempt from eco taxes, where applicable. In addition, one has to enable PV system operators to sell green certificates to CO_2-producers.

The European Union is on track to fulfil its own target of 3 GWp in terms of **Renewable Electricity from Photovoltaics** for 2010 – compared to Japan, which seeks to achieve 4.8 GWp (approx. 38 Wp per capita), however, this is not very ambitious. If the growth rates realised in the installation of PV systems between 2001 and 2005 could be maintained in the next years, the White Paper target would already be achieved in 2007 (Fig. 6.7).

In 2010, total installations would then exceed 10 GWp or approx. 22 Wp per capita, which would still be less than the Japanese target of 38 Wp per capita. The adoption of the Japanese target would result in 17.25 GWp installed in 2010, which would generate around 17.25 TWh or 0.61% of total EU electricity consumption in 2002. The PV installation growth rate curve in the European Union exactly mirrors that of wind power, with a delay of approximately 12 years.

The European PV industry has to continue its impressive growth over the next years in order to maintain its market position. This will only be achieved if reliable political framework conditions are created and maintained to enable return on investment for PV investors and the industry alike. Besides this political issue, targeted improvements of the solar cell and system technology are still required.

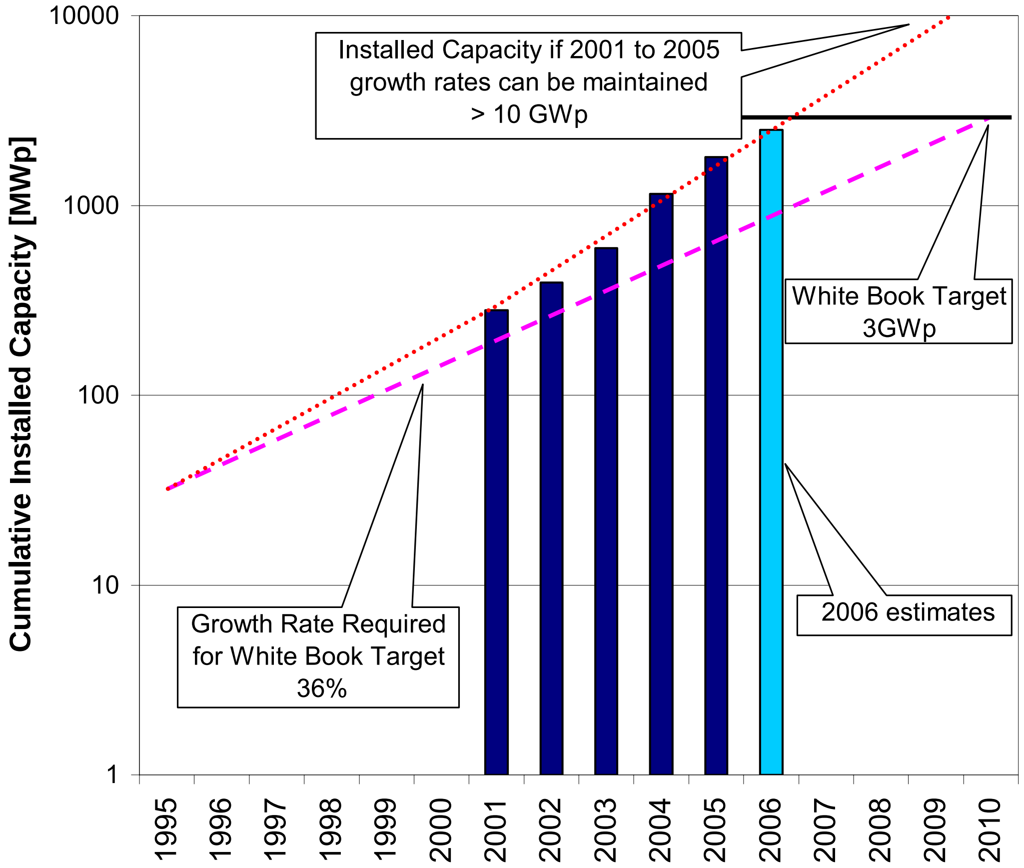


Fig. 6.7: White Paper target growth rate and estimates based on 2001 to 2005 installations

6.4 Outlook

In 2005 Japan again had the major market share in photovoltaic device production, with four companies in the top ten manufacturers (Sharp N°1, Kyocera N°3, Sanyo N°4, Mitsubishi Electric N°5), followed by one European company (Q-Cells N°2), three with production capacities in more than one continent (Schott Solar N°6, BP Solar N°7, Shell Solar N°10) and one Chinese and one Taiwanese company (Suntech N°8, Motech N°9). Since 1999 the European PV production grew on average by 50% per annum and reached about 470 MW in 2005. European market share rose in the same time from 20% to 26%, whereas the US share decreased due to a weak home market, while the Japanese share increased close to 50%.

The German market was very strong again in 2005 and installations were in the range of 600 MW [Sys 2006]. A further increase of the market is expected in 2006. However, due to the limited availability of solar modules and the increasing demand in countries like Spain and Italy, the increase is expected to be “only” in the range of 10 to 15% or 660 to 700 MW.

The current temporary shortage in silicon feedstock as a result of the extremely high growth rates of the photovoltaics industry over the last years, is showing its effects. Advanced production technologies, thin film solar modules and technologies like concentrator concepts are introduced into the market much faster than expected a few years ago.

The rising number of market implementation programmes world-wide, as well as the commitments made at the International Conference on Renewable Energies, Bonn in June 2004, will continue to keep the demand for solar systems high. In the long-term, the growth rates for photovoltaics will continue to be high, even if the economic frame conditions can lead to a short-term slow-down of growth rates. This view is shared by an increasing number of financial institutions, which are turning towards renewables as a sustainable and lucrative long-term investment. Increasing demand for energy is pushing the prices for fossil energy resources higher and higher. An increasing number of analysts predict that oil prices could well hit 100 $/bbl by 2010 [Cib 2005] or even exceed it, as stated by Matthew Simmons, member of the Energy Task force of US Vice-President Dick Cheney.

If Oil-futures for 2012 and 10 year US treasury bonds (4.88%) are taken as a benchmark, the oil price will rise to at least $ 90/bbl (€ 72) in 2012. Otherwise Oil-futures will be loss, which is highly unlikely. At the same time, electricity costs are on the rise and peak prices in July 2006 were higher than what was paid as feed-in tariffs. These developments work in favour of Photovoltaics as the cost gap is closing on both sides at the same time. PV system costs are still decreasing according to the learning curve and energy prices are rising at the same time. Therefore, the future for PV looks bright.

Europe is on track to fulfil its 2010 targets. 2005 saw yet again a 50% growth of production volume in Europe and additional production capacities will become available over the next years. Japan is increasing its capacities at a similar pace. Should the current trend in the field of world-wide production capacity increase continue, Europe will only be able to increase its market share slightly from 26 to 29% even with the impressive growth rates of the last years. At the moment it is hard to predict how the market entrance of the new players in the United States, India and China will influence future developments of the markets. In 2010 Japan will still dominate the PV world-market with about 50% market share, but it is already obvious that China becomes a driving force in the photovoltaic manufacturing and will probably be close to reaching a 20% market share (Fig. 6.8).

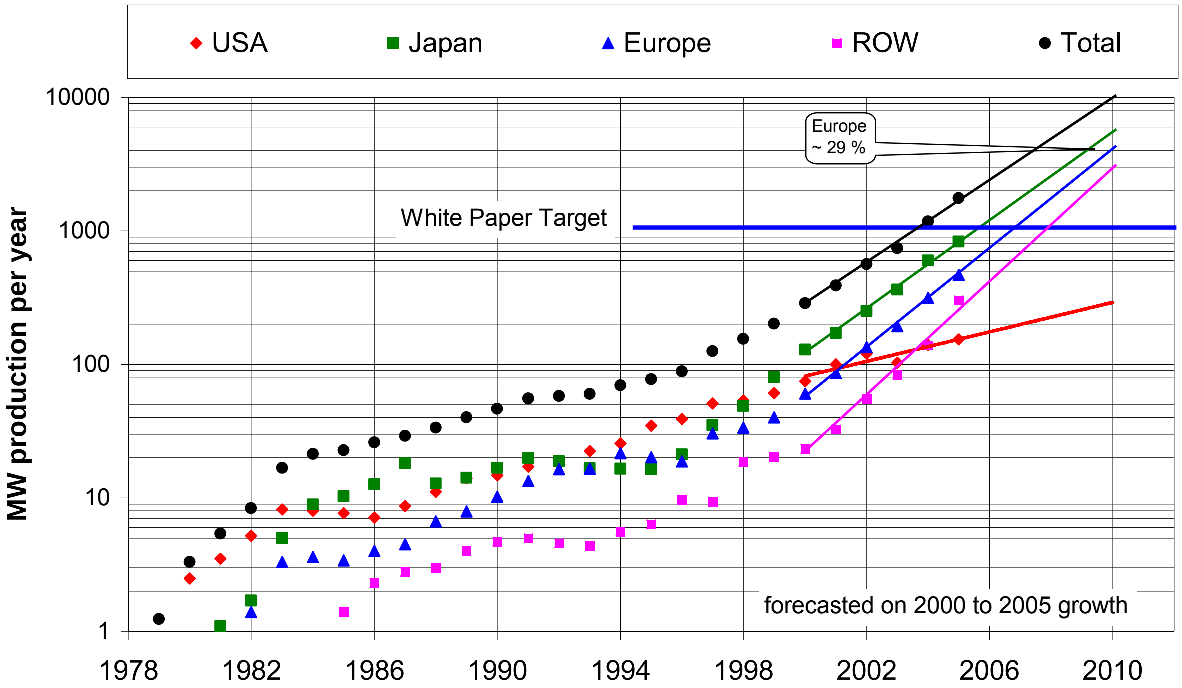


Fig. 6.8: Extrapolated increase of production capacities up until 2010 using the growth rates from 2000 to 2005 (Data source: PV News [Pvn 2006])

It is still true that Photovoltaics need significant initial investment, as was the case for the other energy sources, such as coal, oil and nuclear energy. It should not be forgotten that most of these investments were either made by public companies or secured by public credit guarantees. The European Environment Agency reported that the total energy subsidies in the European Union (EU15) were more than € 29 billion in 2001 [EEA 2004a]. About 18% or € 5.3 billion were given to renewable energies, whereas the rest went to coal, oil, gas and nuclear. These figures exclude external costs and for nuclear exclude the cost of not having to pay for full-liability insurance cover. In addition, the fact that some of Europe's nuclear companies are still state owned or controlled and arising liabilities will eventually have to be covered, or are actually being covered by the taxpayers, are not taken into account either.

At the current time we can observe a continuous rise of oil and energy prices, which highlights the vulnerability of our current dependence on fossil energy sources and increases the burden developing countries are facing in their struggle for future development. On the other hand we see a continuous decrease in production costs for renewable energy technologies as a result of steep learning curves. Due to the fact that external energy costs are not yet taken into consideration, renewable energies and photovoltaics are still more expensive in the market than conventional energy sources. However, apart from conventional energy sources, renewable energies are the only ones to offer a reduction of prices instead of an increase in the future.

Chapter 7

SOLAR RESOURCE DATA AND TOOLS FOR AN ASSESSMENT OF PHOTOVOLTAIC SYSTEMS

Marcel Šúri

Solar resource information is needed in all stages of the development of a photovoltaic (PV) project. Reliable solar radiation statistics are required for system siting, design, and for financing. In most case, monthly averages, probability statistics or Typical Meteorological Years (TMY) are sufficient. This information is sufficient also for the manufacturing industry and for policy makers defining support programmes.

On the other hand, siting of a multi-megawatt concentrating solar power or solar thermal power station needs time series of direct normal irradiance derived from high-resolution, high accuracy satellite data sources. Map-based time series of global irradiance are needed for analysis of grid electricity flows in regions with large PV capacities. Real-time data flow is required for large-scale operation and monitoring of PV systems and for the forecasting of solar electricity generation to optimise supply/demand patterns in the electricity grid.

Development of PV projects benefits also from availability of other graphical data, such as temperatures, rainfall, wind, elevation, land use, electricity grid, or economical data. Geographical information systems provide added value by integration of these data with parameters of technology, thus allowing for spatial analysis.

Many of those who search or use information on solar resource have difficulties with finding appropriate data, accessing and exploiting them due to various formats, protocols, units, observation periods, sampling or spatial resolution. Quality issues and uncertainty that relate to the methods of measurement and data processing are still not fully appreciated. It is often difficult to compare or combine information from various sources and raw data do not always meet the needs of users which are looking for more advanced information. In many projects, an uncertainty in data accuracy can make a difference between profit and loss from an investment.

According to accepted terminology [Pag 1986], two terms for solar short-wave radiation are used in this chapter. The term irradiance denotes the solar power (instantaneous energy) falling on a unit area per unit time (Wm^{-2}). The term irradiation denotes the amount of solar energy falling on a unit area over a stated time interval (Whm^{-2}).

Based on the previous analyses [Per 2001, Cro 2004, Wal 2006], this chapter provides a summarised and updated overview of the existing global or continental databases of solar resource and related climatic data, and tools for technical and economic assessment of photovoltaic systems.

7.1 Ground-measured site data and global datasets

Solar radiation has been measured at ground meteorological stations since the mid 20th century. The stations belong to the national weather services or networks that are managed for specific purposes. Several institutions collect data from national files and archive them into global databases. Availability and pricing of data depends on the country or radiometric network, type of data and their use. Ground-measured solar radiation data are typically disseminated as daily sums or monthly averages; for a few stations also hourly or more detailed values are available.

Ground stations, measuring solar radiation, are placed very heterogeneously within the world, and most regions are covered insufficiently to provide a representative picture of geographical and time distribution of solar resource (about 300 stations in Europe, [Esr 2000]). To overcome this limitation, other measurements, such as sunshine duration or cloud cover are used for estimation of global irradiation from empirical models. However, validity of these models is limited within a region for which they were calibrated. In most cases, only the global horizontal irradiation is measured (estimated), but in solar energy projects also direct and diffuse components are needed for calculations on inclined surfaces. Diffuse radiation is measured in a very limited number of stations (about 60 stations in Europe, [Esr 2000]), therefore it is often estimated by empirical models. Synthetic time series (Test Reference Years, Typical Meteorological Years, Design Reference Years) are constructed from observations and are thus available only for selected measuring stations.

To get spatially-continuous data from measured or estimated solar radiation, interpolation techniques are used. In regions with sparse distribution of ground stations, such maps might be missing important regional climatic patterns. A typical relative accuracy of measurements at meteorological stations by a well-maintained pyranometer is 3 – 5 %. The data accuracy obtained through the empirical estimations of global irradiation and its components is within the range of 20 – 30 %. The accuracy of spatial interpolation close to the measuring locations might be within a limit of a few percent, however, uncertainty increases with a distance between the location of interest and the measuring stations, especially in hilly and mountainous terrain. Users should be aware that all the mentioned sources of errors cumulate. Important in decisions based on solar radiation data is not only understanding of overall root mean square error (RMS), but also of bias that indicates systematic under- or over-estimation. The reader is invited to read more about uncertainties in [Per 2001].

World Meteorological Organisation (WMO) has compiled a CD-ROM with climatological normals, i.e. monthly and annual averages of measured parameters worldwide (the period 1961 – 1990). For a few stations, also solar radiation data are available (see publications at http://www.wmo.ch/).

A great deal of the worldwide measured data are collected, archived and published at the **World Radiation Data Centre** (WRDC) in St Petersburg, Russia. Although WRDC archive contains data from about 1,200 stations, the measurements are unevenly distributed in time and space. From 10 radiometric parameters, mainly global horizontal irradiation and sunshine duration can be retrieved (hourly, daily and monthly values). For much less stations, also diffuse irradiation can be retrieved. This archive is available online through two web sites. The data for the period of 1964 – 1993 are stored on the server of National Renewable Energy Laboratory, USA (http://wrdc-mgo.nrel.gov/), and data for the period 1994 – 2004 can be consulted on the web of the Voeikov Main Geophysical Observatory, Russia (http://www.mgo.rssi.ru/).

The **Global Energy Balance Archive** (GEBA) is a project of the World Climate Programme – Water (WMO, UNESCO, ICSU) that aims at assimilation of the ground-measured surface energy fluxes (monthly means, mostly global radiation) from about 1,500 locations over the world into one database [Gil 1999]. The quality of the measurements coming from various sources is rigorously controlled. The registered user can retrieve data from the GEBA web application (http://bsrn.ethz.ch/gebastatus/). The database is managed by ETH, Switzerland, and is available for scientific use; commercial exploitation is licensed to the Meteotest company (see below).

Baseline Surface Radiation Network (BSRN) is a project of the World Climate Research Programme (WMO). It was established to detect changes in the earth's radiation fields which may cause climate changes. At 39 stations in important climatic zones, solar and terrestrial radiation is measured with instruments of the best accuracy available and at high frequency. The BSRN radiation measurements are used to validate the radiation schemes in climate models and to calibrate satellite algorithms. The data are archived at the World Radiation Monitoring Centre (WRMC), Switzerland, and are available to scientific institutions (http://bsrn.ethz.ch/).

International Daylight Measurement Programme (IDMP) set-up by the Commission Internationale de l'Eclairage (CIE) operates a network with 48 stations, specialised in high quality daylight and solar radiation measurements. The IDMP server is operated by ENTPE, France, but the accessibility of data from each station depends on the policy of the particular institution involved (http://idmp.entpe.fr/).

7.2 Satellite data and derived databases

Satellite images, mainly from geostationary weather satellites (Meteosat, GOES, MSAT, etc.), are the second important source for developing solar radiation databases at global to regional scales. The main advantages are spatially-continuous (grid) data with consistent accuracy, measured by the satellites at frequent and regular time sampling. Spatial resolution of derived products is in a wide range of 1 – 300 km. The relative accuracy of the estimations, measured by RMS, is approximately about 20 – 25% for hourly values, 15 – 20% for daily values, and less than 15% for monthly averages (with some seasonal variation, see e.g. [Lef 2006]). Unlike interpolated maps from ground stations, where the accuracy depends on their spatial distribution, the accuracy of satellite assessments is spatially more stable and practically without bias. Satellite-derived maps are more sensitive to errors in high mountains and high latitudes, due to low observation angles and complex interactions with terrain.

Some global databases are a result of data assimilation and numerical weather modelling from both ground measurements and satellite images. The NCEP/NCAR and ECMWF are two examples. National meteorological services and international institutes use these data, as well as the products of other consortia, such as LSA-SAF and CM-SAF of the EUMETSAT organisation, for numerical weather forecasts and as input into general circulation models of the atmosphere.

Closer to renewable energy applications, models such as e.g. Heliosat-2 [Rig 2004], Perez model [Per 2002], and SOLIS [Mül 2004] are developed to calculate high resolution and high quality solar radiation databases. These models are routinely applied, for example in the USA (State University of New York at Albany), Germany (University of Oldenburg, DLR), France (Ecole des Mines de Paris, ENTPE), Spain (CIEMAT), Italy (ENEA), Australia (Australian Bureau of Meteorology). Further progress, in terms of increasing spatial and temporal accuracy, improved calculation of radiation components, depends on improvements of existing algorithms, but also on the development of input data to models, such as aerosols, ozone, and water vapour.

The **National Centre for Environmental Prediction** (NCEP) and **National Centre for Atmospheric Research** (NCAR) are co-operating in a reanalysis to produce a 40-year record of global analyses of atmospheric fields for research and climate monitoring. This effort involves recovery, quality control and assimilation of data from all available observations [Kal 1996]. The global archive with the grid resolution of 210 km (at the equator) is available without restrictions, and it contains also flux parameters, including global downward shortwave radiation (http://www.cdc.noaa.gov/PublicData/). A CD-ROM was published, containing 13 years of selected climatologic data (daily and monthly values) from the NCEP/NCAR re-analysis with 2.5-deg grid resolution. Daily values are accessible also through SoDa portal (see below).

The result of the two reanalysis projects of the **European Centre for Medium-Range Weather Forecasts** (ECMWF) – ERA-40 (1957 to 2002) and ERA-15 (1979 – 1993) are commercially available at the resolution of 2.5° × 2.5° and higher through the extended web services (http://data.ecmwf.int/data/). A selection of maps can be downloaded from the ERA-40 atlas that contains surface and column-integrated fields describing the climate during 1979 – 2001 (http://www.ecmwf.int/research/era/ERA-40_Atlas/).

To support renewable energy projects, the **NASA's Surface Meteorology and Solar Energy** (SSE) data set has been developed by the project Prediction of Worldwide Energy Resource (POWER). The data set is freely available and it contains about 200 monthly averaged solar and other climatic parameters derived from data assimilation programs and satellite sources (ISCCP, GEOS, SRB, TOMS). It represents a 10-year climatology (1983-1993) interpolated to 1°× 1° grid regions (grid size of about 111 km at the equator) covering the entire globe. The data are considered accurate for preliminary feasibility studies of renewable energy projects and their purpose is to fill gaps where ground measurements are missing [Cha 2004]. The data are directly linked to design tools such as Homer and RETScreen (see below).

The database **HelioClim-1** has been developed at the Ecole des Mines de Paris, France, from Meteosat Prime satellite images at reduced (sampled) B2 resolution (grid cell of about 30 km × 30 km at the equator). The database consists of daily global irradiation for a period 1985-2005, covering Europe, Africa, southwest Asia and part of the South America [Lef 2006]. The higher resolution database HelioClim-2 contains time-series of hourly irradiance calculated from Meteosat-8 satellite since February 2004. More about the HelioClim project at http://www.helioclim.org/. For selected location the time series of the data can be retrieved from the SoDa web service (see below) on a free basis or at moderate costs.

The **Satel-Light** server (managed by ENTPE, France) delivers data for Western and Central Europe of statistical type: monthly averages, frequency distributions of half-hourly values (http://www.satel-light.com/). The data can be consulted for free also in the form of active maps or in a form of a report for the chosen site. They represent a period of 1996-2000 and were derived from Meteosat images (solar radiation, and daylight) and ground measurements (temperatures).

Solar Energy Mining (SOLEMI) is a service set up by German Aerospace Agency (DLR) that aims at providing high-resolution (2.5 km × 2.5 km) solar radiation data and maps from Meteosat satellites (http://www.solemi.com/). The solar radiation products, including high frequency time series and direct normal irradiance, are developed on request. Together with related GIS services (STEPS) they are used mainly in preparatory stages of renewable energy projects.

7.3 Systems integrating data and assessment tools

Besides servers offering data, there are integrated information systems, where databases are supplemented by maps, software, and support services. Such systems are available online through the internet or on CD-ROMs. They enable better exploitation of basic data, and calculation of derived parameters for an assessment of solar energy projects.

Meteonorm (http://www.meteonorm.com) is a global climatological database combined with a synthetic weather generator on CD-ROM. It contains a database of ground station measurements collected from various sources (Swiss Meteorological Institute, GEBA, WMO-CLINO, etc.). The main period of the measurements is 1961 – 1990. Besides solar radiation it contains other climatologic data needed for solar energy and applied meteorology projects (temperature, humidity, wind speed, precipitation). This commercial software outputs climatologic averages and derived products for any point on earth, estimated by interpolation.

The **European Solar Radiation Atlas** is a comprehensive publication, documenting state of the art in solar energy and applications in Europe at the end of 1990s [Esr 2000]. It was realised on behalf of the European Commission by a group of European institutions. The publication can be purchased at http://www.helioclim.org/esra/. It includes CD-ROM with theory on basics and solar energy applications, and homogenised input solar radiation and climatic data, based on the period 1981 – 1990. The extended set of algorithms, software and digital maps provide for a range of PV, solar energy and other applications.

Photovoltaic Geographical Information System (PVGIS) is a research, demonstration and policy-support instrument for geographical assessment of solar resource and PV systems in the context of distributed energy generation [Sur 2005]. The server, operated by the Joint Research Centre of the European Commission, offers map-based query of basic statistics of solar radiation, temperature and other data for two regions: (1) European subcontinent (1-km grid, period 1981 – 1990) computed from ground measurements, and (2) for the Mediterranean Basin, Africa and South-West Asia (2-km grid resolution, period 1985 – 2004) developed by processing and spatial enhancing of the HelioClim-1 satellite database. The PVGIS databases and algorithms are developed in open source software and the web tools enable simple estimation of performance of PV and solar energy systems (http://re.jrc.ec.europa.eu/pvgis/pv/).

The server of the US **National Renewable Energy Laboratory** (NREL) (http://rredc.nrel.gov/) delivers solar radiation data, derived products, overview maps and atlases, as well as a range of publications, algorithms, and source codes. Solar calculator PVWATTS can be used for performance estimates of grid-connected PV systems. It can be linked interactively to a dynamic solar atlas of USA that on grid cells of ~ 40 km by 40 km provides monthly averages of daily total solar resource available to flat plate photovoltaic modules and concentrators (http://www.nrel.gov/gis/solar.html).

The **Solar Information Resource Service** (SIRS) is another example of a service offered to those who own or plan a PV system (http://www.iedat.com/sirs-ny/sirs-ny.php3). The site is operated by NYSERDA, and provides mapped solar resource from geostationary satellites for the State of New York. It is updated on a monthly basis, and accessible back to 1998. The SIRS is linked with the Clean Power Estimator service, allowing economical estimation and monitoring of PV systems.

The **Solar and Wind Energy Resource Assessment** (SWERA) is a UNEP/GEF project that provides for free solar and wind resource data, country energy analyses, and geographic information assessment tools to public and private sector in developing countries. Currently, the SWERA website holds online information of 13 countries (http://swera.unep.net/).

The **SoDa Service** (SoDa: Solar Data) offers one-stop access to information sources related to solar radiation and applications in various domains (http://www.soda-is.com). By means of a smart network it integrates climatic databases, and application-specific user-oriented numerical models and advanced algorithms located in various institutes in the world. The service does not centralise the data into a warehouse nor does it write software for applications. In the PV domain, the SoDa service co-operates with other web servers to construct and deliver requested products using the data and software maintained on remote sites, such as HelioClim, Meteotest, ESRA, Satel-light, NCEP/NCAR, etc. This co-operation is entirely automatic by the means of standard data protocols.

On a commercial basis, new services, based on the use of satellite data, are being developed for planning and monitoring of existing installations, and calculating energy forecasts for electricity grid management (see e.g., http://www.spyce.de/, http://www.meteocontrol.com/, http://www.flyby.it/).

7.4 Project development software

Besides systems offering data and simple tools, various software packages exist for development of PV projects.

RETScreen International is a decision-support tool for evaluation of energy production and savings, life-cycle costs, emission reductions, financial viability and risk for various types of renewable energy technologies. The software is provided free-of-charge, and includes product, cost and climate databases, detailed user manuals and textbooks (http://www.retscreen.net/). The software is available in several languages, and provides users' access to climatic data from ground monitoring stations, or as an alternative, to the NASA SSE satellite-derived data sets. The development and support is managed by the Canadian RETScreen International Clean Energy Decision Support Centre with the aim of assisting in building capacities by disseminating knowledge to better analyse the technical and financial viability of projects, and thus to reduce costs of pre-feasibility studies.

Homer is also a free-of-charge computer model for the evaluation of design options for both off-grid and grid-connected power systems for remote, stand-alone and distributed generation applications. The algorithms for optimisation and sensitivity analysis allow to evaluate the economic and technical feasibility of a number of technology options and to account for variation in technology costs and energy resource availability. The development of the software is supported by US National Renewable Energy Laboratory (http://www.nrel.gov/homer/).

A range of commercial software packages are on the market, aimed for sizing, simulation, monitoring, and economic assessment of PV systems. Many of them include or provide an access to meteorological and PV-components databases. To mention some of them: PVSYST, TRNSYS, PV*SOL, INSEL, PV F-Chart, PV-DesignPro, etc. The main customers are engineers, project planners, researchers and education institutions.

7.5 Conclusions

The existing data sources have limitations in terms of their spatial and temporal resolution, and suitability for a given application. Some data are difficult to access or directly use in PV projects, especially for developing countries. Due to the growing reliance on solar and other renewable energy technologies worldwide, a research task was formed under the International Energy Agency (IEA), Solar Heating and Cooling Programme, entitled "**Solar Resource Knowledge Management**". It operates via an international consortium of experts who are involved in the analysis and processing of data from ground measurements and satellite imagery for developing large-area site-time specific data and maps of the solar energy resource. The goals are benchmarking and validating data products, improving access to data resources, and developing improved products and new services (http://re.jrc.ec.europa.eu/iea-shc-task36/).

This chapter provides an overview of available global solar radiation and climatic data sources that are needed for photovoltaic projects. This brief summary must not be considered as exhaustive, the reader is invited to look for updates and submit comments at the online version http://re.jrc.ec.europa.eu/pvgis/pv/solrad/.

Chapter 8

EUROPEAN POLICIES FOR THE PROMOTION OF RENEWABLE ENERGIES AND ENHANCED ENERGY EFFICIENCY IN DEVELOPING COUNTRIES

Magda Moner Gerona

Energy as a key to promote development

Energy is a key issue to promote development, as explicitly referenced in the commission communication "Green paper: A European Strategy for Sustainable, Competitive, and Secure Energy" [EC 2006, EC 2006a]. In this section, following the energy-development approach, we analyze the European policies that promote sustainable development in developing countries by supporting renewable energies and raising the profile of energy efficiency in development programmes.

Energy cooperation

EU launched in 2002 an EU Energy Partnership Initiative[28] in order to promote cooperation between Europe and developing countries in the energy sector [EC 2002]. In the "Energy cooperation with the developing countries" communication [EC 2002a], the Commission of Council analyzes the energy situation in developing countries and then proposes a reference framework for energy cooperation. The energy initiative for Poverty Eradication and Sustainable Development (EUEI) particular focus its effort on poverty eradication by improving access to adequate sustainable energy services through several technical and institutional options, including rural electrification, decentralised energy systems, increased use of renewable energy, and enhanced energy efficiency[29].

Through the development of partnerships, the core of the initiative will support the spread of sustainable energy services in developing countries by:

- Integrating energy as a general component of EU development aid programmes.
- Developing institutional support and the necessary regulatory framework to give the beneficiary countries the capacities to implement their energy choices and to promote the use of locally available renewable energy sources.
- Assisting to promote the necessary technical capacity
- Providing improved access to renewable energy and energy efficiency technology as developed by EU industry. RTD efforts deployed in the EU

[28] The European Union (EU) developed the Energy Initiative for Poverty Eradication and Sustainable Development in order to respond to unmet needs for energy services.
http://ec.europa.eu/comm/development/body/theme/energy/initiative/index_en.htm
The Initiative was launched at the World Summit on Sustainable Development in September 2002.
http://www.un.org/events/wssd/

[29] This includes cleaner, more efficient fossil fuel technologies, technology for more efficient appliances, and more efficient use of traditional biomass.

should address the constraints to using these technologies in non-industrialised countries or in remote rural areas.

- developing an appropriate regulatory framework and innovative financial mechanisms in order to promote investments in clean technologies in the context of public-private partnerships[30]
- developing coordination within the EU and with other international providers of finance and organisations

Demand-side cooperation

Improving energy efficiency is a crucial area that has not been largely exploited in developing countries. The penetration of modern energy-efficient technology in developing countries requires basically three elements:

- Creating a legal and financial framework, instruments, and/or economic incentives to ensure the implementation of technology
- Providing access to capital for the necessary (often higher) investment in energy efficiency
- Promoting local manufacturing

The high priority given to energy efficiency in the EU, as expressed in the European Commission's proposal for the "Intelligent Energy for Europe" programme [Intelligent Energy] provides an excellent basis for cooperation with developing countries in this field. COOPENER[31] (Community cooperation with developing countries) focuses on sustainable energy services to overcome poverty in developing countries, contributing to the EU Energy Initiative. The supported projects of this programme enhance:

- Local policies, legislation and market conditions[32].
- Local energy expertise[33]

The community development aid programmes (Euro-Mediterranean Partnership[34] (MEDA) and European Development Fund (EDF)[35]) complement the COOPENER programme (which has a limited budget).

Promoting energy diversification

The purpose of energy diversification is to reduce dependence of developing countries on the traditional fossil fuels, whose drawbacks are well known (price

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30 Development Banks, investors and the private sector will be invited to participate in the financing.

31 COOPENER is part of the Intelligent Energy - Europe programme, implemented by the Intelligent Energy Executive Agency, a new agency under the European Commission's Directorate General for Energy and Transport. http://ec.europa.eu/energy/intelligent/index_en.html
Links are drawn to the EU Energy Initiative for poverty alleviation and sustainable development in Africa, Asia, Latin America, and the Pacific
http://europa.eu.int/comm/dgs/energy_transport/index_en.html

32 COOPENER policies
http://ec.europa.eu/energy/intelligent/projects/coopener_en.htm#policies#policies)

33 COOPENER expertise
http://ec.europa.eu/energy/intelligent/projects/coopener_en.htm#expertise#expertise

34 The MEDA programme is the principal financial instrument of the European Union for the implementation of the Euro-Mediterranean Partnership. The programme offers technical and financial support measures to accompany the reform of economic and social structures in the Mediterranean partners, DG EuropAid implements the reform.
http://europa.eu.int/comm/europeaid/projects/med/index_en.htm;
http://ec.europa.eu/comm/external_relations/euromed/meda.htm

35 The European Development Fund is the main instrument for Community aid for development cooperation in the ACP countries and the Overseas Countries and Territories (OCT).
http://ec.europa.eu/comm/europeaid/projects/edf_en.htm

volatility, limited reserves), by broadening the energy mix. The potential of renewable energy is increasing because of its benefits from the point of view both of the environment and of security of supply. Nevertheless, its share in developing countries is remaining limited, especially as, in the absence of specific policy measures, such as those taken by the EU to promote renewable energy (in general, the high cost of renewable energy is an obstacle to its expansion). In order to develop a long-term strategy for promoting PV in developing countries the European Photovoltaic Technology Platform[36] established in 2005 the developing countries working group (WG4).

Rural areas

The investment in electricity transmission and distribution of centrally generated electricity for rural area is too high since its sparse population and low potential electricity demand. Then, the potential of renewable energy is extremely attractive since in rural areas access to energy depends on decentralised electricity generation. Locally produced electricity from wind or solar power may offer the best solution to cover basic energy needs for light, communications, health services and initial production and commercial development. This aspect is particularly important in the context of poverty eradication. If properly integrated in rural development policy, renewable energy will also contribute to improving life in rural areas, thus hopefully contributing to reducing the incentives for migration from rural to urban agglomerations with all the associated social problems.

The Alliance for Rural Electrification (AERE)[37] is an international non-profit organization founded in 2006 by the most important European Renewable Energy Industry Associations: the European Photovoltaic Industry Association (EPIA), the European Small Hydropower Association (ESHA), the European Wind Energy Association (EWEA), the European Biomass Industry Association (EUBIA) and the Global Wind Energy Council (GWEC).

ARE was created to respond to the outstanding need of providing a sustainable access to electricity to the developing world and to facilitate the involvement of its industry members within a rural electrification global dialogue, involving not only government and donor agencies but also manufacturers, rural entrepreneurs, end-consumers, local technicians, NGOs, utility companies and banks.

Conclusion

The EU has proposed different programmes, to work with developing countries towards creating the necessary conditions in the energy sector to achieve their national economic, social, and environmental objectives.

[36] PV Platform is an EU initiative which aims at mobilising all the actors sharing a long-term European vision for photovoltaic; realising the European Strategic Research Agenda for PV for the next decade(s) and give recommendations for implementation; ensuring that Europe maintains industrial leadership.
http://www.eupvplatform.org

[37] ARE http://www.ruralelec.org/

Chapter 9

OUTLOOK AND CONCLUSIONS

Arnulf Jäger-Waldau

The analysis of the progress and resource data on Renewable Energy and Energy End-use Efficiency revealed that a lot fragmented data and interpretations are available, but they lack a consistent quality system for data verification and clearly defined criteria for their visualisation, comparison and interpretation. Discrepancies have to be identified and resolved as well as better statistical methodologies elaborated. The Scientific Reference System task is to enhance the availability, quality and interpretation of renewable energy data and to serve as a one-stop-shop for policy and decision makers, serving them with unbiased, reliable inventory information on green energy -technologies, -potentials, -investments, -trends, -markets, and comparisons with modelling results.

In the following, a few key results for electricity are summarised.

9.1 Europe

With all the different political and legislative developments like the EU Directives, national and regional policies etc., where are we now to reach the goals of the White Paper [EC 1997]?

- Figure 9.1 shows the development to reach the White Paper targets on renewable electricity and the actual status for 2005. The pathways towards the targets are logarithmic (linear in a logarithmic plot) in order to account for the typical form of growth curves of new technology business branches.

Table 9.1: Contribution and growth rates for different energy sources to reach the White Paper targets

Type of energy	**Electricity produced [TWh/a]**			**Growth needed to reach White Paper Targets**	
	1995	2005	2010	1995 to 2010	2006 to 2010
Biomass	23	70	230/162*	17% / 14% (actual 11.8%)	27% / 19%*
Wind	4	82	80/160*	22% (actual 35%)	0% / 14.5%*
Photovoltaic	0.03	1.5	3	36% (actual 48%)	14.5%

*: revised targets

The following methodology was used to determine the 2005 "status quo" values for the generated electricity:

- Biomass: The 2005 value is reported by the Communication of the Commission on the 'The share of renewable energy in the EU' [EC 2007] and own data collections.
- Wind: The installed nominal rated capacity of 2004 + 50% of the additional installations for 2005 are multiplied by 2000 h of operation. This reflects the fact

that not all installed power in one year contributes to the actual electricity generation.

- PV: The installed rated peak power capacities of 2004 + 50% of the additional installations for 2005 are multiplied by 950 h of operation.

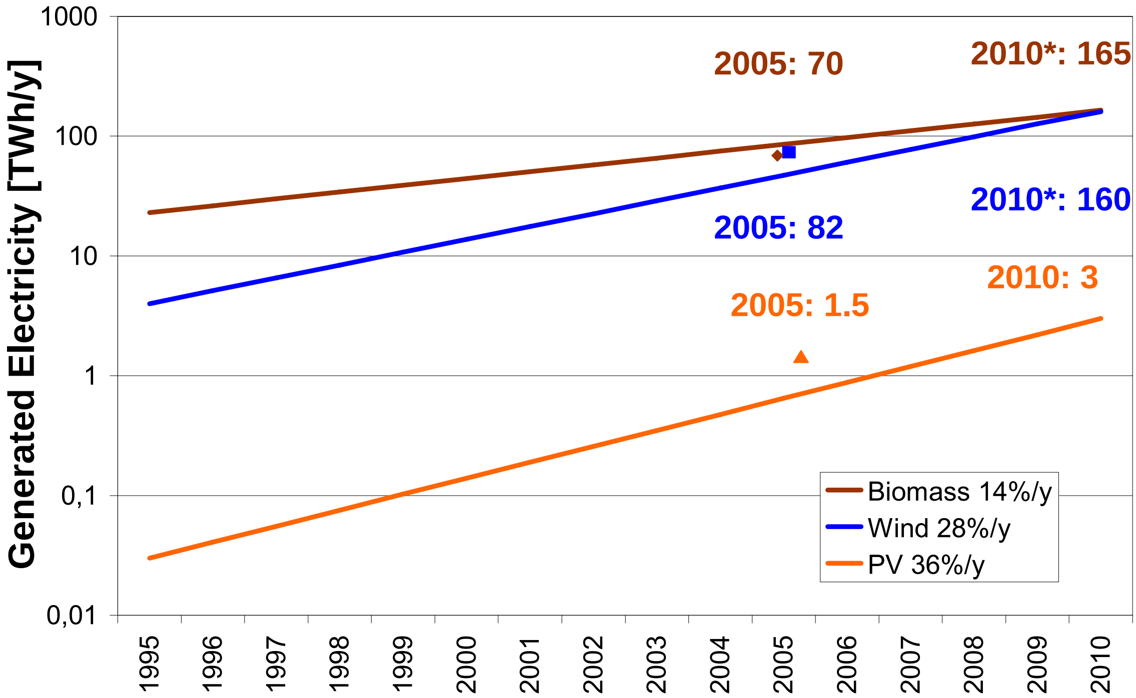

Fig. 9.1: Pathway to reach the White Paper targets and values for 2005. In order to reach the revised targets biomass must increase to 19 %/year (11.8% until now), whereas wind could slow down to 14.5 % (35%). With the continuation of the current averaged 48%growth, PV could exceed the White book target by 2007 and reach 10 TWh in 2010.

Wind has already reached the original White Paper target and photovoltaic is well on track to reach it already by 2007. For wind it can be even expected that it will reach the revised target of 160 TWh by 2010 and compensate for the shortcoming of electricity from biomass, where the target was revised downward. If the electricity generation from Photovoltaic systems continues to grow like the past, more than 10 TWh of electricity could be generated by Photovoltaic systems in 2010.

As already pointed out earlier, the actual investment into a specific renewable energy do not primarily depend on the available resources, but on the policy measures taken to promote it. The leading role of Germany in the field of wind and photovoltaic is due to the already mentioned renewable energy law [EEG 2004], which was revised and went into force on 1 August 2004.

Electricity from biomass faces multiple challenges, which reflect the diversity of fuelling options and technologies. However, as it is very close to the conventional energy conversion chain, its integration into the existing energy system could be easily managed with the targeted political support. The latter is required to realise advanced conversion technologies and the development of appropriate expertise and market infrastructure in dedicated energy crop production. This inevitably calls for a much better integration of the sustainability goals from bio-energy into the Common

Agricultural Policy and the realities of crop markets at the level of the producers. The biomass role is crucial and should not be "given up": In a renewable energy scenario where different renewable energy sources are combined, regionally distributed biomass will play an important role in buffering the energy needs during times when intermittent energy sources like wind or PV have less output.

However, effective use of biomass for energy purposes depends on the interactions between public policy in the fields of energy, agricultural, waste, forestry, rural development, environment and trade policy. Community institutions play a key role in all these policy areas. Specific attention has to be paid to the new Member States, taking into account the high and unexploited biomass potential that many of them have.

Wind power is already a well-developed technology with a rapid growing, world-wide market. The technological advances during the last decade have made wind energy already cost competitive with conventional energy sources in regions with good wind resources. The sector is very innovative and further cost reductions are predicted with economy of scale and new developments; windmills without gearboxes are a good example, bringing down costs in production as well as operation and maintenance. The learning curve will slow down naturally, over the next 10 to 20 years.

New market developments – offshore installations with larger turbines and building integrated installations with small turbines – as well as the expansion of wind into new world markets offer the chance that wind will indeed become a substantial part of tomorrows sustainable power supply. To realise this policy support to develop these markets and realise the necessary cost reductions is needed.

Photovoltaics is right now transforming from a manufacture type production to a full fledged high-tech industry. This offers the possibility to make use of economy of scale in larger production plants and lower the costs of PV systems considerably. PV still offers a large potential for cost reduction through market growth and innovation over the next decades. Already now, PV offers cost competitive solutions not only for remote and off-grid locations but also for peak load electricity. E.g., during the extreme heat wave in July 2006, peak prices paid at the European Electricity Exchange (EEX) spot market exceeded the feed-in tariff paid in Germany. Ever more standardising building integration and grid connected PV is one of the main driving forces for market growth. To maintain this growth stable economic and political framing conditions are necessary to encourage private consumer and industry investments.

For all these renewable energy sources it holds true, that all still differ in terms of commercial and industrial maturity. Some technical solutions are already economic competitive whilst others still need support measures to get them into the markets. Appropriate policies are needed to support research and development of promising options as well as market implementation and the fair access of renewable energies to the markets.

An additional benefit of renewable energies was already highlighted in the first report on the White Paper and Action Plan Implementation [EC 2001] – ***job creation***. The Commission presented figures of a study, which described likely job creation by the White Paper's targets, only considering the domestic market. The results suggested that around 530,000 jobs could be created between 1999-2010 across EU-15 Member States within the renewable energy sector, considering operation and maintenance as well as construction and installation. This figure took already into account the jobs displaced from employment in conventional energies. It was furthermore anticipated, that further work is still necessary, in order to provide more accurate information to decision-makers on job creation generated by RES investments.

The recent developments concerning energy have put the topic high on the political agenda. In January 2007, the European Commission adopted new proposals for an ambitious energy policy for Europe. The guidelines are that European energy policy must pursue the objective of a sustainable, competitive and secure supply of energy. The following statements are taken form the Communication from the Commission to the Council and the European Parliament from 10 January 2007 [EC 2007a].

To achieve the strategic energy objective means transforming Europe into a highly energy efficient and low CO_2 energy economy, catalysing a ***new industrial revolution****, accelerating the change to low carbon growth and, over a period of years, dramatically increasing the amount of local, low emission energy that we produce and use. The challenge is to do this in a way that maximises the potential competitiveness gains for Europe, and limits the potential costs.*

Existing measures on areas such as renewable electricity, biofuels, energy efficiency and the Internal Energy Market have achieved important results but lack the coherence necessary to bring sustainability, security of supply and competitiveness. No one element of the policy provides all the answers – they must be taken together as a whole. Energy policy must be addressed by many different policy areas. For example, as mentioned above the social dimension of Europe's energy policy needs to be taken into account throughout all stages of designing and implementing the individual measures[7] and it will be necessary to develop the further use of oceans and seas to promote the EU's energy goals, given their potential to support the generation of energy and to diversify energy transport routes and methods[8]. The first step is for Member States to endorse a strategic vision and an Action Plan for the next three years: with the explicit aim of moving towards an international alliance of developed countries at least with a view of reducing global Greenhouse gas emissions by 2020 by 30% and making a significant contribution to reducing the EU's greenhouse gas emissions by 2020 by 20%. This will be backed up with careful monitoring and reporting of progress, as well as the effective exchange of best practice and continued transparency - through the regular presentation by the Commission of an updated Strategic Energy Review.

The measures outlined will not only put the EU on the path to becoming a low carbon knowledge-based energy economy, but will at the same time improve its security of supply and make a progressively more significant contribution to competitiveness.

9.2 Global

The world-wide growing energy and electricity demand could be supplied by renewable energies as shown in Figure 9.2. The main resources are geothermal and solar, which are sufficient to supply a world population of 10 billion people with approx. 300 GJ of energy per capita and year. Solely Europe and Asia, whose potential is only 100 GJ/capita and year, would be required to import energy.

The UN World Summit on Sustainable Development in Johannesburg 2002 made a commitment to: “Increase access to modern energy services, increase energy efficiency and to increase the use of renewable energy.” and “To phase out, where appropriate, energy subsidies” [Joh 2002]. At the same time, the European Union announced a $ 700 million partnership initiative on (renewable) energy and the United States announced that it would invest up to $ 43 million in 2003.

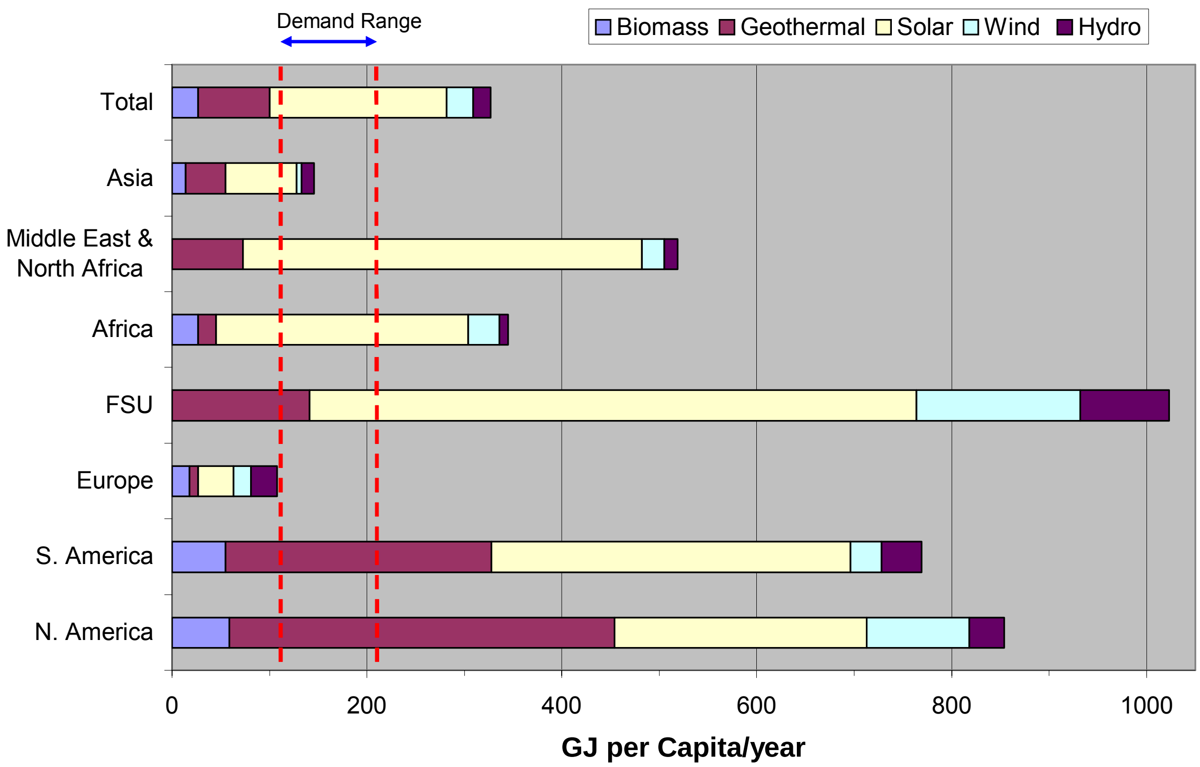

Fig 9.2: Potential of usable renewable energies calculated for a world population of 10 billion people [Joh 2002]

From 1 to 4 June, 2004, the International Conference for Renewable Energies took place in Bonn, as promised at the in Johannesburg Summit. It paved the way towards an expansion of renewable energies worldwide, responding to the call of the Johannesburg Summit for the global development of renewable energy. It also kept up the momentum generated by the Johannesburg Renewable Energy Coalition (JREC). Around 3,600 participants met in Bonn for *renewables 2004*, amongst them official governmental delegations from 154 countries, including energy, environmental and development ministers, representatives of the United Nations and other international and non-governmental organisations, civil society and the private sector. All EU-30 countries and EFTA countries as well as the European Commission were represented. The Conference addressed primarily the issues of *how can the proportion of renewable energies used in industrialised and developing countries be substantially increased*, and *how can their advantages and potential be better used*. The conferences' outcome concentrated in particular on:

- Formation of enabling political framework conditions allowing the market development of renewable energies,
- Increase in private and public financing in order to secure reliable demand for renewable energies,
- Human and institutional capacity building, and coordination and intensification of research and development.

The key results of this International Conference are the “Policy Recommendations for Renewable Energies” [Bon 2004a]. These recommendations based on the current understandings on policies and decision-making are designed to promote renewable energies in the world. The document is based on experiences and lessons learnt from policies, programmes, projects and other initiatives in the public and private sectors worldwide. The diversity of challenges, resource opportunities, as well as financing and market conditions among and within regions and countries implies that different approaches are required. Thus, these non-binding recommendations provide decision-makers with a menu of policy options based on available experience and knowledge.

Concrete actions and commitments by governments and other actors were united in an International Action Programme (IAP) [Bon 2004] that in its published version consists of 197 actions and commitments, partly of very important scale and wide-ranging practical importance. Governments, the UN, other international organisations including financial ones like the World-Bank and stakeholders from civil society and the private sector had contributed to the IAP and underlined its importance as part of the outcomes. All actions and commitments included were the voluntary result of a bottom-up approach. They reflect specific national and regional conditions, capacities of actors, specific sectorial objectives and overall development targets of the contributors.

The follow up of the Bonn Conference was held on 8-9 November 2005 in Beijing. The “2005 Beijing International Renewables Conference” discussed the status of the global implementation of Renewable Energies. The outcome of the Conference was the Beijing Declaration which states [Bei 2005]:

"We emphasize the multiple benefits of increased energy efficiency and the use of renewable sources of energy for improving access to energy services, thereby contributing to the eradication of poverty as called for in the UN Millenium Development Goals (MDGs), increasing job opportunities, improving air quality and public health, reducing greenhouse gas emissions and combating climate change, enhancing energy security, and offering a new paradigm for international co-operation."

Last but not least one has to remind that the implementation of renewable energies into the world’s energy supply and the substantial investments needed to do so, call for an integrated approach to utilise all different available technologies and resources as well as energy end –use efficiency to minimise demand. No energy source alone can supply the future needs of mankind and even our conventional energy sources face the problem of fluctuating generation capacities. However, we have to keep in mind, that no alternative energy system will be available when we need it in the coming decades, if we do not start to change it now.

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ANNEX

A1
Key Energy Figures

2004 Total Primary Energy (world) [IEA 2006c]
and Gross Inland Consumption (EU) [EST 2006c,d]

World		EU 25		EU 15	
[Mtoe]	[EJ]	[Mtoe]	[EJ]	[Mtoe]	[EJ]
11 059.4	**463.0**	**1 746.8**	**73.2**	**1 536.5**	**64.3**

Energy Demand of Energy Branch and Energy Conversion Losses 2004 [IEA 2006c, EST 2006d]

	World		EU 25*		EU 15*	
	[Mtoe]	[EJ]	[Mtoe]	[EJ]	[Mtoe]	[EJ]
Gross (Inland) Consumption	**11 059.4**	**463.0**	**1 746.8**	**73.2**	**1 536.5**	**64.3**
Energy Branch Own Use	**624.7**	**26.1**	**87.2**	**3.7**	**72.9**	**3.1**
Electricity Generation Losses**	**2 053.1**	**86.0**	**387.2**	**16.2**	**338.2**	**14.2**
CHP Plant Losses**	**242.6**	**10.1**				
Distribution Losses	**180.3**	**7.5**	**25.2**	**1.1**	**20.7**	**0.9**
Other Losses**	**314.4**	**13.2**	**18.9**	**0.8**	**11.1**	**0.5**
Available for Final Consumption	**7 808.2**	**326.9**	**1 242.1**	**52.0**	**1 103.8**	**46.2**

*: preliminary data
**: Eurostat does not distinguish between pure electricity plants and CHP plants
*** i.e.: Statistical Differences, Gas Works, Petroleum Refineries, Coal and other Transfers,

Total Final Consumption 2004 [IEA 2006c, EST 2006d]

	World		EU 25		EU 15	
	[Mtoe]	[EJ]	[Mtoe]	[EJ]	[Mtoe]	[EJ]
total	**7 644.4**	**320.1**	**1 242**	**47.8**	**1 104**	**42.5**
Industry	**2 058.3**	**86.2**	**319**	**13.3**	**280**	**11.7**
Transport	**1 974.6**	**82.6**	**350**	**14.7**	**322**	**13.5**
Other Sectors	**2 932.6**	**122.8**	**470**	**19.6**	**412**	**17.3**
Non-Energy Use	**678.9**	**28.4**	**101**	**4.2**	**91**	**3.8**

* extrapolated
** World: Total Primary Energy Supply

World Oil Demand [IEA 2006d]

2001 average	2006 average	Estimated 2007
75.7 million barrel per day	**84.49 million barrel per day**	**85.93 million barrel per day**
12 029 million litre per day	**13 434 million litre per day**	**13 663 million litre per day**
10.2 Mtoe/day	**~ 11.2 Mtoe/day**	**~ 11.4 Mtoe/day**

Electricity Generation in 2004 [EST 2006c, e]

	EU 25 [TWh]	EU 15 [TWh]
Total electricity production	**3 152.1**	**2 796.3**
Conventional thermal power plants	**1 729.5**	**1 468.2**
Nuclear power plants	**986.1**	**910.2**
Hydro	**303.9**	**287.8**
Absorbed by pumping	**46.6**	**42.7**
Other Renewables	**132.7**	**130.0**
White Paper Target for Renewables in 2010	**685***	**634**

* Assuming the White Paper Target for EU15 and 2% increase of electricity demand in the New Member States

Greenhouse Gas Emissions in 2004 [IEA 2006c, EEA 2006]

	EU 25 [Mt]	EU 15 [Mt]
Total GHG emissions in CO_2 equivalent	**4 979.6**	**4 227.4**

	World [Mt]	EU 25 [Mt]	EU 15 [Mt]
Total CO_2 emissions	**26 583**	**3 891.9**	**3 320.9**
Emissions by sectors			
Energy use excl. Transport			**2 291.4**
Industrial Processes			**199.3**
Transport			**830.2**

	World [Mt]	EU 25 [Mt]	EU 15 [Mt]
Total CO_2 emissions	**26 583**		
Emissions by fuels			
Oil	**10 607**		
Gas	**5 263**		
Coal	**10 633**		
Other	**80**		

A2
Preliminary list of biomass resources for Regional Biomass Resource Assessment

Agricultural resources:

- Cereals (wheat, barley, oats, rye, corn and others)
- Oil crops (rape seed, sunflower and others)
- Starch crops
- Sugar crops (sugar beet, sweet sorghum and others)
- Herbaceous crops (miscanthus, reed canary grass and others).

Agroforestry and Short Rotation Forestry

- Poplar, Willow and others

Forest/Sylviculture

The use of agricultural or forestry residues will be addressed as well.
At this stage, the draft list of data to be collected at regional level (NUTS2 level, EU25+2) is as follows:

Regional characteristics (Geography and climate)

- Area [km^2]
- Latitude range [deg]
- Longitude range [deg]
- Elevation [m]
- Yearly and monthly sums of global solar radiation [kWh/m^2]
- Temperature (monthly averages) max/min and daily average [°C]
- Precipitation monthly average, and max/min [mm/year]
- Main soil types in agricultural zones
- Natura 2000 and nature protection areas
- Water protection areas

Regional characteristics of land use and crop production

- Land use/land cover (CORINE Land Cover 2000 and latest available) [ha]
- Share of land used for bioenergy (2001-2005 or latest available, Utilized Agricultural Area, arable land, grasslands, set aside and abandoned land, less favoured areas, organic farming area…)
- Crop acreage [ha], and yield [t/ha] (2001-2005 or latest available)
- Main cropping systems used (intensive, extensive, irrigated…) and their share [%]

Estimated land potential available for bioenergy

- From agricultural land presently used
- From set aside land and land temporarily unused
- From forestry and agroforestry

Crop parameters

- Growing period [start-end date], temperature and water requirements…
- Parts of the plant used for energetic purposes [grain, whole plant, straw…]
- Competitive use [type and percentage]

Environmental impacts

- Soil quality (erosion, soil compaction, loss of organic carbon, moisture retention, nutrient input…)
- Water quantity and quality (groundwater and surface water)
- Emissions (Nitrous oxide, carbon release…)
- Biodiversity

Energy related technical issues

Energetic characteristics of the crops

- Heating value [LHV MJ/dry kg]
- Moisture content at harvesting and when used [%]

Conversion technologies used

- Combustion
- Gasification
- Fermentation
- Refining

Economic issues

Regional assessment of the energy consumption and biomass contribution

Regional Energy consumption

- Heating
- Electricity
- Transport

Main uses of bioenergy at regional level (Type and %, including if possible small scale domestic use)

- Heating
- Electricity
- Combined Heat and Power (CHP)
- Transport
- Biomass plants presently operational in the region (installations/facilities/plants)
- Resource [type] and amount [t]
- Technology [type] and conversion chain
- Conversion factor [%]
- Capacity [W]

- Transportation distance radius [km]

Policy and economic bioenergy related issues

Market prices and costs

Energy

- Heat [€/GJ]
- Electricity [€/kWh]
- Oil fuels [€/l]

Biomass resources and products

- Crops, crop residues, forestry residues, fuel wood, wood industry residues [€/GJ, €/t.Dry Matter]
- Biogas [€/GJ]
- Biofuels [€/l]

Policy issues and bioenergy support schemes (European, national and regional)

Common Agricultural Policy

Direct Support Schemes

- Quota based systems (Green certificates, Tendering)
- Fixed price systems (Feed-in tariffs, fixed-premium mechanism, straight subsidy)

Tax incentives

- Income tax deduction for investment
- Energy taxes
- Eco-taxes
- Tax reductions/exemptions

Subsidies schemes

- Investment subsidies
- Energy production subsidies
- Subsidies for the use of RES as a fuel
- Provision of special loan schemes
- Bioenergy Research/Development and Demonstration Programmes
- Programme and budget
- Agricultural and Rural Development programmes, EU Structural Funds

Socio-economic issues

- Population (size and density)
- Number of households
- Employment rate and sectorial distribution
- Bioenergy related employment rate
- Domestic consumption of energy (Breakdown of energy carriers used).

A3
Support mechanisms for Photovoltaic in the European Union and Switzerland

Austria	The amendment of the Austrian Eco Electricity Law (Ökostromgesetz) was passed the Parliament on 23 May 2006 and went into force on 1 July 2006. But the tariff negotiations are still ongoing. It is expected that they will be decided in October 2006. **Key elements of the Law are:** Electricity from all renewable energy sources will be supported with € 17 million per year. 10% are earmarked for PV, with the same amount added by the Federal States, because of their co-financing duty. The support will be constant for 10 years, with a degressive support for 3 more years and thereafter an obligation for the utilities to accept the electricity from a PV system for another 13 years. Some of the Federal States have investment support schemes.
Belgium [Ode 2006]	Green Certificates (with guaranteed minimum price): 0.15 €/kWh; Flanders from 1 January 2006: 0.45 €/kWh for 20 years. Additional support in Flanders depends on whether the PV installation is done privately, by an enterprise or a farmer. The support schemes used are investment subsidies, eco premiums, tax reductions and interest reduced mortgages.
Cyprus	Feed-in tariff: 0.224CYP£/kWh (0.391 €/kWh) for households and 0.196CYP£/kWh (0.342 €/kWh) for enterprises. If an investment grant is taken, the tariff is reduced to 0.012CYP£/kWh (0.21 €/kWh). Investment grants for households, other entities and organisations, not engaged in economic activities are limited to a maximum 55% of the eligible costs and the maximum grant is 16.5 k€ (CY£ 9.500). For enterprises, the grant is 40% of eligible costs and the maximum amount of the grant is 12 k€ (CY£ 7.000).
Czech Republic	New Law on the Promotion of Production of Electricity from Renewable Energy Sources went into effect on 1 August 2005. Producers of electricity can choose from two support schemes: • Fixed feed in tariff for 2006: Systems commissioned after 01/01/06: 13.2 CZK/kWh (0.466 €/kWh) Systems commissioned before 01/01/06: 6.28 CZK/kWh (0.222 €/kWh) • Market price + Green Bonus; Green Bonus for 2006 Systems commissioned after 01/01/06: 12.59 CZK/kWh (0.445 €/kWh) Systems commissioned before 01/01/06: 5.67 CZK/kWh (0.200 €/kWh) From 2007 onwards the annual price decrease for new installations should be 5% maximum.
Denmark	No specific PV programme, but settlement price for green electricity 60 Øre/kWh (0.08 €/kWh) for 10 years, then 10 more years 40 Øre/kWh.
Estonia	No specific PV programme, but Renewable Portfolio Standard and tax relief. Feed-in tariff for electricity produced out of RES is 5.1 ct/kWh.

Finland	No PV programme, but investment subsidy up to 40% and tax/production subsidy for electricity from renewable energy sources (6.9 €/MWh).
France	New feed-in tariff since 26 July 2006: (only valid for new installations) 0.30 €/kWh (0.40 €/kWh in Overseas Departments and Corsica) for 20 years. For building integrated PV installations there is a supplement of 0.25 €/kWh (0.15 €/kWh in Overseas Departments and Corsica). 50% of the investment costs are tax deductible. Lower VAT of 5.5% on system costs (without labour). Accelerated depreciation of PV systems for enterprises. Regional support still possible. The 5% tariff digression for new installations was cancelled. All tariffs (old and new) will be adjusted annually in accordance to the inflation during their duration.
Germany	Feed-in tariff for 20 years with built-in annual decrease of 5% from 2005 onward. For plants, neither on buildings nor sound barriers, the annual decrease is 6.5% from 2006 onward. **Tariffs for new installations in 2006:** Free standing systems: 0.406 €/kWh Systems on buildings and sound barriers: 0.518 €/kWh < 30 kWp, 0.4928 €/kWh > 30 kWp and 0.4874 €/kWh > 100 kWp. For façade integration there is an additional bonus of 0.05 €/kWh.
Greece	New feed-in tariff since June 2006: 0.45 €/kWh (0.50 €/kWh on islands) for systems < 100 KWp and 0.40 €/kWh (0.45 €/kWh on islands) for systems > 100 KWp guaranteed for 20 years. Commercial installations are eligible to grants (30 to 55% of total system costs), while small domestic systems are eligible for a 20% tax deduction capped at € 500 per system (€ 700 in 2007). For 2020 a target to reach at least 700 MWp (500 MWp mainland, 200 MWp islands) has been set.
Hungary	No PV specific measure, but feed-in tariffs for RES were set through the Electricity Act, which entered into force on 1st January 2003. According to Regulation No. 105/2003. (XII.29.) GKM, the Electricity Suppliers are obliged to purchase electricity from producers utilising RES, if their capacity is over 100 kW. However, in the case of smaller plants, individual arrangements are possible. There is no differentiation between the renewable sources. The current feed-in tariffs are: • Peak: 25,30 HUF/kWh (0,1 Euro) • Off Peak: 15,80 HUF/kWh (0,063 Euro) • Average: 19,36 HUF/kWh (0,077 Euro) • Average over the year: 18,35 HUF (0,073 Euro)

Ireland	The Alternative Energy Requirement (AER) tender scheme was replaced by a new Renewable Energy Feed in Tariff (ReFIT) scheme in 2006. However, PV is not included.
Italy	Feed-in tariff: guaranteed for 20 years. The tariffs for 2005 and 2006 are listed below, after that there is a 5% decrease for new systems each year, but tariffs and digression will be corrected according to inflation (ISTAT). The original cap of 100 MW to be reached in 2012 was raised to 500 MW (Ministerial Degree 6 February 2006). 1) up to 20 kW: 0.445 €/kWh + "net metering", i.e. each kWh used at home, is deducted from the electricity bill. (1 and 2 together have a cap of 60 annually) 2) between 20 kW and 50 kW: 0.46 €/kWh 3) between 50 kW and 1 MW: 49 €/kWh (cap of 25 MW annually)
Latvia	Feed-in tariff but not PV specific: Licensed before 01.06.2001: double the average sales price (~ 0.101 €/kWh) for eight years, then reduction to normal sales price. Licensed after 01.06.2001: Regulator sets the price A national investment programme for RES has been running since 2002.
Lithuania	No specific PV support. National Control Commission for Prices and Energy approves **long-term purchase prices for renewable electricity**, and grid operators must give priority to its transport.
Luxembourg	A support scheme was set with a "Règlement Grand Ducal" in September 2005. The Règlement has a cap of 3 MW by 2007. The new feed-in tariff is 0.56 €/kWh for 20 years, for 20 years (but due to the fact that this is a "Règlement" and not a Law it is not binding.). In addition, grants up to 15% are available, but limited to € 900 per each member of a household (only the head of the household can receive double that amount).
Malta	Net metering for electricity from PV systems: 0.126 €/kWh Surplus exported to the grid: 0.063 €/kWh – but there is a one-off charge of € 46 for the extra metre. 20%-grant for roof-top PV installations.
Netherlands	Feed-in tariff: 0.097 €/kWh for 10 years and Net metering up to 3000 kWh/year for existing systems. On 25 August the Minister of Economy announced the immediate suspension of support for new electricity generation plants using renewable energy sources.
Poland	Tax incentives: no customs duty on PV and reduced VAT (7%) for complete PV systems, but 22% for modules and components. Some soft loans and subsidies. A new law was passed in April 2004 that tariffs for all renewable energies have to be approved by the regulator (until now only for projects larger than 5 MW).

Portugal	Revision of feed-in tariff in 2005 with cap of 150 MW (2010). The tariff is guaranteed for the first 15 years or 21 GWh/MW (whatever is reached first). : • 0.45 €/kWh < 5 kWp • 0.28 €/kWh > 5 kWp. Reduction of VAT rate from 21 % to 12 % on renewable equipment, custom duties exemption and income tax reductions (up to € 730 for solar equipment). Grants up to 40 % of the total eligible cost (max. € 150,000 per application) are available under the PRIME programme (2000-2006).
Slovakia	Feed-in tariff set by regulator each year. 8 SKK/kWh (ca. 0.206 €/kWh) for 2006. Tax deduction on income earned. RES feed-in tariff in 2005: ~ 3 ct/kWh
Slovenia	Feed-in tariff: either fixed price or electricity price (8 SIT/kWh) + premium The plant size limit was removed in June 2006. Uniform annual price — Uniform annual premium 89.67 SIT/kWh — 81.67 SIT/kWh 0.375 €/kWh — 0.346 €/kWh
Spain	Feed-in tariff with cap of 150 MW: • 0.44 €/kWh < 100 kWp for 25 years (575% of average electricity price). After 25 years 460% of average electricity price. • > 100 kWp 0.23 €/kWh for 25 years (300% of average electricity price), after 25 years 240% of average electricity price.
Sweden	70% tax deduction on investment and installation cost for systems on public buildings from May 2005 until end of 2007, with a maximum limit per building of € 550,000 and covers both material and labour costs. Electricity certificates for wind, solar, biomass, geothermal and small hydro. Energy tax exemption.
Switzerland	Net metering with feed-in tariff of min. 0.15 CHF/kWh (0.10 €/kWh); investment subsidies in some cantons; promotion of voluntary measures (solar stock exchanges, green power marketing).
United Kingdom	Investment subsidies in the framework of a PV demonstration programme. Reduced VAT.

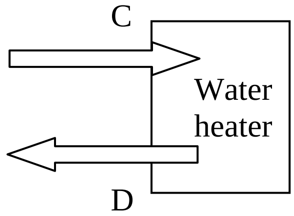
A5
Heat Measurement Principles and Technologies

Introduction

The measurement of a flow of thermal energy is based on the measurement of two physical properties, e.g. a flow and a temperature difference. The analogy with the measurement of electrical energy is illustrated in the figures below.

The electrical energy [Wh] consumed in the resistance is calculated from the potential difference [V] measured between point A and B, and the flow of electrons, current [A]

The equivalent to consumed thermal energy is calculated from the temperature difference between point C and D [ºC] and the flow of water [m^3/s].

	
Electrical energy measurement	Thermal energy measurement

The measurement of thermal energy is in principle similar to electrical energy however due to the physical differences, like dimension of water pipes, complexity of installations, etc. it is in practice more difficult than electrical energy measurement. The accuracy of the measurements depends not only on the applied sensors and instruments but also on the correct place where the sensors are positioned.

Renewable Energy Heat measurement

Three technologies are considered under RES-Heat:

- Solar Thermal
- Geo-thermal and
- Biomass.

The applications of these technologies are mainly in the building and industrial sector and differ in the size of the plant: small solar thermal collectors for domestic hot tap water, to large geo-thermal district heating plants.

Quantification of the produced heat by a plant is in principle the measurement of a mass-flow (usually water) and a temperature difference. A second way is an empirical method. The produced heat is derived from calculation that has no metrological inputs.

Note that most data available for RES-Heat come from calculations and not from measurements. The reason is that enormous amount of small sized installations exist, like fire places, solar collectors and heat pumps which become too costly to measure individually.

Heat counters, from the smallest domestic appliances to the largest industrial equipment with far more than 10 MWatt ratings, consist of three basic parts:

1. Flow meter (water is used almost exclusively as heat transfer medium)
2. Temperature sensors (usually two parts to measure a temperature difference)
3. Processor (often also called integrator)

An overview of measurement principle could be given. An initial attempt is given below.

Measuring the energy flows

As has been decided the measurement of the RE-H energy flow will take place after the conversion which means that all storage and transfer issues are neglected. Biomass is measured after the combustion, solar thermal after the collector and geothermal after the heat exchanger (direct system) or after the heat pump.

Note that auxiliary energy supply within the conversion process is only considered when being more than 5 %. It is expected that only Heat Pumps will find consideration as auxiliary systems. The energy used to produce and transport biomass shall not be considered.

Temperature measurement

Sensors and instruments are available on the market that perform the same measurement but that can have a different accuracy or precision. To measure temperatures in a flow of water, usually thermocouples or platinum resistance (PT-) sensors are used. Thermocouple sensors are available for different temperature ranges each with its own accuracy. A PT100 temperature sensor can have a higher precision than a thermocouple. Note that the quality of the instruments and sensors are not related to the measurement itself. A PT100 temperature sensor can be measured in different ways (2-, 3- or 4-wires) with different accuracies.

Transit Time Meter Basic Theory

Measurements are made by sending bursts of signals through a pipe. The measurement of flow is based on the principle that sound waves travelling in the direction of flow of the fluid require less time than when travelling in the opposite direction. At zero velocity, the transit time or delta T is zero. If we know the diameter of the pipe, the pipe wall thickness and the pipe wall material the angle of refraction can be calculated automatically and we will know how far apart to space our transducers. The difference in transit times of the ultrasonic signals is an indication for the flow rate of the fluid. Since ultrasonic signals can also penetrate solid materials, the transducers can be mounted onto the outside of the pipe. Fast Digital Signal Processors and signal analysis guarantee reliable measuring results even under difficult conditions where previously ultrasonic flowmeters have failed.

Doppler Flowmeter Basic Theory

Doppler ultrasonic flowmeters operate on the Doppler shift principal, whereby the transmitted frequency is altered linearly by being reflected from particles and bubbles in the fluid. The net result is a frequency shift between transmitter and receiver frequencies that can be directly related to the flow velocity. If the pipe internal diameter is known, the volumetric flow rate can be calculated. Doppler meters require a minimum amount of solid particles or air in the line to achieve measurements.

Thermal Mass Flow Meters

These are based on an operational principle that states that the rate of heat absorbed by a flow stream is directly proportional to its mass flow. As molecules of a moving gas/liquid come into contact with a heat source, they absorb heat and thereby cool the source. At increased flow rates, more molecules come into contact with the heat source, absorbing even more heat. The amount of heat dissipated from the heat source in this manner is proportional to the number of molecules of a particular gas/liquid (its mass), the thermal characteristics of the gas/liquid, and its flow characteristics.

District heat metering

The idea of district heating is to heat up a whole district from a central source through a distribution network. The heat is extracted from the distribution network by heat exchangers and the water is then subsequently returned to the central. The heat exchange between the district heating network and the building occurs in district heating substations. Heat meters are located in such substations and are divided into two main categories depending on their heat energy estimation frequency modes, which is either constant or flow rate dependent.

In the district heating industry, heat meters, consisting among other things of a flow meter, are used for billing purpose. The district heating industry desires accurate and low cost flow measurements. The total cost for measuring, including the cost for the heat meter, the reading and the maintenance, represents a relatively large part of the total energy cost. small commercial ultrasonic flow meters were investigated. These commercial meters are commonly used in heat meters in small district heating subscriber stations. The results demonstrate that both temperature changes and installation effects introduce errors in the flow measurements.

Renewable heat at the output side

For Solar Thermal the technically produced energy will find a corrective by a general assessment of the energy consumption in the specific application (e.g. one – family house).

The figures below explain the principle energy flow measurement points. (Figures by B. Sanner)

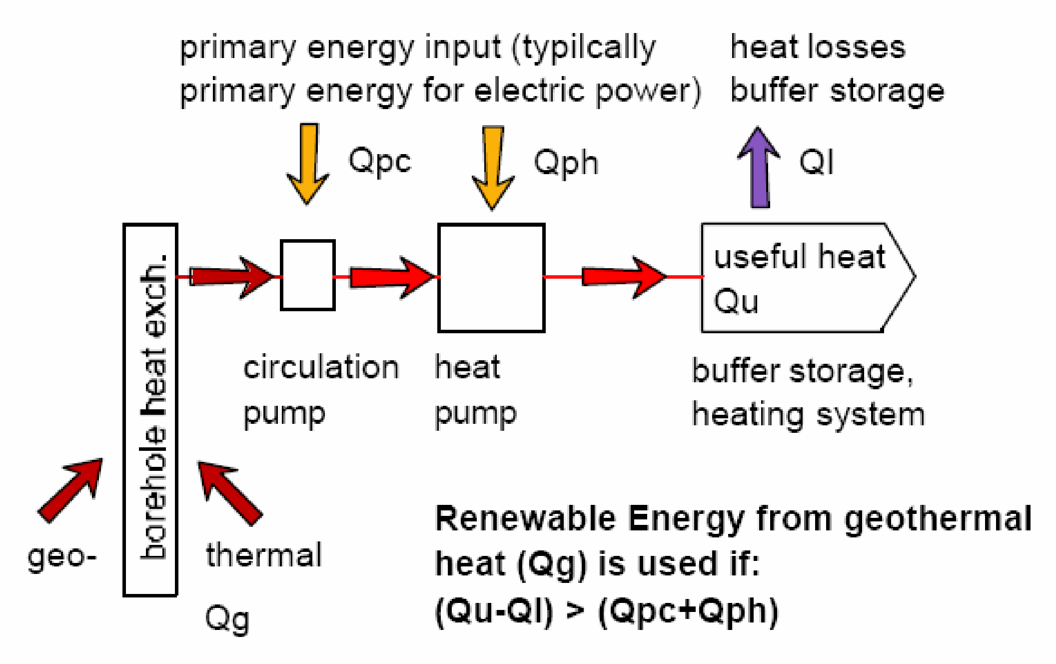


Fig. A.1: Borehole Geothermal

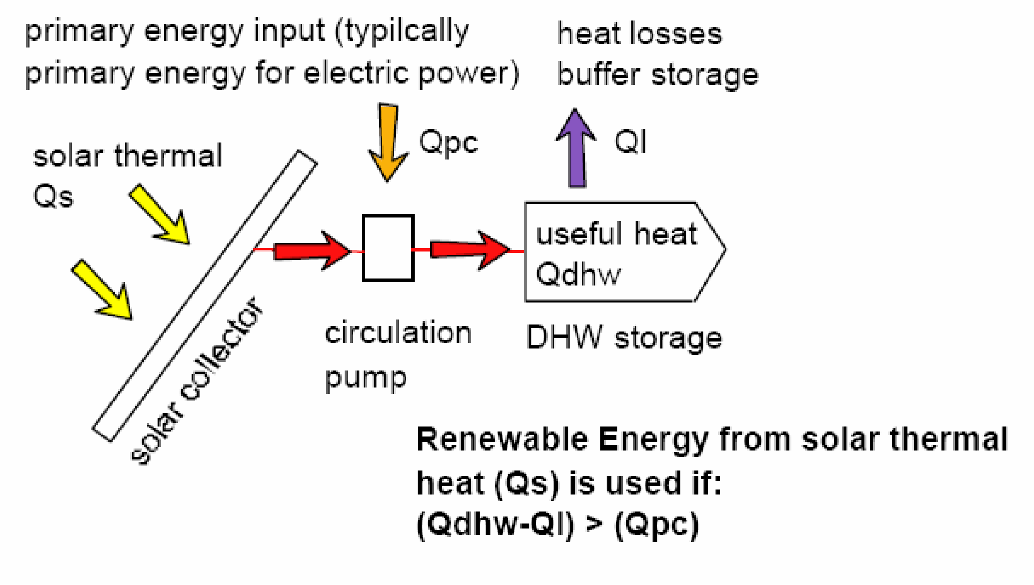


Fig. A.2: Solar Thermal

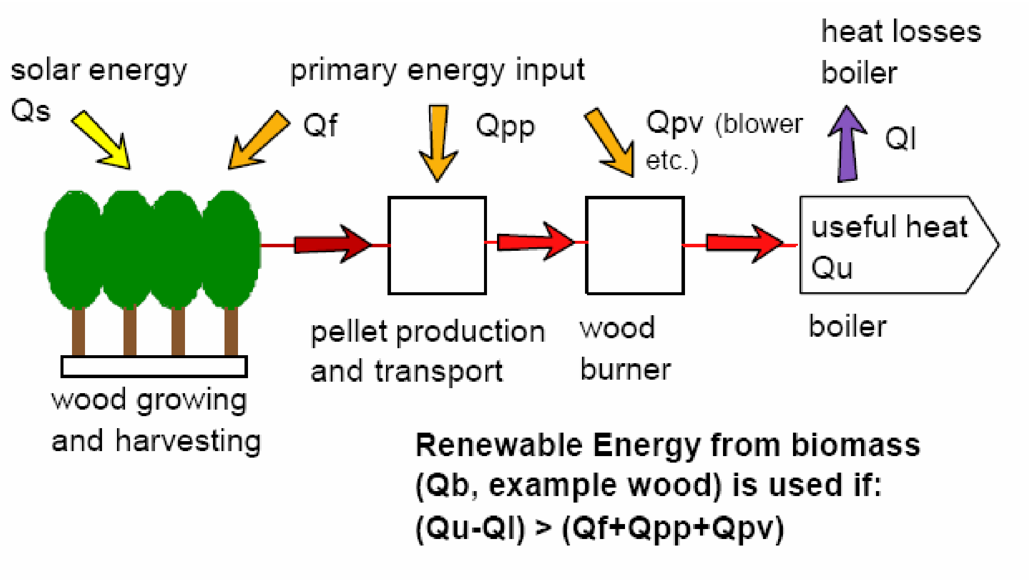


Fig. A.3: Biomass

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Abstract

The European Union is implementing challenging commitments to reduce greenhouse gas emissions by 8% in accord with the Kyoto protocol, and has established ambitious targets for renewable energies and energy end-use efficiency in its White Paper: Energy for the Future: Renewable Sources of Energy.

In the past decade, renewable energy technologies have made significant progress in terms of performance, cost and reliability, thanks to vigorous research, development, demonstration and market introduction programmes at European, national and also regional level.

Three major drivers are determining today's socio-economic framework for the impressive industrial and market developments of renewable energies. First, successful application of legally binding feed-in tariffs; secondly, liberalisation of the electricity market, and thus new possibilities for decentralisation of power generation. Third, and in the medium term, there is the undisputed need for massive re-powering the larger part of Europe's generation capacity. This will incur generally higher electricity costs, which reflect somewhat better the real costs (incl. externalities) of all the different energy technologies. Thus a more favourable market situation for sustainable technology choices will evolve, e.g. for massive renewable power generation. While technology development has been a key driver in the progress of renewable energies, first examples of significant penetration would have been impossible without appropriate, supporting policies including instruments such as introduction targets, carbon taxes, elimination of non-technical barriers, internalisation of external costs of energy, and harmonisation of market rules.

The efficient end-use of energy is a parallel area where modern technology, policies, better public conscience of the issues and market forces, like the utilities’ interest to exploit the potentials for avoidance of new transmission and generation capacity, have combined to achieve significant results. New integrated marketing concepts, like energy service companies, have been very successful lately, and organisationally break ground for the implementation of sharper physical efficiency concepts as well. This is of particular strategic importance for the New Member States of the EU, as the use of energy, including electricity, in these countries is still significantly less efficient than in the old Member States.

The aim of this Status Report is to provide relevant, validated and independent information on renewable energy and the efficient end-use of electricity to decision makers and the public.

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