EUROPEAN COMMISSION
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Status Report 2004

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

Energy End-Use Efficiency and Electricity from Biomass, Wind and Photovoltaics in The European Union

Editor
Arnulf Jäger-Waldau

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1) Source: Schüco Solar, Freiburg

2) Pix Nr.: 01221 **Title:** 2 Wind turbines on hillside with flowers; **Credit:** Gretz, Warren; acknowledge DOE/NREL

3) Pix Nr.: 04744; **Title:** New technology fuels high-efficiency electricity generation with biomass; **Credit:** Gretz, Warren; acknowledge DOE/NREL

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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, August 2004

Arnulf Jäger-Waldau
European Commission
Joint Research Centre; Renewable Energies Unit

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.

STReference@jrc.it

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CHAPTER 1

INTRODUCTION

Arnulf Jäger-Waldau and Harald Scholz

Between 1990 and 2000 the energy consumption in the European Union (EU15) increased by 10%, thus leading to an increase of energy imports as the Union's own production was insufficient for its energy requirements [EC 2003]. As a result, the dependence of EU15 on external energy sources and markets has been and is still increasing, presently resulting in an import quota of about 49% (in energy units). The EC's Green Paper on Security of Energy supply [EC 2000] anticipated, that this dependency could menace to reach over 70% over the next 20-25 years, already taking into account the enlargement of the European Union. In addition, 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.

Ever better scientific evidence about CO_2-, Methane- and other GHG-avoidance being **the** way to curb climate change is resulting in a major socio-economic challenge and a long-term issue for the international community. The commitments made in the Kyoto Protocol [Kyo 1997] are therefore seen as a first step only. Despite the fact that the European Union has reached its objectives in 2000 and ratified the Kyoto Protocol in 2002, greenhouse gas emissions are still above the pathway for the 2010 targets.

After two years when emissions of the six greenhouse[1] gases had risen by 0.2% and 1.3% a year in 2000 and 2001 respectively, there was a decline by 0.5% from 2001 to 2002. EU15 emissions of CO_2, which make up just over 80% of all EU greenhouse gas emissions, dropped by 0.3% between 2001 and 2002. CO_2 emissions nevertheless stood 1.4% higher than in 1990, largely because of growing emissions from road transport since the early 1990s [EEA 2004]. To reach the 8% GHG reduction between the base year 1990 and 2008 – 2012 with a linear approximation pathway, emissions in 2002 should have been 4.8% lower instead of the actual 2.9%. This leaves the EU with a long way to go to meet its commitment. However, several EU and national initiatives to reduce GHG emissions have been approved since 2002. This could lead to an accelerated progress in the coming 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 2004c], this presents unique research challenges and industrial opportunities for the global energy community.

[1] CO_2, methane (CH_4) and nitrous oxide (N_2O), plus three fluorinated industrial gases: hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6)

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 to this question leaves us with few options to decrease the energy intensity and, as this is not enough, to increase the Union's indigenous energy supply.

- **Decrease Energy Intensity[2] (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 can not 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 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 don't face these safety and security concerns. In addition, there is an abundant resource situation within the European Union. 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 it 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 30% 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.

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

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 ~0.7 Moe/M€) compared to EU-15 (average ~200 kgoe/1000 €) [EC 2003] 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 until 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 renewables 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 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. Renewables 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 € 29b 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 actually been 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 available technologies and resources 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 keep in mind, that not any alternative energy system will be available when we need it in the coming decades, unless we start to change it now.

1.1 Technologies to Generate Electricity from Renewables

In order to achieve the White Paper target of 12% Renewable Energies and 21% electricity from renewable energies for the European Union by 2010 indicative targets for different renewable energy technologies were set. The main challenges are within the following technologies: Biomass, Wind and Photovoltaic where the planed increase of electricity production is 10, 20 and 100 times respectively (Table 2.1).

Chapters 4, 5 and 6 will give an overview about the different renewable energy technologies, their options and their status of implementation. The conventional energy conversion chain to convert fossil or nuclear fuels into electricity is depicted in Figure 1.1. This is done for comparing it with the different renewable energy technologies.

Combustion is the first step in the total conversion chain from fossil fuels to electricity. Chemical energy stored in the fuel is converted into thermal energy. In the case of nuclear fuels a controlled nuclear reaction converts the chemical energy into thermal energy. The thermal energy is then transformed via a steam generator into mechanical energy used in a turbine. The mechanical energy drives a generator, which via a electromagnetic energy conversion generates electrons and the electric current.

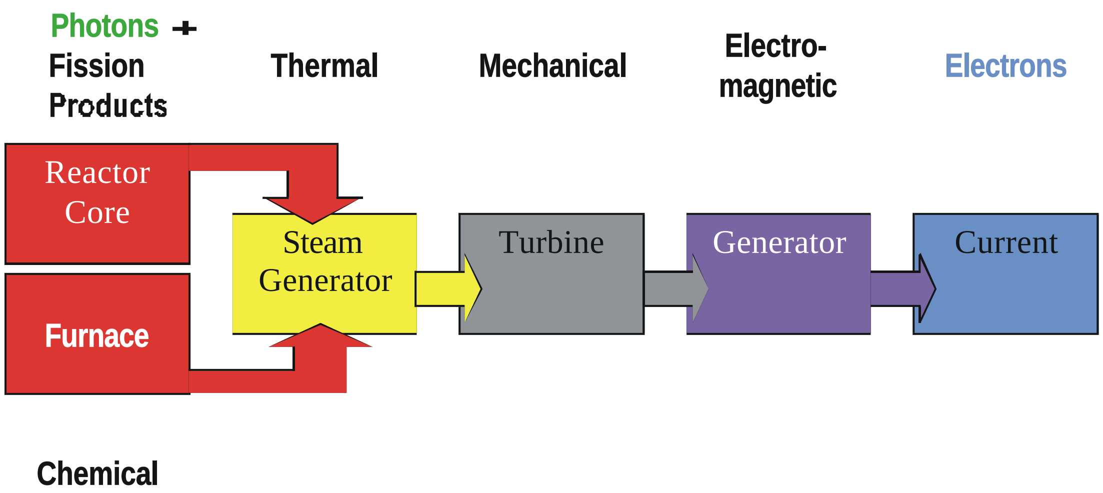


Fig. 1.1: Conventional Energy Conversion Chain (Figure: courtesy of H. Ossenbrink)

The First Law of Thermodynamics tells us that the energy is conserved in all its transformations. So, the ratio of energy output to energy input is always unity, or 100%. From this it is obvious that the efficiency of conversion devices is important, i.e. to obtain the best change into every form with the least amount of undesirable “loss” in the form of energy which can’t be used, e.g. heat or waste fuel. This shows, that due to the different energy transformation steps in this conversion chain, a considerable amount of the primary energy is converted into energy forms, which can’t be utilised and therefore are considered as losses.

Due to the different maturity stages of the above mentioned renewable energy options to generate electricity this report focuses on Energy End-use Efficiency and Electricity from Biomass, Wind and Photovoltaics.

CHAPTER 2

THE POLITICAL FRAME IN THE EUROPEAN UNION

Harald Scholz, Andrew Machirant, Paolo Bertoldi and Arnulf Jäger-Waldau

2.1 White Paper and beyond: EU strategic awakening towards a sustainable energy system

The establishment of a stable and common policy framework for renewable energy deployment at EU level was driven by four main concerns: the growing EU energy import dependency, security of supply, evermore scientifically evidenced man-made climate change and the threat of missing the future of a global technology market. *"In the early 1990s it became clear that, in addition to the efforts made over more than thirty years to develop renewable technologies through Community research, demonstration and innovation programmes, a policy framework that combines legislative and support measures was necessary to increase and foster renewable energy market penetration."* [Ere 2004]. The last decade's development of RE-targets in Europe is shown in Figure 2.1.

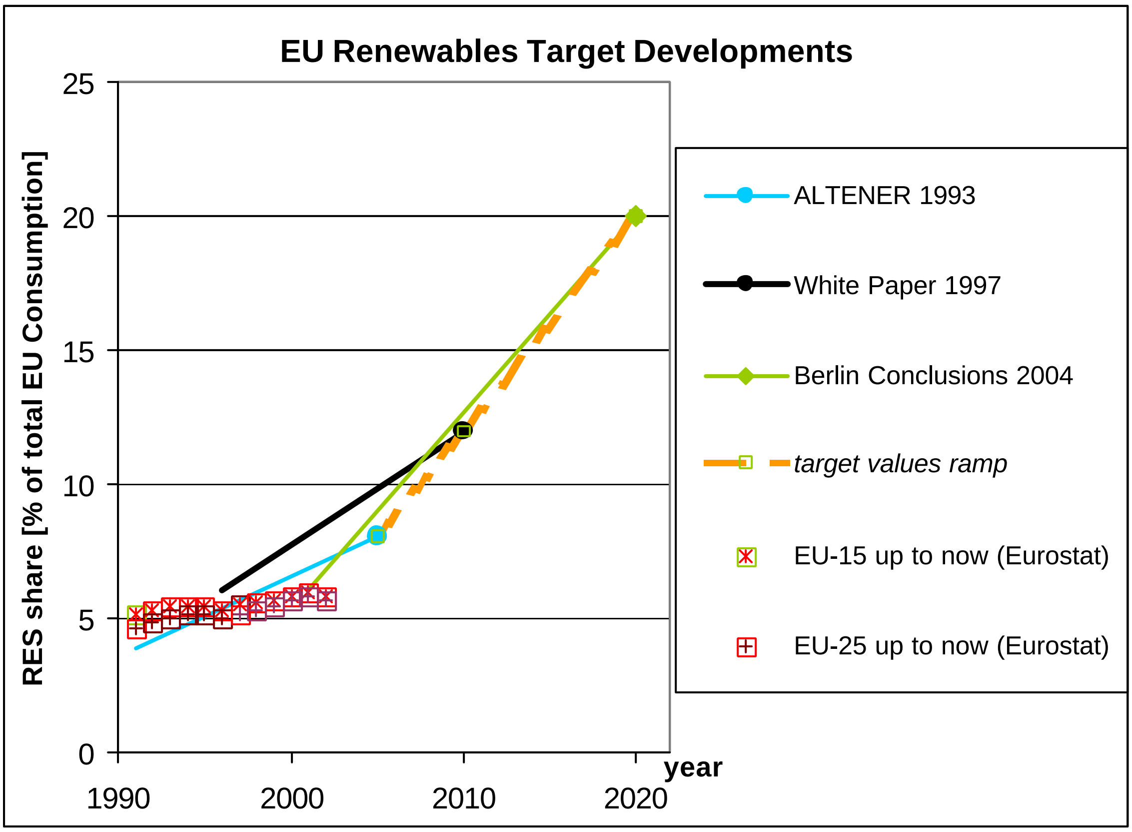


Fig. 2.1: Pace of official and indicative mid-term targets for the deployment of RE at EU-level, compared to the consolidated data of Eurostat up to 2002.
Note: The base-value for the target of the Berlin Conclusion [Ber 2004] was taken from latest consolidated EUROSTAT figures for 2001

It can be seen that the increase of targets at the political level has taken place in a linear fashion – significantly steeper than the real growth of the RE-share as far as statistically consolidated. In the following, we will shortly analyse the evolution of the most important documents representing the EU's political RE-targets. A differentiation of the main underlying motivations serves to explain chosen implementation instruments: Strategy and Consultation Papers, Action Programmes, RTD&D initiatives and, most importantly, EU-Directives. The latter are influencing and demanding policy actions at national level, and its possible to emphasise the paradigm changes that formed the enhanced political position RE has today in European decision-making.

In December 1997, the European Council and Parliament adopted the European Commission's "**White Paper for a Community Strategy and Action Plan**" [EC 1997], in which concrete goals for the development of Renewable Energies were motivated and described. "*Renewable energy sources may help to reduce dependence on imports and increase security of supply. Positive effects are also anticipated in terms of CO_2 emissions and job creation.*" As at that time renewable energy sources accounted for approximately 6% of the Union's gross internal energy consumption, the aim was formulated to double this figure towards 12% by 2010. With this central quantitative element, the paper formed a strategic basis for much of the recent work on renewable energy at EU level. It also established an Action Plan for achieving this goal, including a *Campaign for Take-Off* (CTO), which ran from 1997 until the end of 2003. The White Paper also set targets for each RE *technology*. Table 2.1 shows for the EU-level, which relative multiplication factors need to be achieved by each technology, in order to achieve originally foreseen contributions.

Table 2.1 Estimated Electricity Contribution for different energy sources in 2010 as set out in the White Paper [EC 1997] (data only available for EU15).

Type of energy	Installed Capacity		Electricity produced [TWh/a]		Increase of electricity production from 1995 to 2010
	1995	2010	1995	2010	
Wind	3 GWe	40 GWe	4	80	× 20
Hydro (large)	83 GWe	91 GWe	270	300	× 1.11
Hydro (small)	10 GWe	14 GWe	37	55	× 1.35
Photovoltaic	0.03 GWe	3 GWe	0,03	3	× 100
Biomass (total)	45 Mtoe	135 Mtoe	23	230	× 10
Geothermal: el.	0.5 GWe	1 GWe	4	7	× 1.75
TOTAL			337	675	× 2
Total electricity Consumption			2366	2870	
Share of RES-E			14%	23.5%	
White Paper Target				634 22.1%	

The main challenges are within Biomass, Wind and Photovoltaics, where the planned increase of electricity production is 10, 20 and 100 times, respectively. Such factor comparisons indicate learning curves that remain to be accomplished, and add arguments in the discussion regarding RTD&D measures, which are important for providing future opportunities and ultimately market chances. Chapters 4, 5 and 6 of this Status Report give an overview on the different renewable energy technologies, their options and their current status of implementation.

Progress in reaching these targets was first reported to the Council and the European Parliament (EP) by the Commission in February 2001 [EC 2001]. In this Communication, the reactions of the Council, the EP and the Committee of the Regions on the White Paper were briefly described. Although in any case adopted by both, it clearly indicates a higher grade of thrust towards RE-development by the EP in comparison with the Council at the time. Whilst the EP saw the targeted 12% as "*a minimum*", the Council viewed upon the target as "*providing useful guidance for increased efforts*". Also, the EP foresaw the necessity of legislative measures in RES-E and biomass, whilst the Council officially suggested to take the substantial expectations of the biomass RE-sector into account when formulating future Community policies on agriculture and waste management. This Status Report shows that there are still major obstacles in this latter respect.

In analysing initial progress of the White Paper, one must bare in mind that the February 2001 EC Communication hardly had the chance to base conclusions on *new*, statistically consolidated data. At the time, EUROSTAT figures showed a likely 5.9% RES-share for 1998 as compared to a consolidated 5.8% in 1997; in parallel, a lack of experience in RE-data gathering at all levels had to be admitted. RES-E from Wind, however, was ascribed a very remarkable take-off (+70% installed capacity from 1997 till summer 1999), specifically in those countries which had implemented appropriate political framework conditions.

Equally important was the finding that the increase of RES-contribution in absolute terms resulted only modestly in an increase of the RES market share, because of the total increase of energy consumption. The trends in energy consumption therefore highlighted the necessity of measures, alongside RE, for demand management and energy efficiency in order to reduce the gross EU inland consumption. The rationale that Energy End-Use Efficiency *helps* raising the share of RE in the home portfolio became more widely acknowledged. Together with many parallel developments in the Member States, it was also this discourse deriving from the White Paper, which anticipated and triggered the later development towards legally indicative and binding targets, both in RE technology and in Energy End-Use Efficiency.

2.1.1 Reducing EU Energy Supply Dependency: Diversifying Energy Sources and Improving Energy Security

Three years after the White Paper, the *Green Paper* "Towards a European strategy for the security of energy supply" [EC 2000] confirmed earlier argumentation. It highlighted an EU energy supply dependence of ~50% imported at that time and stressed that if no measures were to be taken this dependence would rise within the next 20 to 30 years to ~70 % of the Union's energy needs. As can be seen from Figure 2.2, the enlargement in 2004 and a further enlargement round towards EU-28 were already predicted to hardly compensate nor reverse this trend. Taking the desired economic growth prospects of New Member States and Candidate Countries into account, and also the foreseeable increased wealth and mobility of their citizens, a comparable growth rate of energy import dependence will be the likely result. After a first wave of market-driven independency from former energy import pathways, specific domestic fossil resources (such as coal in Poland and the Czech Republic) may even come under pressure considering the climate change and emissions aspect, and the forces of liberalised markets. Such a situation is certainly not paving the way towards lowered energy import dependence either.

A further variable influencing EU energy import dependence over the next decades will be forecasted 'time to depletion' of the finite North-Sea Oil resources. In 2001, the British and Danish oil production together accounted for 18% of the EU-15 and 15% of the EU-25 primary energy production [EUR 2004]. The Green Paper showed three scenarios ("low", "probable" and "high") of the North Sea Oil reserves to be depleted in 2015, 2025 and 2035, respectively.

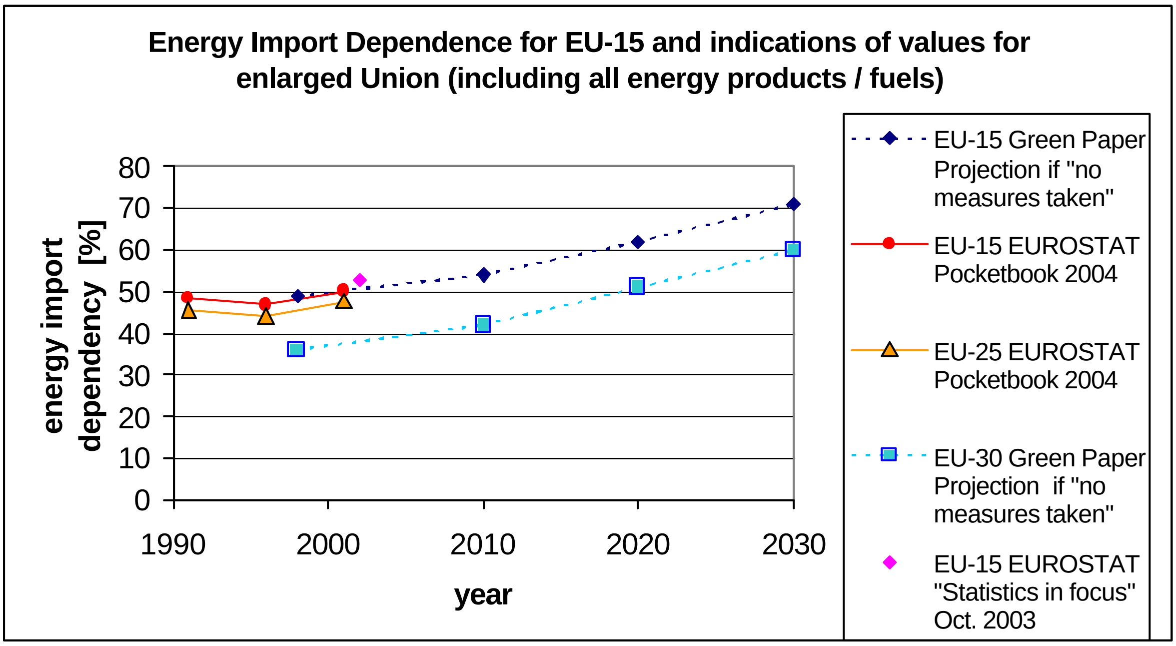


Fig. 2.2: Comparison of EUROSTAT figures in energy import dependency and the forecasts used in the Green Paper [EC 2000].

Note: The lower levels for the 30 European countries are due to domestic resources of the New Member States, Accession States, and notably Norway. The development of Eastern- and Southern-European New Member and Candidate State's consumption, however, remains difficult to preview. Generally, they are expected "*to become more similar to the energy structure of the EU over the next decades*" [EC 2000]. 'Leapfrogging' towards more efficient energy technology may mitigate their rising energy hunger. However, higher wealth and intensified mobility may pose a problem with further increasing consumption.

Independent observers continue to diffuse the year 2020 as a likely ending [Ale 2004]. The UK Department of Trade and Industry (DTI) has published graphs with consolidated figures, which in fact show the sum of UK's "*Proven and Probable Reserves*" plus its "*Possible Reserves*" having almost halved from 1993 to 2003 [DTI 2004]. It appears that in spite of the Green Paper's warning, this aspect is not influencing the EU-level strategic discussion to an appropriate extent.

The direct consequence of the described growth in energy import dependency will be a Europe becoming ever more exposed and vulnerable to price fluctuations in the short term, with potentially massively negative impact on national economies and trade balances, if no preventive action is taken.

The European Union's long term strategy for energy supply and security must, in contrast to the current development, "*be designed to ensure the well-being of its citizens, while respecting environmental concerns and looking towards sustainable development*" [EU 1997]. Retrospectively, the analysis in the Green Paper has proved itself to be rather accurate, as energy dependency of the EU-15 in 2002, e.g., already reached 52.9% [EUR 2003b]. Consequently, the Final Report on the Green Paper [EC 2002] concluded: "*Renewable sources of energy have a considerable potential for increasing security of supply in Europe. Developing their use, however, will depend on extremely substantial political and economic efforts. In the medium term, renewables are the only source of energy in which the European Union has a certain amount of room for manoeuvre aimed at increasing supply in the current circumstances. We cannot afford to neglect this form of energy.*"

It is interesting to observe that for all big OECD economies growing energy import dependency has become a main driver in political argumentation for RE, probably because the negative consequences (trade balance, risk increase for economic and geo-strategic stability) are more tangible in the short-term than for instance global consequences of substantial climate change. At the level of *political statements*, not yet governmental *targets*, statements of the form "20% renewable by 2020" are used by different political poles to define new horizons, however, careful attention has to be given on what quantity these 20% are referring to. The US-Assistant Secretary for Energy Efficiency and Renewable Energy within the Department of Energy (DOE), David Garman, announced at the World Renewable Energy Congress 2004 in Denver, that by 2020 the US will most probably produce 20% of its *electricity* by Renewables, mainly Hydropower, but increasingly wind energy as well [Gar 2004]. The 2004 US Democratic Party candidate for Presidency, John Kerry, announced "*We have to set a goal by 2020 that 20 percent of our energy will come from renewable fuels*" in reply to the question "*How would you get the US to become more self-reliant for our energy needs?*" [Ker 2003]. This latter goal referring to all US energy consumption (not only electricity) is notably similar to the final Declaration of the EC organised European Conference for Renewable Energy "Intelligent Policy Options" held in January 2004 in Berlin. Also there, the recommendations to the EU institutions were to achieve 20% of renewable energy in overall EU consumption by 2020 [Ber 2004].

The increasing demand for energy by the *transport sector* (+50% by 2010) and that specific sector's 98%-dependence on oil creates a further demand for renewable energies, i.e. bio-fuels. This is of particular importance as the European Union is already 76% (EU15) dependent on oil imports and is likely to rise to 94% dependency (EU30) in 2010 if the 'business as usual' approach is maintained. For this Status Report these facts are relevant, because bio-fuels development and biomass (for heat and/or electricity production), may increase competition for land-use and energy-crop supporting funding schemes.

As the EU to a large extent relies on imported energy, the dependence on supply and demand conditions in the international market have to be taken into account. Due to the world's population growth and the growing demand of developing countries, there is forecasted a rise in global primary energy demand by some 55% over 20 years, from 9.9 billion toe in 2000 to 15.4 billion toe in 2020. This will have a substantial impact on international fossil fuel prices and accordingly on electricity from fossil fuels.

Much more deployment of renewable energies and improved end-use efficiency are thus believed to be necessary elements of the strategy for affordable long-term supply of energy services. There will be a foreseeable rise of primary fossil fuels import dependence if no counteractions are taken. Moreover, an intensification of international security problems and conflicts in fossil fuel exporting countries, notably in the strategic ellipse covering the Persian Gulf countries up towards central Asia, can be observed. Short term effects of ever growing energy demand in the so-called BRIC economies (i.e., Brazil, Russia, India and China) with China in particular making an impact on world markets, will have fossil fuel prices most probably rising in the years to come.

Furthermore, there is enormous societal cost to pay for these developments mentioned above, Europe being no exception. Decision-making for alternatives *today* controls our option portfolio and available energy sources mix for the next decades to come, notably in electricity generation. This explains why there is a strong interest in renewable electricity and energy end-use efficiency technology motivated by the Supply Situation. This is *not* a problem with a "50 year +" -perspective, leaving us the option of "denying and delay", but critical in already much shorter time spans. Organising the responses with technologies acceptable today, whilst at the same time organising the long-term development of even better ones is clearly a policy issue.

2.1.2 The EU in the Global Challenge to Mitigate Climate Change

Whilst reducing EU energy-exterior-supply dependency and thus improving energy security, is one important policy-driving aspect, an equally important further one is the response to global warming, which has both short-term and long-term aspects. Often, the greenhouse gas (GHG) emission-triggered global warming is politically still seen as a long-term phenomenon with perceived time constants still much bigger than those of day-to-day policy and election campaigns, or in short, not yet in the mainstream of political business and argumentation. However, the risks of inaction are great and the infrastructure system changes necessary in largest parts of our fossil fuel based energy system are extensive and thus there is an urgency to start. This situation led at least to fixing short-term targets for GHG reduction by a substantial portion of the world's nations in the *Kyoto Protocol to the United Nations Framework Convention on Climate Change* (UNFCCC) [Kyo 1997] however, with delays in the ratification process of important signatory countries.

At EU-level, the political importance and the will to cope with the issue became manifest through the European Council in Gothenburg in June 2001, where Heads of State and Governments indicated that combating Climate Change is a major priority of the European Union's Sustainable Development Strategy. Accordingly, a proposal for a Council Decision to ratify the Kyoto Protocol was worked out [EC 2001a]. This document contained the negotiated burden-sharing of GHG emission reductions or at least controlled increases, to be shouldered by the different Member States, in order to achieve fulfilment of the overall EU-commitment: a reduction in EU-15 greenhouse gas emissions of 8% compared to 1990 levels by 2008 to 2012. The Council approved this on the 25 April 2002 [EU 2002].

These *binding* political commitments were prepared and accompanied by another important communication authored in DG Environment, aimed at taking full stock and further developing the EU Member States' responses to the climate change challenge, and entitled: "EU policies and measures to reduce greenhouse gas emissions: Toward a European Climate Change Programme (ECCP)" [EC 2000a]. This paper called for an integration of European policy, science and technology efforts. As can be seen from the first Communication on the *implementation of the first phase of the European Climate Change Programme* [EC 2001b], the ECCP bundled different implementation processes, legislative and non-legislative proposals, awareness campaigns, etc. This was done in order to set a new pace and mainstream of policy action, notably also in the energy field. Many of the actions announced therein meanwhile play a role in today's policy framework for Renewable Electricity and Energy End-Use Efficiency (see chapter 2.2). The Kyoto protocol has forced the pace of European policy-making for more sustainable energy. The first phase of ECCP was a starter for cross-cutting issues, like:

- promoting a more effective use of the Integrated Pollution Prevention Control Directive,
- proposing an EC emissions-trading scheme directive in such a manner as to link to project-based Kyoto mechanisms including the Joint Implementation (JI) and the Clean Development Mechanism (CDM) type,
- proposing a review of the GHG Monitoring Mechanism, thus adding much more seriousness of this aspect in day-to-day policy making *(This led to a Council Decision as a legal basis of the EU-wide compilation of the inventory for the UNFCCC [EU 2004a]).*

In addition it initiated action on energy issues alongside the Directive for Renewable Electricity (see chapter 2.2), like

- proposing a framework Directive for Minimum Efficiency Requirements in End-Use Equipment, and also initiatives on public procurement to look after energy-efficient goods and services,

- proposing a Directive on Energy Demand Management and on the promotion of Combined Heat and Power (CHP).

A second ECCP Progress Report "Can we meet our Kyoto targets?" was published in April 2003 [EC 2003a]. It confirmed the earlier one, indicating that the EU would not achieve the Kyoto target with the measures currently in place, but could successfully reach or exceed the target with *additional* policies and measures. Those taken into consideration included better linking EU agricultural policy with the Climate Change issue, including the ongoing Council process on a future reform of the Common Agricultural Policy (CAP). This latter aspect may prove important for a better development of the bio-energy sector, incl. electricity from biomass.

Nevertheless, the state of the art in GHG reduction is very inhomogeneous for the different Member States. Averaging across the statistically-available values for EU-15 is partly hiding critical developments. Given the fact, that the European Environment Agency (EEA) has now implemented an effective reporting system for the GHG emissions of the Member States, this Status Report takes the very latest EEA data in order to give a graphical overview about where the EU-15 Members stand (Figures 2.3a,b,c).

Those countries still in a fast process of achieving higher wealth, productivity and individual mobility levels, often featuring relatively high GDP growth rates etc., are *remarkably behind* in fulfilling their Kyoto target. This is particularly valid for Ireland, Portugal, Spain, Greece and Italy. For 2001 one can observe in these countries energy import dependencies reaching over 80%, Spain and Greece at around 70%.

This creates a logical bridge between the explanations for Energy Supply Security being a prime mover to renewable energy decisions and the commitments against Climate Change being a parallel one.

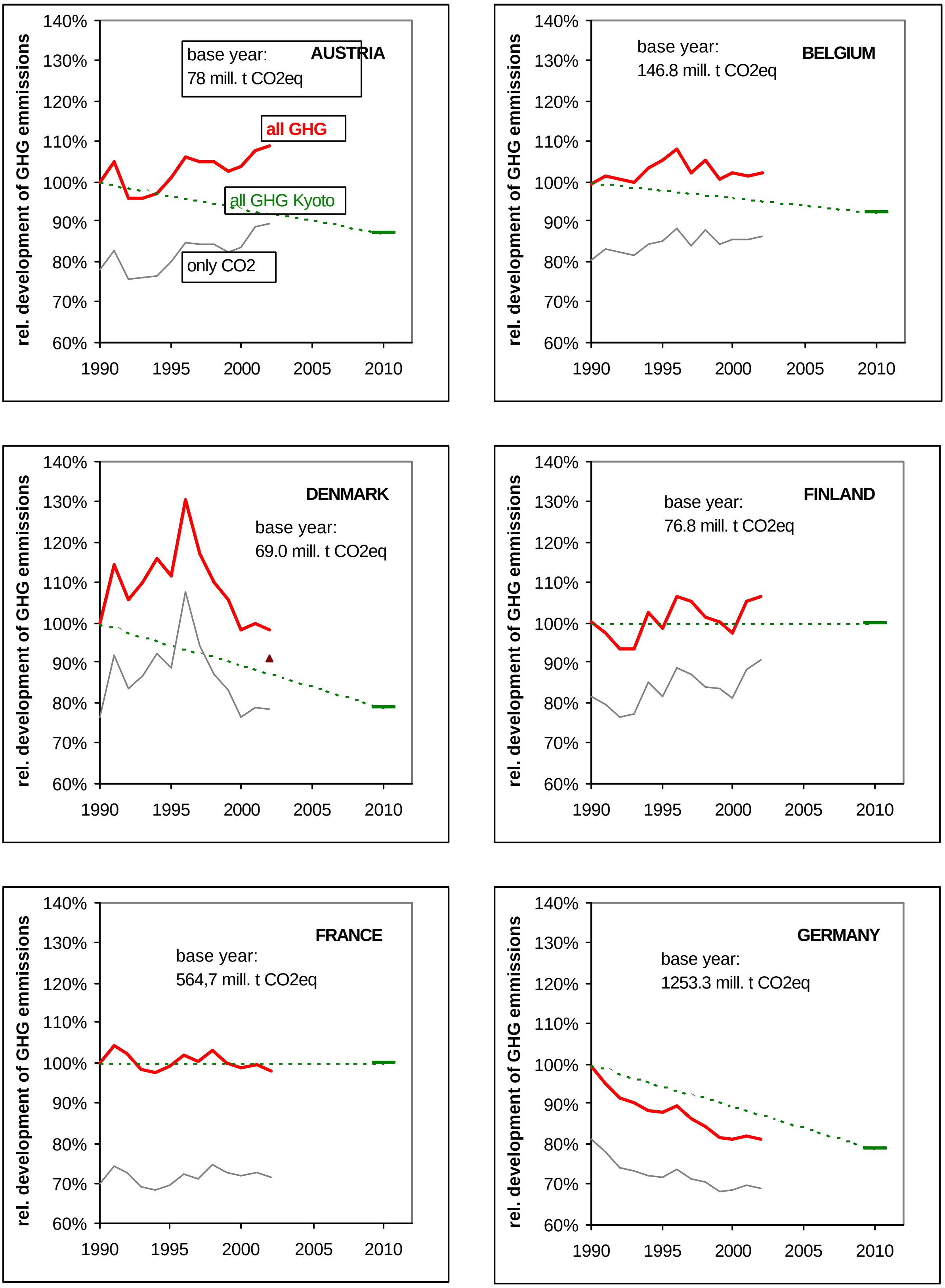


Fig. 2.3a: Relative fulfilment or lack of the singular Kyoto burdens by EU-Member States (source: EEA [EEA 2004b])

Fig. 2.3b: Relative fulfilment or lack of the singular Kyoto burdens by EU-Member States (source: EEA [EEA 2004b])

Fig. 2.3c: Relative fulfilment or lack of the singular Kyoto burdens by EU-Member States (source: European Environment Agency [EEA 2004b])
Remarks: The red lines are total yearly GHG emissions in CO_2-equivalent, without Land-Use Change and Forestry, and given as percent of the originally negotiated "base year value" in 1990. (For fluorinated gases, 13 Member States use 1995 as base year. This explains why the red curve not always starts exactly at 100%). The absolute base value at 100% in 1990 is also written, in million tons CO_2 equivalent. The dotted green line is simply the "Kyoto target path" from the base value in 1990 to the target value to achieve between 2008 and 2012, i.e. around 2010. Note that some countries were permitted to even increase their emissions in certain limits by the EU burden-sharing agreement. The grey line is for real CO2 only, and show emissions (again as percentages of TOTAL GHG base value), which have been caused by CO_2.

2.1.3 Trading Mechanisms Globally and European

At the global level, the Kyoto Protocol broke new ground with its three innovative "mechanisms". They aim at reducing the cost of emission curbing by allowing parties to pursue opportunities to do so abroad. In fact, the cost of curbing emissions varies considerably from region to region as a result of differences in, for example, energy sources, energy efficiency and waste management. It makes economic sense to cut emissions where it is cheapest to do so, given that the global impact on the atmosphere is the same. However, there are concerns that the mechanisms could allow parties to avoid taking climate change mitigation action at home, confer a "right to emit" on certain parties, or lead to exchanges of fictitious credits, which would undermine the Protocol's environmental goals. The Marrakech Accords sought to design a system that would fulfil the cost-effectiveness promise of the mechanisms, whilst also addressing concerns about environmental integrity and equity [Mar 2001].

Basically, the Kyoto Protocol defines three mechanisms to allow credit to be gained from action taken in other parties:

Joint Implementation (under Article 6) provides for Annex I parties to implement projects that reduce emissions, or remove carbon from the air, in other Annex I parties, in return for emission reduction units (ERUs).
Clean Development Mechanism (CDM) defined in Article 12 provides for Annex I parties to implement projects that reduce emissions in non-Annex I parties, in return for certified emission reductions (CERs), and assist the host parties in achieving sustainable development and contributing to the ultimate objective of the Convention.
Emissions Trading, as set out in Article 17, provides for Annex I parties to acquire units from other Annex I Parties. These units may be in the form of assigned amount units (AAUs), removal units (RMUs), ERUs and CERs.

The planned bookkeeping of these above-mentioned units within the Kyoto Flexible Mechanisms is rather complicated. This will be the object of a future publication in as far as its influence on the prospects of Renewable and Energy Efficiency investments needs specific explanations beyond the scope of the present status report. However, an important point for rounding off the EU policy framework description here, is that the **European Union Emission Trading Scheme (EU ETS)** will become compatible with the international (UN) trading schemes described above. It has been decided that the EU ETS will start the beginning of 2005 through a Directive of the EP and the Council dated 13 October 2003, "*establishing a scheme for greenhouse gas emission allowance trading within the Community*" [EU 2003f]. This was based on the extensive political discourse also triggered by the Green Paper and the ECCP platforms. Notably, the Sixth Community Environmental Action Programme (established by [EU 2002b]) had identified climate change as a priority for action and provided for the establishment of a Community-wide emissions trading scheme by 2005. The EU ETS Directive expresses clearly that its linking to trading schemes in third countries will increase the cost-effectiveness of achieving the EU emission-reduction targets. It also mentions the possibility for project based mechanisms including the JI/CDM, however, as stated in the Kyoto Protocol and the Marrakech Agreement, *supplemental* to domestic action.

How will the new EU ETS influence the area of renewable electricity and energy end-use efficiency?

The European Commission controlled *national allocation plans* for emission allowances will have a great deal of influence on the consequences of this new market instrument. The scheme concerns primarily combustion power stations of >20MW$_{th}$ and a range of high energy industries, including large production and processing plants of glass and ferrous metal, mineral industry, pulp and paper, but also coke ovens and mineral oil refineries. The new market pressure is on directly GHG emitting installations, and will certainly give a strong push towards more modern and environmentally more benign technologies. **Most**

importantly for RES-E and RES-H, biomass (including biofuels and biogas) is considered as CO_2-neutral in the Commission Decision [EC 2004c] establishing the guidelines for the monitoring and reporting of greenhouse gas emissions in the EU ETS. An annexed list in this Commission Decision clearly defines those substances considered biomass: it does include biomass fractions of waste, but does not permit peat. This will strongly boost biomass firing and co-firing in the future, notably in larger installations, as the economic advantage for the operator is evident: it exempts from the need to buy or use allowances.

Of course, the Member States are under tight control to keep the allowances “rare” and in line with their national Kyoto commitment and the technological development. In total, there are 11 criteria, which govern the acceptance for a national allocation plan of allowances. Thus optimising energy efficiency in such installations is expected intrinsically by the scheme. An important issue of political interpretation, if not controversy, is foreseeable when it comes to the coexistence of national support measures for RES-E and EEE (like feed-in tariffs, tax cuts, direct subventions, etc.) with the EU ETS. RE-critical voices used already the following argumentation line: tax-payers’ money or consumers’ billed add-ons from the RE-support measures would be used to produce a higher share of green electricity in utilities’ power generation portfolios, thus performing overall CO_2-“avoidance”. This would lower their demand for allowances from the market, and consequently the free market prices of those allowances. Ultimately, it would lead to even non-optimum fossil fired power stations being kept in place – thus it was argued, that the RE-supportive measures would lead to *more* emissions. But such a line of thought ignores completely the EU ETS intrinsic instruments of generating sufficient scarcity of allowances though updating the allocation, and is therefore expected to not happen at all. Apparently, it is rather a new occasion to put the relatively low extra costs from RE-support measures to consumers into the centre of a pseudo-debate.

2.1.4 Sustainability as political orientation

The rise of technologies of renewable electricity from biomass, wind and solar, as well as advanced energy-efficiency strategies are examples of *sustainable* developments. This holds not only because they avoid resource depletion, but also in a social sense e.g., due to the decentralised creation of societal benefits, like savings and jobs, or the preparation of future world markets for a coming productive generation. Already in the Treaty of the European Union, Article 2 defines sustainable development as a fundamental objective for the Community. The Helsinki European Council in December 1999 invited the European Commission to "*prepare a proposal for a long-term strategy dovetailing policies for economically, socially and ecologically sustainable development*" for the Gothenburg European Council in June 2001. Where are we now with it at the EU-policy level? A good answer was summarised by the two co-chairmen of the EEAC Working Group on Sustainable Development [EAC 2003]: “*The EU Sustainable Development Strategy (EU-SDS) is a moving asset: The Lisbon and Gothenburg European Council conclusions and the Johannesburg commitments are forming the politically binding essence of the EU-SDS, with the Gothenburg conclusions defining its environmental dimension while the 6th Environmental Action Programme (6EAP) and the Cardiff integration process supplement the environmental dimension of sustainable development in Europe. Also of relevance for European sustainable development policies were the Commission Spring Reports and the Commission's Communication "A sustainable Europe for a better world"* [EC 2001d], *which the Gothenburg Council draws upon. These documents are intertwined and refer to each other, making it difficult to pinpoint content and scope of a European Sustainable Development Strategy.*”

In their recommendation the authors and their working group members reviewing the EU SDS, proposed the introduction of more ambitious targets and timetables to what is the essence of the political philosophy of sustainability: **decoupling economic development and resources consumption**. They named biodiversity, shifting of energy production to renewable energies and a clean energy supply and expressed the wish that the whole societal concept of sustainability to become more concrete and understandable.

Interestingly, in the sustainability context of [EC 2001d] the difficult problem of internalisation of external cost of environmentally harmful energy sources was taken up. It helped a remarkable development to take place that led to the 2003 EU Directive on energy taxation [EU 2003a], which enables most important tax advantages for sustainable forms of energy, like renewables (see also chapter 2.2.4).

A further example of stimulation for short-term deployment of sustainable technologies, notably also in favour of RES-E, has been the development of the EU Environmental Technology Action Plan, abbreviated ETAP [EC 2002a, EC 2003b]. It aims at faster introducing environmentally helpful technologies and strategies into all fields and commercial sectors. This goes far beyond the "classical" understanding of environmental technologies like protection technologies, environment clean up technologies, etc. The definition of an "environmental technology" is more general, i.e. "a technology, whose use is less detrimental to the environment than today's standard solutions". The most important point in ETAP for RES-E is that this Action Plan orients to push the identified "environmental technologies" towards a faster deployment success in the market. In the Commission's Communication "Stimulating Technologies for Sustainable Development: An Environmental Technologies Action Plan for the European Union" [EC 2004d] the renewable energy technologies and energy end-use efficiency measures received also a prominent role.

Sustainability as an overarching new policy orientation is generally and concretely helping to put RES and EE on the societal agenda, and also to take measures in speeding up their implementation.

2.2 Legislative instruments at EU-level and their Monitoring

The main instruments of the European Commission to implement the Kyoto Protocol are the different Directives to promote *Renewable Energies* and measures to increase the *Energy Efficiency* in the Union. In the following the main Directives are listed and shortly described.

2.2.1 The Directive on the Promotion of Electricity Produced from Renewable Energy Sources in the Internal Electricity Market

Main aspects of this Directive [EU 2001]: An indicative target for the share of RES-E was set for each Member State (Figures 2.4 and 2.5), but the countries have the freedom at least until 2005 to choose the kind of support schemes (measures and incentives) with which they want to reach the targets. The Member States were originally obliged to report about the progress of implementation and the success of the chosen methods every two years. On 27 October 2005 the Commission has to present a report on experience gained with the application and co-existence of the different mechanisms. If deemed necessary, the report should be accompanied by a proposal for a Community framework with regard to support schemes for electricity produced from renewable energy sources to ensure that the targets for 2010 are met. The Directive also regulates the grid access and obliges the Member States to ensure a non discriminating treatment of electricity generated by renewable energies.

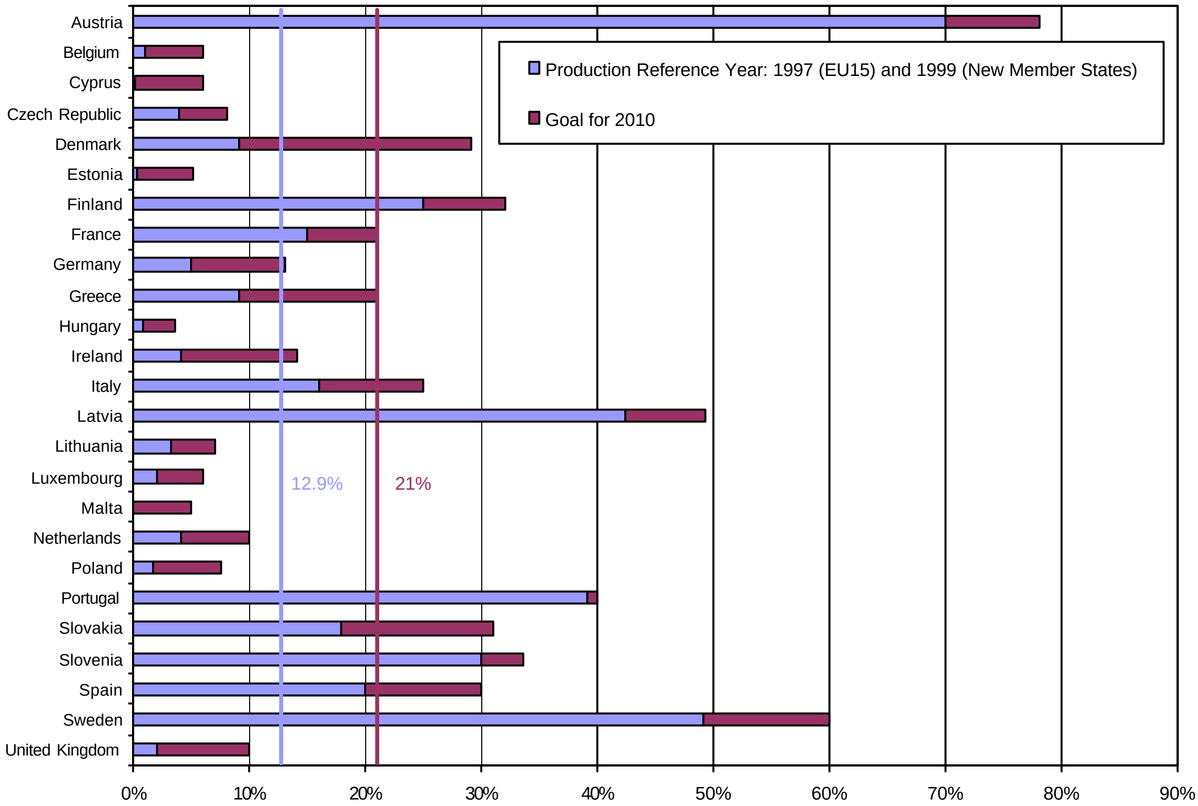


Fig. 2.4: Indicative relative targets for electricity share from RES set in the RES-E Directive for the different Member States. The blue line is the EU-average in 1995 (12%) and the green line is the target average for 2010 (21%), taking into account the enlarged EU-25.

The RES-E Directive was groundbreaking, as the strategy of developing renewables was for the first time cast into a legislation instrument. Though still operating with indicative targets for the electricity production from RES, it strengthened the development with the following principles:

- Quantified national targets for consumption of electricity from renewable sources of energy, *i.e. establishment of RE (here specifically RES-E) ramp up as a common goal in the EU. No "escape" from the targets, except some mitigation, if a country introduces very successfully Energy-End-Use efficiency measures, which then would lower the denominator for the RE-percentage to achieve.*
- Acceptance of the different national support schemes and putting them under these quantitative target benchmarks, *i.e. letting a certain competition of support schemes happen, as long as they lead towards the goal.*
- Announcement of issuing a harmonised support scheme to be suggested by the Commission in case of necessity revealed by regular monitoring, *i.e. threatening enforcement of more efficient (and different) schemes if existing methodologies would turn out to be insufficient.*
- Simplification of national administrative procedures for authorisation, *i.e. addressing obstacles under national authorities, thus underlining the importance of the common goal.*
- Guaranteed access to transmission and distribution of electricity from renewable energy sources, *i.e. enforcing a pro-RE behaviour of the established energy market participants, which in fact contributed ground to pro-RE jurisdiction.*

In fact all EU15 Member States have adopted national targets in line with the reference values listed in Annex I of the Directive; also the 10 New Member States have set up national targets in their Accession Treaties in April 2003. Consequently, these national targets are, on the whole, also sufficiently ambitious to achieve the EU-25 target of a 21% RES-E share by 2010.

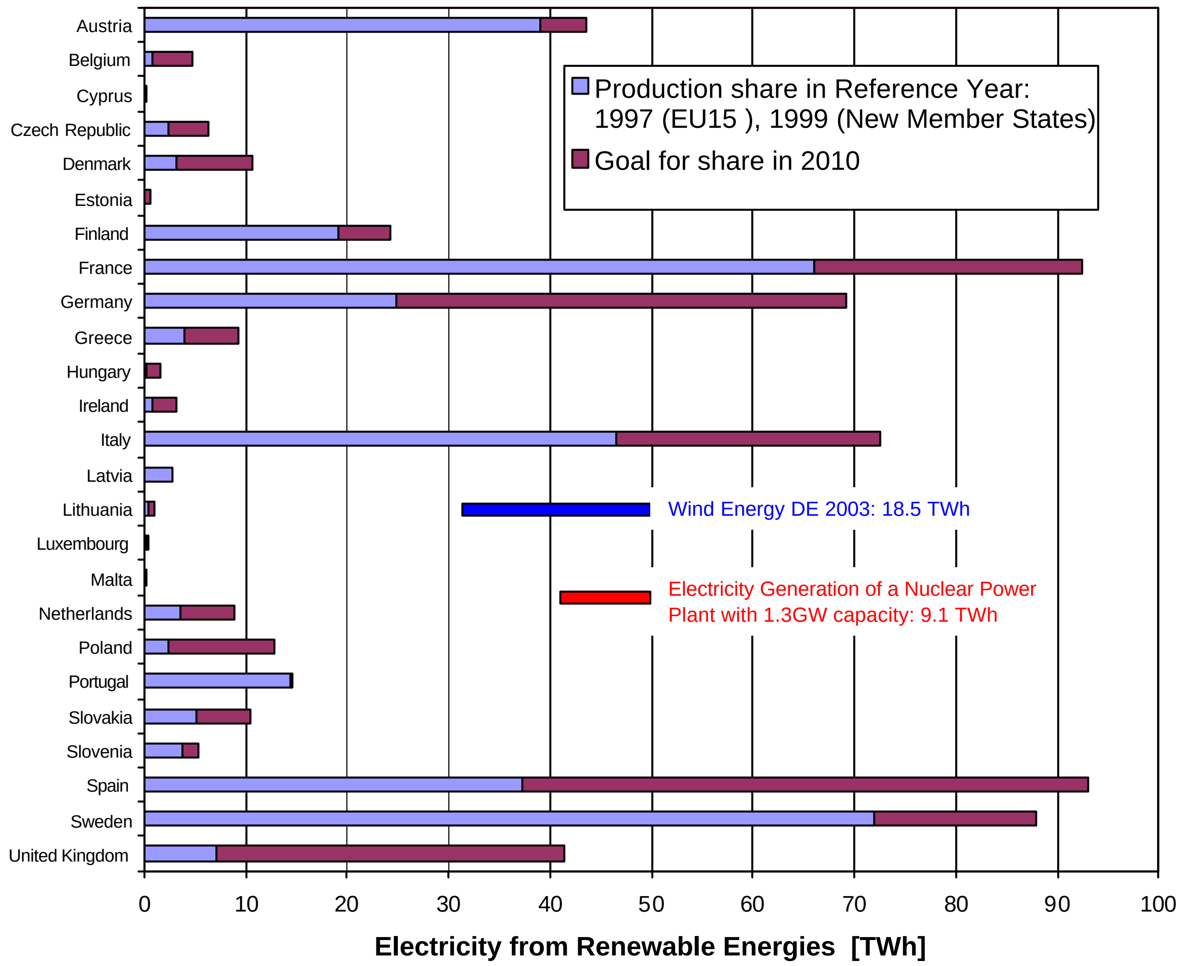


Fig. 2.5: 2010 Indicative absolute targets for electricity from RES in TWh, as per Directive 2001/77 and its amendment by the Enlargement Treaties in April 2003.
Remarks: For the New Member States this was calculated under the assumption of an annual electricity increase of 1.7%. The red bar shows, for comparison, the electricity generated by a nuclear power plant with 1.3 GW capacity assuming 7000h annual operation, correspondingly 80% availability. The blue bar shows the electricity actually produced by wind in Germany in 2003. Wind turbines have in average an annual operation of 2000h nominal capacity.

However, many Member States are behind in implementing their own targets and thus the overall EU-goal. This was shown by a first monitoring communication on this Directive [EC 2004]. It revealed the status of non-achievement for some RE-Technologies, and substantial differences in compliance with the national targets between the Member States. The interpretation was underpinned by a first Commission-staff working document including country profiles [EC 2004a].

2.2.2 Directive on the Energy Performance of Buildings: Energy End-Use Efficiency and Renewables hand in hand

Main aspects of this Directive [EU 2002]: The objective of this Directive is to promote the improvement of the energy performance of buildings within the Community, taking into account outdoor climatic and local conditions, as well as indoor climate requirements and cost-effectiveness. Although this Directive had not yet entered into force in 2003 there was a lot of preparatory activities such as preparing the necessary CEN standards for its implementation.

The following requirements as laid down by the Directive:

- The general framework for a methodology of calculation of the integrated energy performance of buildings
- Application of minimum requirements on the energy performance of new buildings
- Application of minimum requirements on the energy performance of large existing buildings that are subject to major renovation
- Energy certification of buildings
- Regular inspection of boilers and of air-conditioning systems in buildings and in addition an assessment of the heating installation in which the boilers are more than 15 years old.

Renewable energies are mentioned in particular with respect to new buildings over 1000 m^2 floor space. In addition, they play an important part in the general framework for the calculation of the energy performance of buildings.

2.2.3 Directive on the Promotion of the Use of Biofuels or Other Renewable Fuels for Transport

Main aspects of this Directive [EU 2003]: Member States should ensure that a minimum proportion of biofuels and other renewable fuels is placed on their markets, and, to that effect, shall set national indicative targets. The reference values for these targets shall be 2 %, calculated on the basis of energy content, of all petrol and diesel for transport purposes placed on their markets by 31 December 2005 and 5.75 %, by 31 December 2010.

Starting 2004 the Member States have to report to the Commission before 1 July about:

- Measures taken to promote the use of biofuels or other renewable fuels to replace diesel or petrol for transport purposes.
- National resources allocated to the production of biomass for energy uses other than transport.
- Total sales of transport fuel and the share of biofuels, pure or blended, and other renewable fuels placed on the market for the preceding year. Where appropriate, Member States shall report on any exceptional conditions in the supply of crude oil or oil products that have affected the marketing of biofuels and other renewable fuels.

In their first report 2004 the Member States shall indicate the level of their national indicative targets for the first phase and in 2006 the targets for the second phase. The Commission has to present a first evaluation report for the European Parliament by 31 December 2006 and every two years thereafter. The report should describe the progress made in the use of biofuels and other renewable fuels in the Member States. On the basis of this report, the Commission shall submit, where appropriate, proposals to the European Parliament and to the Council on the adaptation of the system of targets. If the report concludes that the indicative targets are not likely to be achieved, these proposals shall address national targets, including possible mandatory targets, in the appropriate form.

This Directive is of importance for the electricity generation from biomass because energy crops can only be used once, either for fuel production or electricity generation.

2.2.4 Directive on restructuring the Community framework for the taxation of energy products and electricity

Main aspects of this proposal [EU 2003a]: To ensure the proper functioning of the internal market and the achievement of the objectives of other Community policies minimum levels of taxation are set at Community level for most energy products, including electricity, natural gas and coal.

Article 15 of the directive allows the Member States to give partial or total exemptions or reductions in the level of taxation to certain forms and uses of energy. In the field of electricity, this includes the different renewable energy sources like of solar, wind, wave, tidal hydro, biomass or geothermal origin. It also includes taxable products used under fiscal control in the field of pilot projects for the technological development of more environmentally-friendly products or in relation to fuels from renewable resources

2.2.5 Directive on the promotion of cogeneration based on a useful heat demand in the internal energy market and amending Directive 92/42/EEC

Main aspects of this proposal [EU 2004]: This Directive is modelled to some extent on the Renewables Electricity Directive. In order to ensure that incentives are provided only to efficient CHP systems, the Directive has to provide a definition of CHP Quality and CHP Certification. Member States will be required to set national targets in accordance with the EU-wide CHP target of 1997. Issues concerning the grid access, cost of connection as well as streamlining administrative procedures have to be addressed.

The CHP Directive will cover technologies ranging from small-scale CHP in the residential and tertiary sectors to industrial CHP and CHP with district heating, with special provisions to promote small-scale CHP and renewables CHP.

2.2.6 EU Energy Efficiency legislation for end-use equipment

For residential end-use equipment (domestic appliances) the main market transformation tools have been the energy labelling and the minimum efficiency requirements Directives. Labelling was introduced through the Council Directive 92/75/EEC of 22 September 1992 on the indication by labelling and standard product information of the consumption of energy and other resources by household appliances [EU 1992]. Under this framework, Directives for the following appliances have been adopted:

1. Household electric refrigerators, freezers and their combinations [EU 1994]
2. Household washing machines [EU 1995]
3. Household electric tumble driers [EU 1995a]
4. Household combined washer-driers [EU 1996]
5. Household dishwashers [EU 1997a]
6. Household lamps [EU 1998]

7. Household air-conditioners [EU 2002a] (still suspended for problems with harmonised test method):
8. Household electric ovens [EU 2002b]

The combined effect of the minimum efficiency requirement and of the energy label reduced the market for refrigerators to three efficiency classes (A, B and C). As the A class reached EU market share of almost 50%, it was agreed to update the label. After a long discussion within the Regulatory Committee whether to shift all 7 categories (e.g. old A class to correspond to the new C class) or to introduce two new classes at the top; the second option was retained (introducing A+ and A++ classes) and a new Directive adopted:

9. Household electric refrigerators, freezers and their combinations [EU 2003b].

As far as the minimum efficiency requirements Directives are concerned, the following Directives have been adopted. These are all Council and Parliament adopted Directives, and the length of the process, as well as the drastic impact on the market, needing some adaptation time, have somehow limited the use of this policy instrument.

1. Efficiency requirements for new hot-water boilers fired with liquid or gaseous fuels [EU 1992a].
2. Energy efficiency requirements for household electric refrigerators, freezers and combinations thereof [EU 1996a].
3. Energy efficiency requirements for ballasts for fluorescent lighting [EU 2000].

2.2.7 Voluntary agreements for energy end-use efficiency

Moreover a number of voluntary agreements have been concluded between the Commission and EU manufacturers associations which have pre-empted the need to propose or introduce specific legislation for efficiency requirements for this equipment. Voluntary agreements can be particularly successful in the area of energy efficiency: in the recent past, two agreements, the first one covering stand-by losses of TV-sets and videocassette recorders (VCRs), and the second covering domestic washing machines, have been implemented successfully as unilateral commitments by industry. Other similar agreements cover dishwashers, electric motors, electric storage water heaters (standing losses) and audio equipment (stand-by consumption), external power supplies and digital TV set top boxes.

Self-commitments on improving the energy efficiency of television-sets and a new agreement on refrigerators have been concluded in 2003.

Another important normative policy action is the European Energy Star Programme. This is a **voluntary** energy labelling programme for office equipment based on the US Energy Star Programme through a formal international agreement (Council Decision of 14 May 2001 concerning the conclusion on behalf of the European Community of the Agreement between the Government of the United States of America and the European Community on the co-ordination of energy-efficient labelling programmes for office equipment (Official Journal L 172 of 26.06.2001, p. 1 – 30). The Energy Star logo helps consumers identify office equipment products that save them money and help protect the environment by saving energy. Office information and communication technology equipment (computers, monitors, printers, fax machines, copiers, scanners and multifunction devices) is responsible for a growing share of electricity consumption in the EU. The implementing rules in the EU are specified in the Regulation (EC) No 2422/2001 of the European Parliament and of the Council of 6 November 2001 on a Community energy efficiency labelling programme for office equipment (Official Journal L 33, 15/12/2001 P. 0001 – 0006)

2.2.8 Proposed Directives and those in the pipeline: More to come

1. *Proposal for a Directive of the European Parliament and of the Council on establishing a framework for the setting of Eco-design requirements for Energy-Using Products and amending Council Directive 92/42/EEC (COM/2003/0453 final)*

This is a proposal for a framework Directive to allow a faster implementation of energy efficiency requirements through Commission implementing Directives and a Regulatory Committee. Future should be based on the minimum of the Life Cycle Cost. Also other environmental impact of equipment shall be taken into account. During the first reading the EP expressed great support for this initiative, recently (June 2004) the Council reached a political agreement on the proposal.

2. *Proposal for a Directive of the European Parliament and of the Council on energy end-use efficiency and energy services (COM/2003/0739 final)*

This proposal aims at increasing investments in energy efficiency when cost-effective through the promotion of audits, energy services by energy distributors, and by energy Service Companies (ESCOs). In addition a mandatory additional efficiency improvement of 1% per year for six years is imposed on Member States.

3. *Proposal for a Directive concerning measures to safeguard security of electricity supply and infrastructure investment COM (2003) 740 final*

Main aspects of this proposal: Investment in adequate transmission capacity is crucial for the future security and sustainability of electricity provision in the EU. New interconnections within Europe are also needed to foster competition, particularly where existing companies have a dominant position. Without such investments Member States may be inclined to take more interventionist measures such as disinvestment or capacity release. It is important, therefore, that decisions on investments are made, and this requires Member States to face up to the issues concerned rather than continuously postponing important investment decisions.

Action is also necessary on the issue of maintaining the balance between demand and supply. ***The first priority here is the need for the unacceptable trends in energy consumption to be constrained. Where new generation investment is necessary this should, to a large extent, come from renewables and co-generation facilities***. However developers of such technologies, as well as any other investors in the sector, need to have a stable framework. Member States must therefore have a clearly defined approach to the supply demand issue which is published in advance and constant. If not, the position will continue to deteriorate and governments may be tempted by other interventionist measures, incompatible with competition with an undue bias in favour of increased generation capacity.

The draft Directive therefore proposes that Member States must adopt a stable regulatory framework in support of the necessary investment and that this should be reasonably consistent between Member States, while also respecting the need for subsidiarity.

2.3 Policy in Support of RES-E in new EU Member Countries

As economic development and income levels grow energy-, and notably electricity-demand in accession countries is expected to increase. The current over-capacity of electricity generation, high-dependence on fossil fuel imports and inefficient use of energy will prove a major challenge for New Member States to deal with electricity demand in an economically, socially and environmentally sustainable manner. As part of accession treaties[3], new EU Member States have committed to ambitious targets, which now form part of the legal framework set out originally in the Renewable Electricity Directive [EU 2001]. In order to comply, countries such as Poland for instance will have to more than quadruple electricity generation from renewable sources (RES-E). See Table 2.2 for RES-E production in 2001 and targets for 2010.

Table 2.2 New Member States RES-E production for 2001 and targets for 2010 (in % of total electricity generation)

COUNTRY	RES-E IN 2001	RES-E TARGETS 2010
Cyprus	0	6
Czech Republic	3.6	8
Estonia	0.1	5.1
Hungary	0.5	3.6
Latvia	42.4*	49.3
Lithuania	0.8	7
Malta	0.2	5
Poland	1.9	7.5
Slovenia	27.9	33.6
Slovakia	18.5	31

* 1999 Figure

Electricity generated from renewable sources provides an excellent opportunity for the ten New Member States to attract foreign investment and boost local, regional and national economies. Lessons learned from EU 15 countries such as Germany, Denmark, Spain and The Netherlands clearly demonstrate the socio-economic benefits that sustainable energy technologies provide. As one of the European Union's fastest growing industries, renewable energy technologies are creating employment opportunities, 135,000 in Germany alone [EC 2004], and can be managed to effectively support rural development. A study has forecasted that employment in this sector could reach over 900,000 in Europe by 2020, with the majority of jobs created in bio-energy technologies together with biomass fuel provision [Eco 1998]. For new Members States of the EU whose energy sectors and labour forces therein will be highly exposed to privatisation, deregulation and increasing competition, the largely untapped renewable energy assets offer a serious economic opportunity.

New Member States are rich in both agricultural land and forest areas that provide excellent resources for biomass generation. Significant wind resources are available in mountainous areas of Central Europe and along the coastal lines of the Baltic and Black Seas which will attract increasing interest in terms of larger scale, offshore wind farm developments. Estimations carried out on behalf of the European Bank for Reconstruction and Development assess the total capacity for wind alone at 3,500 GW, compared to current capacities for all electricity sources of 440 GW [Bla 2003]. In addition, considerable potential exists for small-scale hydro power both as refurbishment of old, previously decommissioned plants under Communist rule such as for instance in Latvia as well as new construction projects. Other paths such as geothermal, solar PV and solar thermal should not be ignored, as mid-to-longer term potential is most promising (see also Chapter 7).

3 Treaty to Accession of the EU in 2003, Annex II

It is the achievement of concrete targets that will set in motion a true push towards European security of supply, decreased fossil-fuel dependency as well as development of national industries and employment opportunities. Realising the potential is undoubtedly linked to the private sector, direct foreign investments in infrastructure and technology, estimated to require € 18 – 40 billion in all thirteen pre-2004 Accession Countries by 2020 [Bla 2003]. However, it is the policy framework conditions put in place by the European Union and individual Mew Member States / Candidate Countries governments that must communicate an irrefutable commitment to the development of renewable energy sources. Attracting investors to develop the vast resources available requires a supportive political climate in these countries' domestic markets. Strong financial support mechanisms must not only be set for a minimum period of 10 – 15 years and guarantee feasible return on investment, but also be accompanied by encouraging administrative procedures to create investor and consumer confidence. In the short-to-mid term this should imply practical, hands-on exchange of proven and workable technology specific policy direction on an EU level in general and for RE-technology exporting countries such as Denmark, Sweden, Finland, the UK and Germany, in particular.

2.3.1 What are the Barriers to Implement Renewables in new Member States?

Weak environmental consciousness amongst the general public is proving to be a major obstacle for renewable energy development. Negligible representation of environmental issues in national governments, unfavourable socio-economic circumstances and lack of broadly targeted education and information campaigns contribute to widespread misconceptions regarding renewable energy technology. Fear of further price increases such as the ones experienced in Poland during the early nineties add to suspicion towards any paradigm changes in the energy system amongst the general public. Most countries in EU 15 saw the organisation of political parties, pressure groups and endorsements that managed to accelerate momentum for renewables in terms of legislative and financial support mechanisms over the last decade. In the new Member and Candidate Countries, however, the lack of grass-roots, bottom-up driving forces for political change in New Member States is likely to remain for some time to come.

The New Member States and Candidate Countries are heavily path dependent on fossil energy sources and fuel imports, notably natural gas and oil from Russia. 7 out of the 10 New Member States have to import more than 50% of domestic fuel demand, while Cyprus and Malta are completely dependent on imports [EUR 2003]. This trend is likely to deteriorate, as energy consumption for housing and transportation grows in tact with the rest of the economies. The above-mentioned path-dependency is partly a question of the given status-quo of infrastructures, difficult to be broken up in both, political and economical terms. Latest investments to overcome such situations (like, e.g., a line overseas power link between the Baltic and Finland) often orient understandably at short-term price and market diversification options, rather than long-term RE development. Moreover, long term contracts with foreign suppliers oblige New Member States to use potentially unnecessary amounts of gas thus locking up resources for further renewables development. Poland alongside the Czech Republic is a large producer of coal – in fact, with 96.26 % Poland featured the world's highest percentage of coal in an electricity generation mix in 2001 (Rei 2003). The availability and subsequent economic interests of this high-emission source creates significant obstacles for the advancement of RES generated electricity, ironically, not least in terms of political good will and public support.

CHAPTER 3

ENERGY END-USE EFFICIENCY

Paolo Bertoldi

The scope of this chapter is to give some background information on the trends in electricity consumption, energy efficiency and the impact of present and new energy efficiency polices in the year 2003. Last but not least this report could also highlight the need for additional polices where cost-effective energy efficiency opportunities are missing.

The EU and its Member States have binding targets to meet the Kyoto Protocol. Many EU Member States have policies in place or are thinking of introducing new, more ambitious post Kyoto targets and policies to reduce energy consumption, or at least to achieve a reduction of its continuous increase by improving energy efficiency. End-use energy efficiency and the control of energy demand are essential climate change mitigation policies in order to contribute to the fulfilment of the Kyoto targets (or post-Kyoto targets). In addition, end-use efficiency contributes to reduce local pollution, to increase the security of supply, and to make the EU economy more efficient by producing the same amount of goods, services and comfort by using less primary energy.

Energy efficiency is just a means of achieving the policy goal of reducing primary energy consumption. Energy efficiency describes how much useful work, activity or service can be generated for each unit of energy consumed. The most traditional indicator for energy efficiency is the ratio between primary energy consumption and GDP. This is however a very 'crude' indicator, as it does not take into account the structure of the economy (e.g. an industrial economy, in particular based on heavy industry, will have a much higher energy intensity that an economy based on the service sector). More refined energy efficiency indicators have been developed in the European Union by the Odyssee project and are available on line at: http://www.odyssee-indicators.org.

Increasing energy efficiency does not necessarily mean that less energy is used. For example the total consumption of a specific domestic appliance (e.g. refrigerator or a washing machine) is determined by the following factors:

- Ownership
- Efficiency
- Usage
- Capacity
- Features

Generally energy efficiency policies tend to act on the efficiency, i.e. decreasing the energy used per litre of refrigerator in test conditions (fixed temperatures inside and outside), or the energy used per kg of soiled cloths in a 60ºC cotton cycle. Traditional energy efficiency policies do not tend to act on the ownership of the appliance, which is constantly increasing (for example air-conditioners, tumble dryers and dishwashers) till saturation (as for the case of refrigerators, which are present in each household in the EU, and now are subject to replacement only), capacity and usage. The usage is also a very important component of the consumption: washing often with a half empty dishwasher or washing machine will increase energy consumption compared to washing only when the appliance is full, as well as using a high temperature wash (e.g. a 90ºC cycle) if there is no need. For some appliances there is a tendency to increase the size (or capacity), this trend is certainly present for refrigerators, televisions and other appliances. Last but not least also particular features may have a significant impact on the overall consumption especially when these are not included in energy consumption test methods (e.g. air conditioners in cars) or when they have special energy consumption allowances (e.g. through the door ice dispensers in refrigerators).

3.1 Electricity Consumption in the Residential Sector[4]

When designing or evaluating policies to improve energy efficiency of end-use equipment it is important to have information on the total energy consumption of specific types of equipment, its usage patterns (hours of use, and mode of use), as well as information on the efficiency potential for this equipment (average model efficiency, model on the market with the best efficiency, the technical potential, etc.) and the associated costs (and possible impacts on stakeholders).

The information on the total energy consumption of specific types of equipment is neither readily available nor collected by any statistical offices. The European Commission during the European Climate Change Programme (ECCP) made a major effort with all the relevant stakeholders to establish the consumption breakdown by end-use equipment for the electricity consumption in the year 1995 for the EU-15 for the residential and tertiary sector, and motor systems [EC 2001c]. Moreover based on a stock model the consumption in the year 2010 was calculated. More recently, the European Commission's DG TREN published the Energy and Transport outlook to 2030 [EC 2004b], where the EU-15 total electricity consumption for the year 2010 was estimated (with a top down approach). The IEA has at the same time created the most accurate stock model for the electricity consumption in the residential sector.

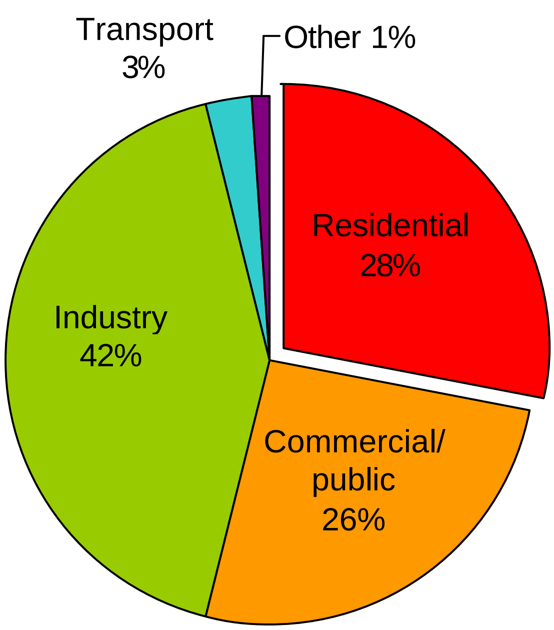


Fig 3.1: Split of electricity consumption between economic sectors in 2000 (source [EC 2004b])

4 In this report only the consumption and energy efficiency trends for the EU-15 Members States are reported, a similar report on the 10 New Member States will be published at a later stage.

Table 3.1 EU Residential Sector Electricity Consumption

	Source		
Year	ECCP [TWh]	Trends 2030 [TWh]	IEA [TWh]
2000	655	636	658
2010	722	750	735

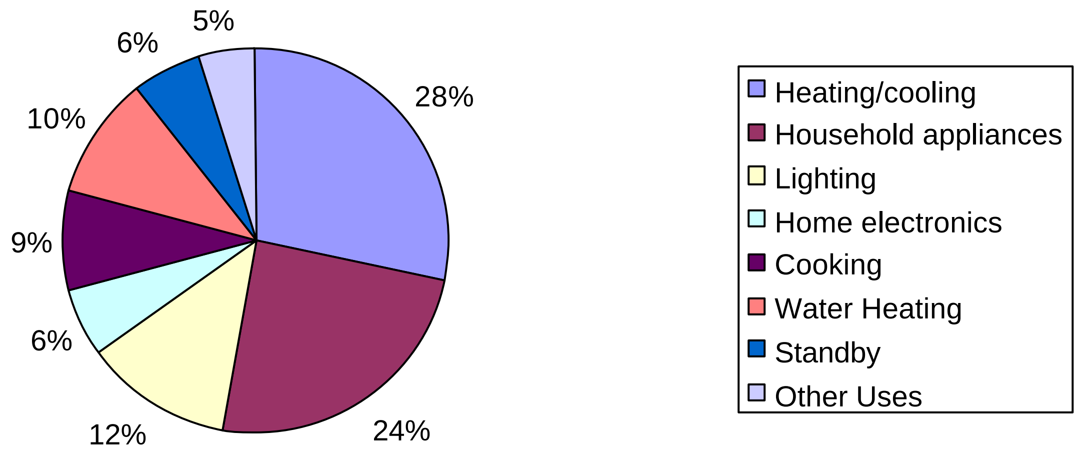


Fig. 3.2: Split of electricity consumption among residential end-use equipment in 2000 (source [IEA 2003c, Wai 2004, 2004a])

Space heating, although present only in a limited number of households in particular in some countries, still comprises the largest single electricity end-use appliance in the residential sector followed by refrigerators and freezers, lighting and water heating.

To build an accurate stock model, there is a need for accurate information on the models presently in use in households (both through the sales data of equipment for the last 15 years and in-situ monitoring of the real energy consumption of equipment, in real use conditions). One of the most accurate monitoring campaigns has been conducted by Mr. O. Sidler of Enertech, in France and in a few other EU countries. Table 3.2 gives a summary of his findings on the average household consumption.

In this table the standby consumption of each type of equipment is included in the consumption indicated for that equipment. Of course the individual household electricity consumption depends on number of equipment installed. Some 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, yet resistance space heating is the largest single electricity use (about 20% of the total electricity consumption in the residential sector). Direct resistance heating, electric as well as storage water heating are decreasing their market share due to strong competition from gas. Sidler measured some households in Italy and Denmark - without the above indicated heating uses their average is 3358 kWh/year for Denmark and 3157 kWh/year for Italy. In France, Sidler found an average electricity consumption excluding water and space heating of about 2500 kWh/year. Moreover the observed mean electricity consumption of electric water heaters amounts to 2364 kWh/year. The average consumption in he EU-15 (total electricity consumption of the residential sector divided the number of households) is 4343 kWh/year.

There is indeed the need to create a more accurate stock model to follow the yearly capital stock changes for end-use equipment and allow more accurate energy consumption monitoring and forecast for individual equipment. This is needed to define the most effective policies and their likely impact.

3.2 Residential electricity consumption in 2003

While the official figures on national electricity consumption are not yet released for 2003, it emerged from preliminary data that electricity consumption continued to grow on an annual basis at a 2 % rate and in particular in the residential and services sector (commerce, public sector, services) at a higher rate. From the preliminary country details in Table 3.3, it can be seen that there was as strong increase in electricity consumption in the residential and service sectors in almost all countries examined.

Table 3.3 Yearly increase in electricity consumption in some countries [Agr 2004, Lan 2004, Pat 2004, Sco 2004, Vol 2004]

Country	Service Sector Electricity Increase 2002-2003	Residential Electricity Increase 2002-2003
Italy	7,1%	2,8%
UK	2,9%	2,1%,
Germany	3,6%	1,8%
France (combined residential and service sectors	2.0%	

This increase occurred during a year of slow economic growth in which GDP grew by merely 0.7% in the EU 15. The increase was partly caused by weather conditions requiring more heating and cooling: a cold winter at the beginning of 2003 and a very hot summer in 2003.

3.2.1 Heating and cooling appliances

One of the main drivers in electricity consumption in the ‘southern’ countries (IT, ES, PT, EL and FR) was a strong demand for small (less then 12 kW output cooling power) residential air-conditioners and their extensive use during the summer 2003. Due to the heat wave in the summer of 2003 all small air-conditioners available on the market were sold and installed in Italy. EU Manufacturers confidential reports indicate that there was a sales increase in the period 2002/2003 of 15%. For Italy, the manufacturer trade association reported the following sale trends:

Table 3.4 Sales of small air-conditioners Italy (source [Coa2004])

Year	Sales (thousand)	Annual increase
2001	950	
2002	1067	12%
2003	1550	45%
2004 (forecast)	2100	35%

Moreover the impact of last summer had also a big effect on sales for year 2004 which are expected to grow even further. Although at European level the penetration of small air-conditioners is still small (about 2% of residential space), in some countries such as Italy and Spain the penetration of small air-conditioners reached 4% in 2003 (this is however still far from the US penetration of 20%).

For *room air-conditioners* (up to 12 kW output power), the energy label does not yet have an impact on the market. The A class limit for the split, non ducted, air-cooled air conditioners up to 12kW is set at EER[5] of 3.2; some new models have been introduced on the market with EER above 4, the best models on the market have an EER of 4.55. This indicates that the A class level is not very ambitious. In addition, there are still several E and D class models on the market, with EER at around 2.5.

For room air-conditioners (up to 12 kW) the improvement of the EER can be attributed to the technological development and transfer (mainly from Japan, where there are very ambitious energy efficiency targets) and to the publication of the EER (and last year also of the energy label) in the Eurovent Certification Scheme [Eur 2004]. Eurovent-Cecomaf has also committed to withdraw from the market the models in G class.

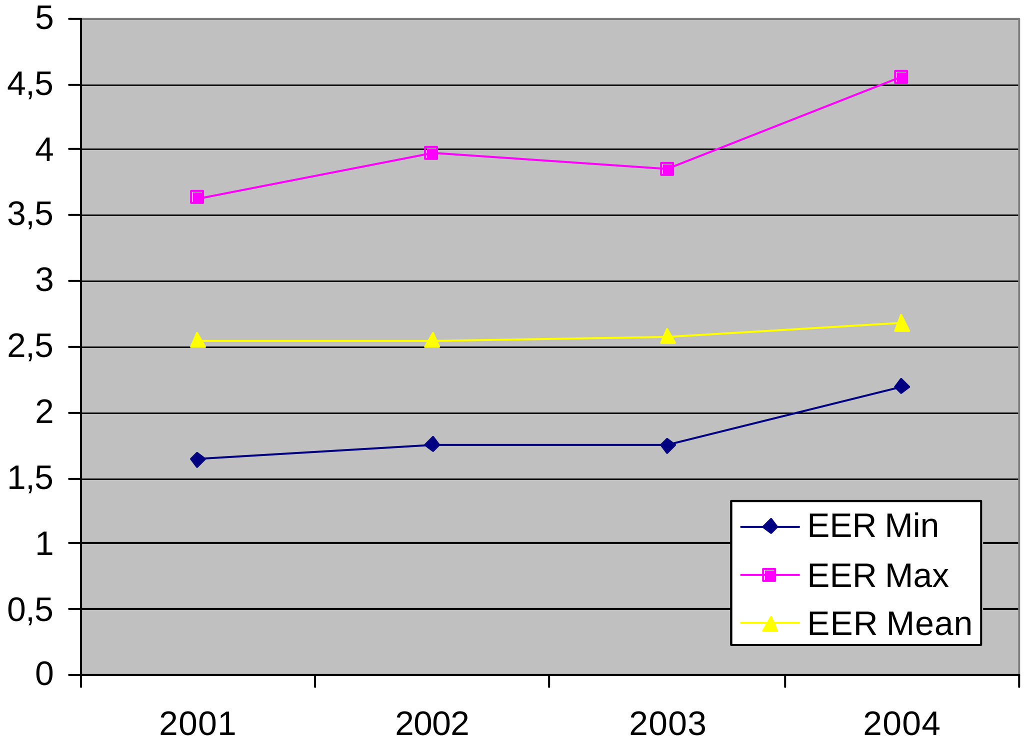


Fig. 3.3: Evolution of the EER (minimum, maximum and model weighted average) for split, non ducted, air-cooled Air conditioners up to 12 kW (source Eurovent [Eur 2004, Bec 2004])

[5] EER = Energy Efficiency Ratio. This the ratio between the output cooling (thermal) power and the input electrical power in the cooling mode. The EER is used to define the energy classes for the energy labelling. For reversible air-conditioners (working as heat pump) the efficiency indicator is the COP (coefficient of performance) which is defined as the EER during the heating mode.

3.2.2 *Major Household appliances*

Sales of major domestic appliances (refrigerators, freezers, washing machines, dishwashers, tumble driers) continue to grow and were up by 4% on the previous year (a normal trend except for year 2002) reaching total sales of about 43 million (about 40% represented by refrigerators and freezers, and 25% by washing machines), with the fastest growing appliances being dishwasher (+ 4%) and tumble dryers (+7%). These two appliances are still far from the saturation level (e.g. 1 appliance per household).

For the major residential appliances there has been a constant improvement of the average efficiency due to: the 'natural' technological developments, the energy labelling, and minimum efficiency requirements and/or voluntary agreements (for those appliances where these policy instruments were adopted).

The most remarkable efficiency improvements have been made *for refrigerators and freezers*. For domestic refrigerators, the energy efficiency index (EEI)[6] was defined in the refrigerator labelling Directive (EEI was set at 102 for the average model on the market in year 1992).

Among the combined refrigerator-freezer, the best model on the market in the year 2004 has an EEI of 19.81 with an annual consumption of 137.0 kWh/year for a 215 fresh food volume and 60 l of freezer (4*) volume. For the same size a C class model just meeting the efficiency requirements would use 522 kWh/year (a factor four energy reduction!). There are now a number of models in A++ class (EEI below 30), and A+ class.

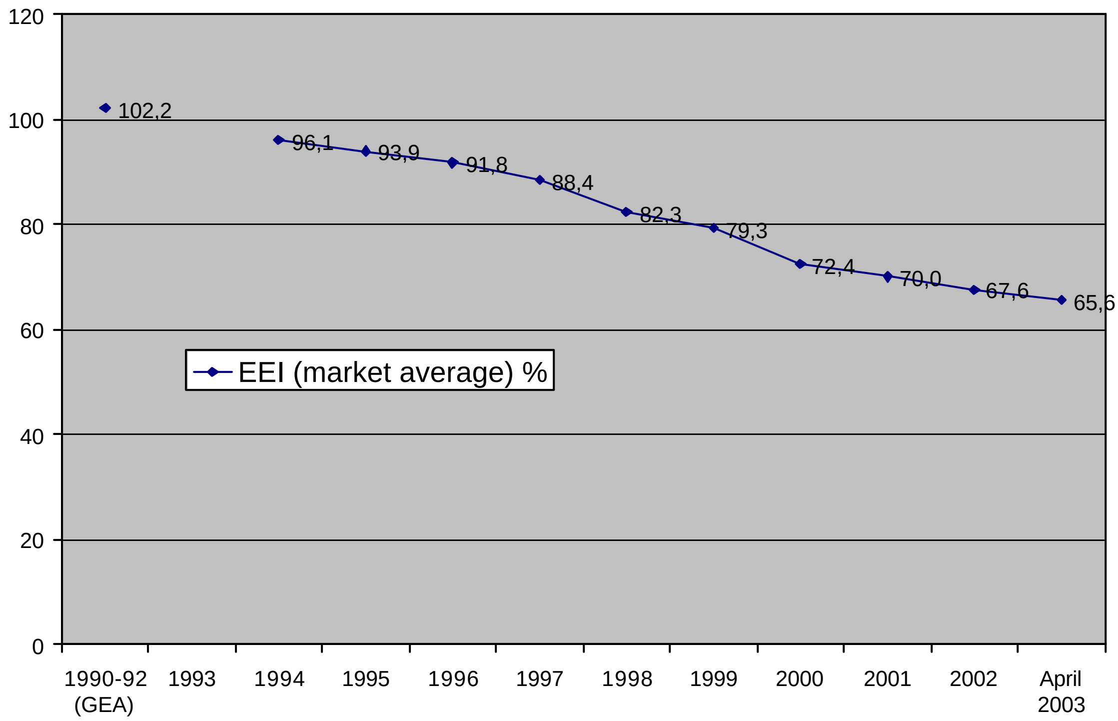


Fig. 3.4: Evolution of the EEI (new model sale weighted average) for cold appliances (source [Wai 2004a])

6 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.

The sale data for 2002 and 2003 for cold appliances show that in two markets (the Netherlands and Germany) the A+ appliances are starting to show an interesting market share (– 13.3 market share), and the share of A class is approaching 50 % of the sale. Large differences still exist between countries due to different national and regional policies and programmes (lowest share of sales of A class appliances in 2002-14.3% in Spain, and the highest share - 71.1% in the Netherlands), in particular the one supporting an energy label.

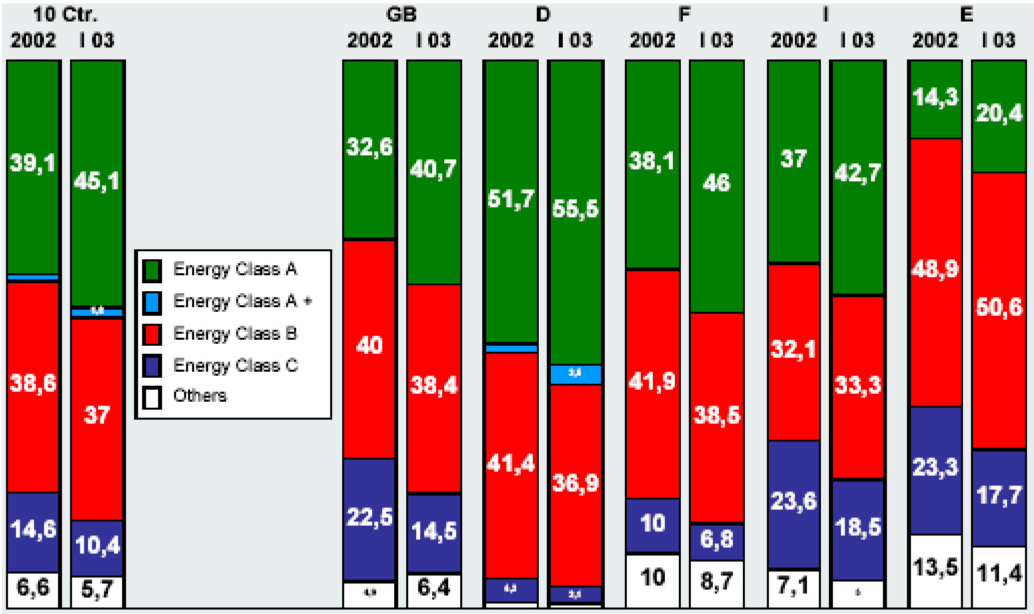


Fig. 3.5: Sales of cooling appliances: comparison for the 5 big country in 2002-03 by energy class (Source [GfK 2004])

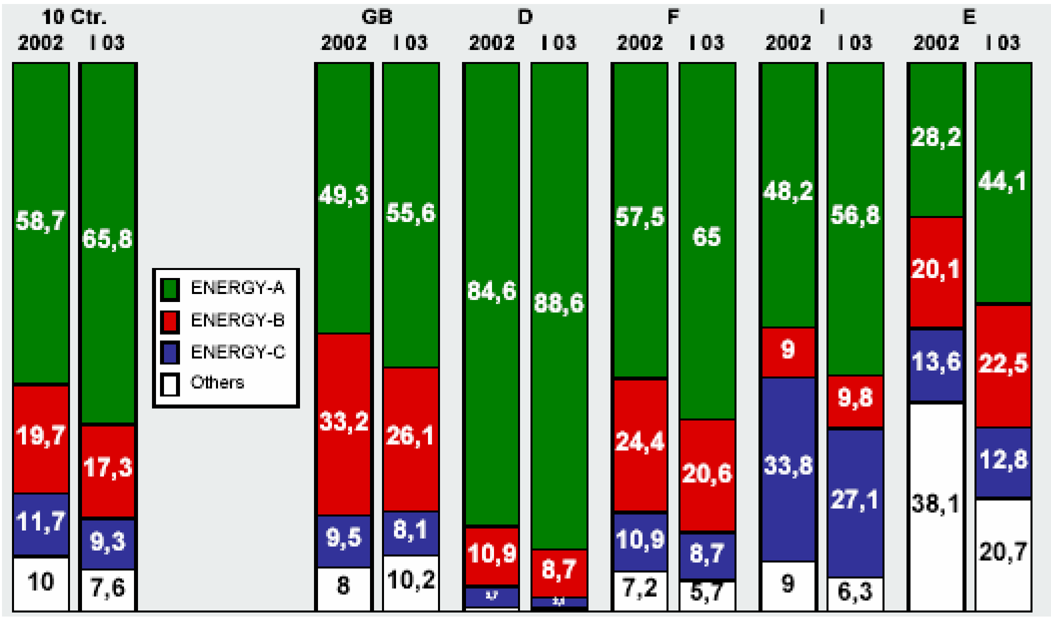


Fig. 3.6: Sales of washing machines: comparison for 5 big countries in 2002-03 by energy class (Source [GfK 2004])

As far as the sales of *washing machines* are concerned, the share of A class appliances was already above 50% in 2002, and in some countries (Germany, the Netherlands, and Belgium) was approaching the 100% marker. The lowest share of sales of A class appliances in 2002 was in Spain14.3%, with the highest share 95.3% in the Netherlands. Class A appliances are seen by consumers as a high quality product (most of A class appliances are AAA, associating to the low energy consump tion, high spin speed and best washing performances).

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

The production weighted average consumption of washing machines corresponded to 1.04 kWh/kg in the year 2002. The best model on the market (already for several years) has an EEI 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 15%, between the average models and the top model.

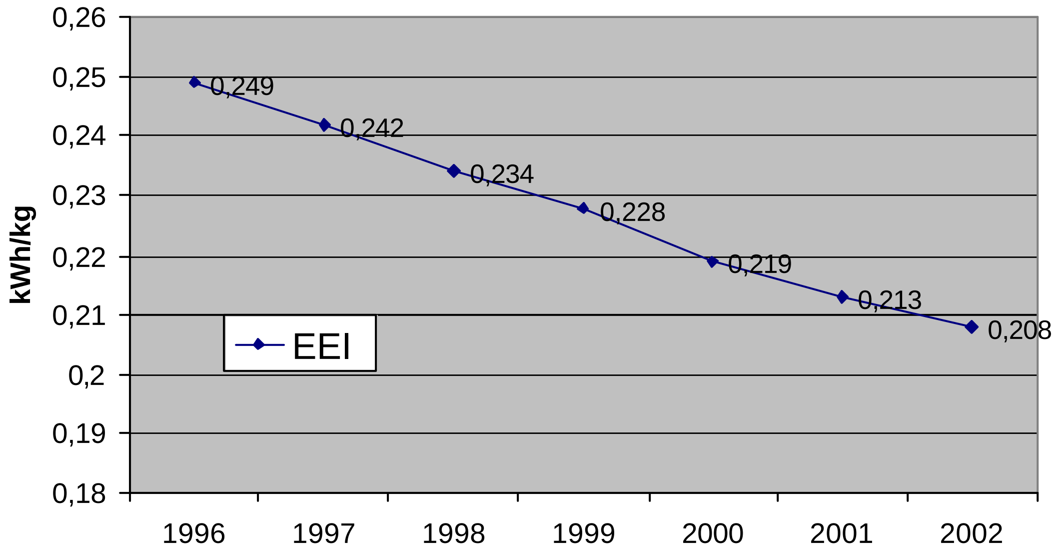


Fig. 3.7: Washing machines energy efficiency index progress, based on production weighted average (source CECED [Cec 2004])

For *dishwashers* only a very marginal saving was observed between year 2001 and 2002. In the year 2002 the average consumption per test cycle wash of a 12 place setting dishwasher was 1.156 kWh down only 0.1% from the average consumption in 2001. The best model on the market (already for some years) has an EEI of 0.80 kWh per wash cycle. This indicates that even with the present technology there is a large energy saving potential of about 25%.

The sales of dishwashers by energy class follow a similar patter to the one of the washing machines, with the class A already above the 50% threshold. The lowest share of sales of A class appliances in 2002 was in Spain 31.2 %, with the highest share 87.8 % in the Netherlands.

For *ovens* the impact of the energy labelling is not yet visible on the market, the best 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.

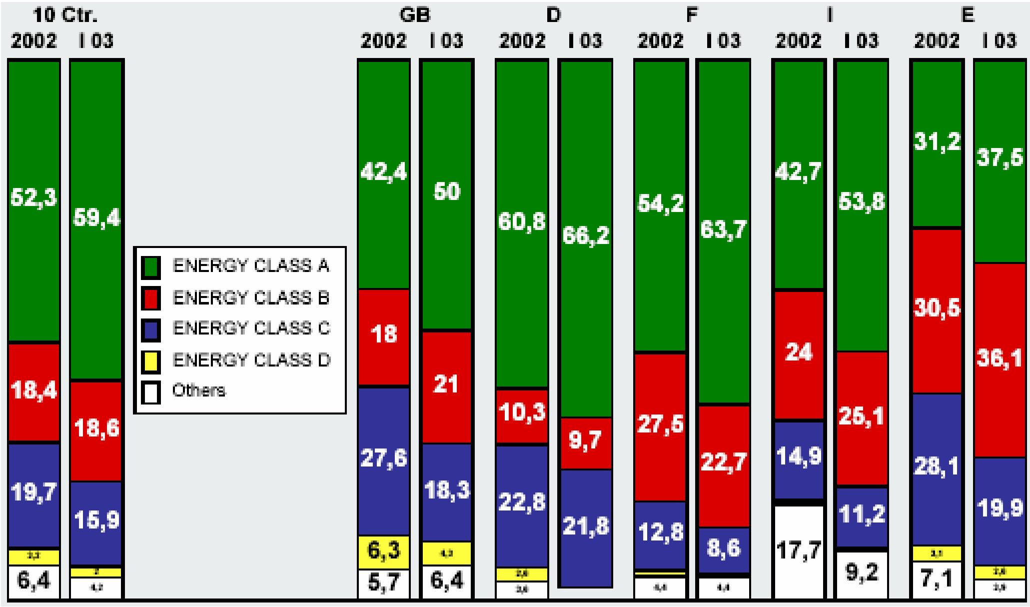


Fig. 3.8: Sales of dishwasher: comparison for 5 big countries in 2002-03 by energy class (Source [GfK 2004])

Dryers are the white good appliance where no progress has been achieved with the energy label. In theory, gas heated and heat pump dryers which use much less primary energy are already on the market, but have almost no market share (with the exception of gas dryer in the UK). Transforming the dryer market to A-label machines will save a lot of energy: for the Netherlands alone calculated savings would be in the magnitude of 0.8 PJ per year [Sid 2004a].

3.2.3 Consumer Electronics and Infornation and Communication equipment

Another driver for the increase in electricity consumption is the move to digital TV and broadband communication. The European Union is rapidly moving toward 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. In early 2004, millions of these boxes will be sold in Italy, the UK and other European countries. 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 (more than one system always on in each dwelling, and increasing electricity demand for each device as it gets more powerful).

The technology supporting these changes is developing at an unprecedented rate. One consequence of this is that the relatively slow and costly manufacturing and marketing cycle of the mass-produced TV cannot viably accommodate the accompanying rapid changes in the technical specification of the hardware. An independent signal interface and data processing platform, the set-top box (STB) has been the preferred manufacturing and market distribution solution. This device readily interfaces with existing and developing TVs and display systems and allows the rapid modification of functionality specifications in high volume production.

The downside of this solution is that the existing voluntary agreement and labelling mechanisms for energy efficient domestic electronic products are too slow to keep up with STB development and could potentially hamper that development. 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 of European households.

Research into proposed development showed that by 2010, the STB could push domestic electronic energy consumption in Europe above that of refrigerators and freezers. With 150 million of these boxes across the EU - equivalent to one per household – the annual electricity requirement for digital service systems with full functionality and poor power management could be around 60TWh (close to the total electricity consumption of Denmark for all sectors).

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 in compilation but recent German research provides an interesting comparative overview of the world-wide trends in broadband technology.

Table 3.5 Share of different broadband technologies

Broadband Technology	Share [%]
DSL	56.5 %
Broadband cable systems	38.0%
Gigabit Ethernet	4.7%
Other Techniques	0.8%

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, 150 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.

Broadband wireless networks, including one-way and two-way satellite, are predicted to supply less than 12% of European access requirements by 2010. In practice, it is likely that a down path through the digital TV satellite network will provide the broadband solution for those households not passed by digital cable and out of DSL exchange range. The outgoing path is likely to be PSTN modem or, for higher data rates, fixed wireless network.

As a future discussion guide, recent UK tests show that the power requirement taken by a best practice, simple terminal, always on, two-way, broadband satellite link for home installation was 25.6 W, including the dish equipment (LNB) Compare this with the current best practice DSL simple terminal power requirement of 4.0 W. 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 per annum could be added to a household's energy overheads.

Since 1997 the main energy efficiency action for *TVs and VCRs* has been to reduce the standby losses. A voluntary agreement by the major manufacturers and their trade association EICTA has contributed to the reduction of the standby losses.

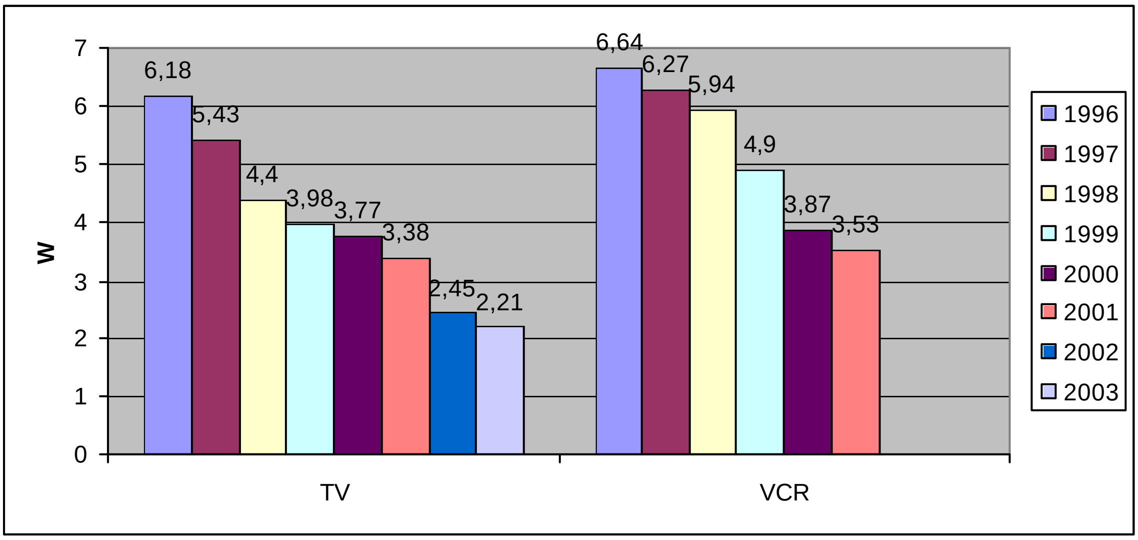


Fig. 3.9: Progresses of the reduction in standby losses (new model sales averages) of TVs and VCRs (source EICTA [Eic 2004])

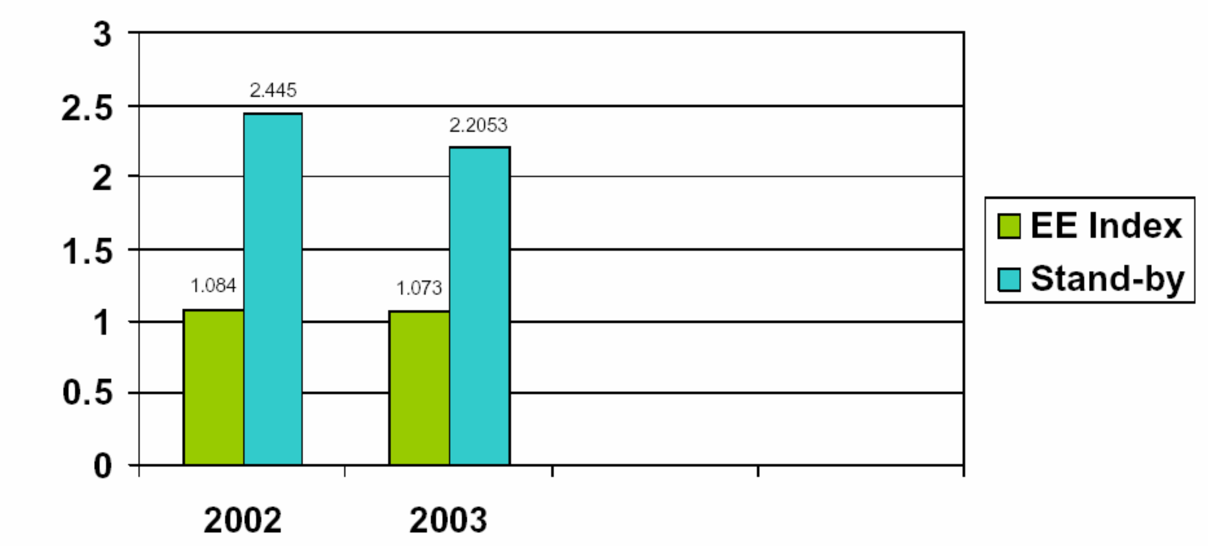


Fig 3.10: EEI index and average stand-by power consumption for Analogue CRT TV receivers

Many new TV models have now standby consumption well below 1 W, 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), many have standby consumption around 2 W, however, it must be noted that VCRs sale are decreasing very rapidly. For DVD-players (which take the place of VCRs on the market and are experiencing a boom in sales) 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.

The data on TVs' EEI is still very limited because most manufacturers do neither indicate the energy efficiency index nor the power consumption in the on-mode. The manufacturers reported EEI (new model sale weighted) are 1.084 for 2002 and 1.073 for 2003. New trend on the market having an important impact on energy consumption are larger screen sizes and plasma TVs, which use considerable more energy (350-400 W, but new developments can decrease this to less than 300). Smaller LCD TVs typically have an EEI of 0.4, larger LCD TVs tend to have the same consumption as CRT TVs7[7]. The better CRTs on the market have an EEI of 0. Finally, prospects for improving efficiency in LCD TVs are better than for improving efficiency in CRT TVs. [Sid 2004a].

3.2.4 Residential Lighting

Compact Fluorescent Lamps (CFLs) represent the most efficient solution available today for the residential market[8]. 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 6000 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 3.6 Sales of lamps (Source [ELC 2004, Str 2004])

Lamp Group	Annual Sales [million units]	Typical Life Time [h]	Typical power per lamp [W]	Electricity use Domestic Applications [TWh/yr]
GLS	1600	1,000	60	67.2
Halogen	280	2,000	35	9.8
Fluorescent	350	12,000	36	4.2
CFLi	75	2,500/12,000	11	1.7

7 Some recent measurements indicate that LCD TVs with screen sizes between 56 and 75 cm have power consumption in on-mode between 55 W and 158 W (for similar size CRT and LCD TVs power consumption is 110 W). Another disadvantage of the LCD models is that they often use power when switched off (up to 5.5 W), contrary to the CRTs where the off power consumption is 0 W.

8 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.

A more accurate 'indicator' of the penetration of efficient lamps is the number of households, which have at least 1 CFL.

Table 3.7 Estimation of the penetration levels (percentage of households (HH) possessing one or more energy saving lamps) for the different countries in 1995-1997 (Source: [Del 1998])

Country	Number of light points per HH	HH with at least 1 CFL [% of HH]	Number of CFL per owning HH	Average number of CFL per HH
Belgium	31	29	3.7	0.4
Denmark	26	46	4.4	2.0
France	18.5	-		0.5
Germany	30	51	4.3	2.1
Italy	20	55	2.0	1.1
Netherlands	36	62	4.5	2.7
Spain	29.5	11.5	1.7	0.2
Sweden	40	10	4.0	0.4
UK	20	23	3.0	0.7
EU-15 average	24	32		

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 5 CFLs per households).

3.3 Tertiary Sector Electricity Consumption

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

Table 3.8 EU Tertiary Sector Electricity Consumption in TWh

Source	ECCP	Trends 2030	IEA
1995	486	503	
2000	-	581	
2010	662	727	

The ECCP in year 2000 arrived at the following breakdown that was endorsed by the all the ECCP experts.

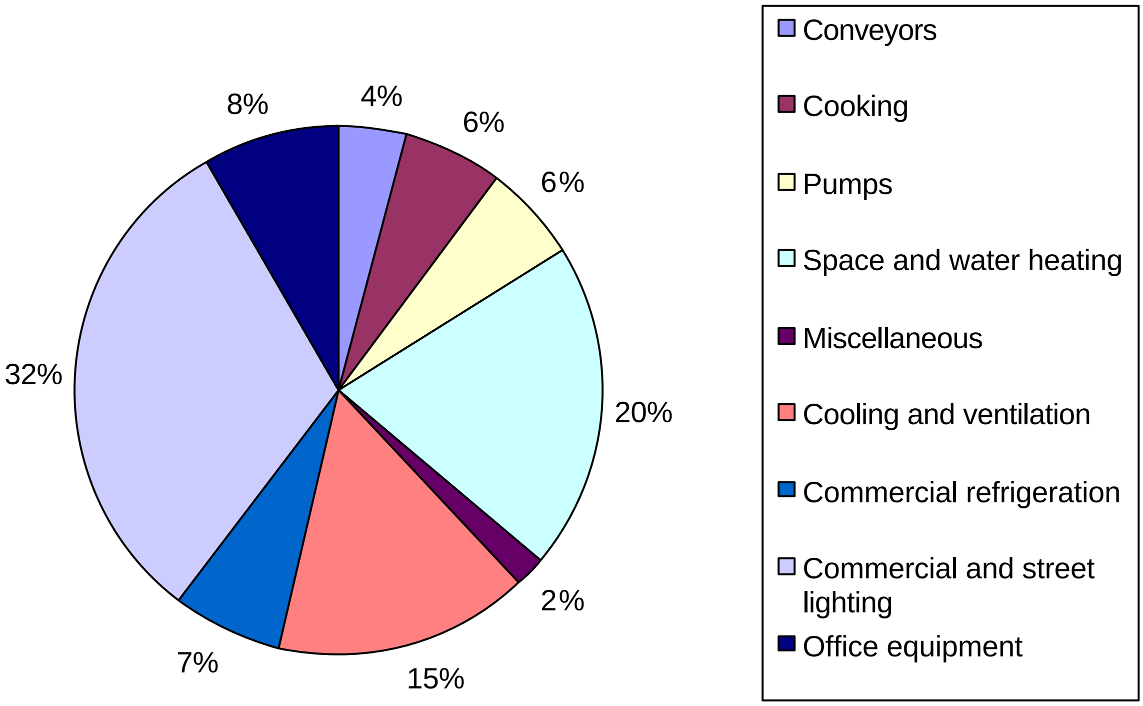


Fig. 3.11: Split of the Tertiary Sector Consumption (Source [EC 2001c])

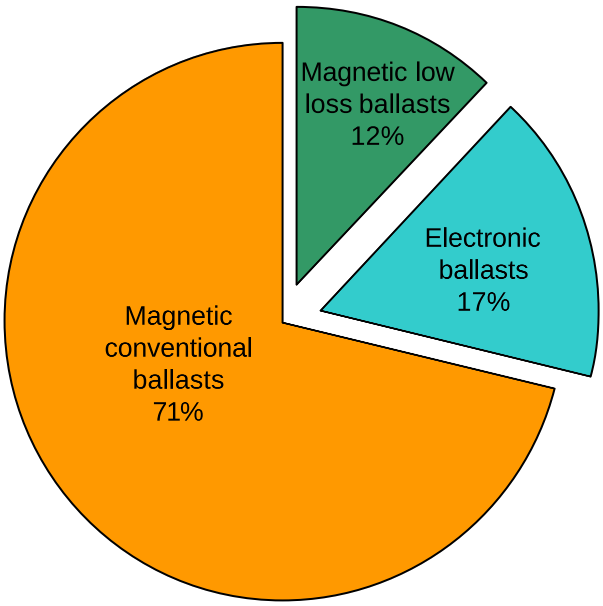
Not only is there less information available on the end use equipment and systems' consumption, but also sales data on efficient equipment and/or energy efficiency indexes are missing.

Lighting is by far the major end-use category in tertiary sector consumption. As far as non-residential buildings lighting is concerned, this is dominated 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. 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 very limited.

Ballasts are needed to run every fluorescent or discharge lamps. 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[9] together with the minimum efficiency requirements for ballasts, which came into effect in 2002, have resulted in a gradual market transformation, there are, however, no sale data available for year 2002 or 2003.



Magnetic ballasts	Class C and D	105,080,000
Magnetic low loss ballasts	Class B1 and B2	17,760,000
Electronic ballasts	Class A1, A2 and A3	25,160,000

Fig. 3.12: Ballast Sales (Source [Cel 2004])

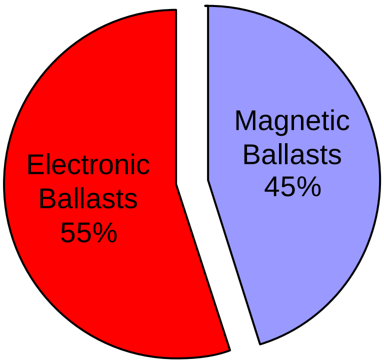
Operated on magnetic ballasts, most lamp wattages need one ballast per lamp. Electronic ballasts are designed to operate several lamps at the same time, which allows the use of one ballast only for any luminaire, independent of the number of lamps. Based on market behaviour (single, twin and multi-lamp luminaires) as a European average, the following lighting point index is valid:

- lighting point index for magnetic ballasts 1.1
- lighting point index for electronic ballasts 1.7

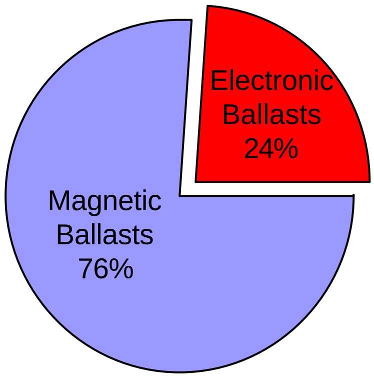
Using the Lighting Point Index the Lighting Points (Lamps) the corrected market share are as follows:

Magnetic Ballasts 135,124,000, i.e. 76%
Electronic Ballasts 42,772,000, i.e. 24%

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



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%.



Lighting Points supplied by ballasts in 2000

Fig. 3.13: Market share of electronic ballasts (Source CELMA [Cel 2004])

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.

For *office equipment* there are no data on the market share of Energy Star labelled equipment or on the rate of enabled equipment. In the year 2003 a rapid penetration of LCD screens occurred, which 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 8% of total electricity consumption in this sector [Sch 2004]. 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).

For commercial buildings another interesting energy efficiency indicator is the total energy consumption (or the specific electricity consumption) per square meter. 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].

Table 3.10 Building Specific Consumption of Primary Energy

Type of building	Primary Energy Consumption [kWh per m^2 gross usable floor space and year]
Average old office building constructed before 1990	591
Average office building	502
Average office building constructed after 1990	421
Average new office	400
Best practice	150

3.4 Industrial sector Electricity Consumption

The energy performance of the industrial sector, although declining in relative terms compared to other sectors, is well documented by the official indicators, which include the tracking of all the energy consumption for the major industrial sectors (steel, pump and paper, cements, etc.). Total electricity consumption for the industrial sector was 792 TWh in year 1990 and 951 TWh in year 2000 [EC 2004b]. Of this consumption, 614 TWh, or 65%, was consumed by motor driven systems [EC 2003a, Eci 2004].

This report focuses on motor driven systems. In particular electric motors are responsible for 10 to 20% losses on the above indicated electricity consumption in the process of converting electrical energy into mechanical energy. Electric motor sales figures have been monitored through the CEMEP 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. The existing voluntary classification scheme allows for classification of motors into three classes[10].

The European manufacturers have managed to increase the market share of medium efficiency motors (class EFF 2) and almost phased out the low efficiency motors (class EFF 1) as can be seen in the graphs below.

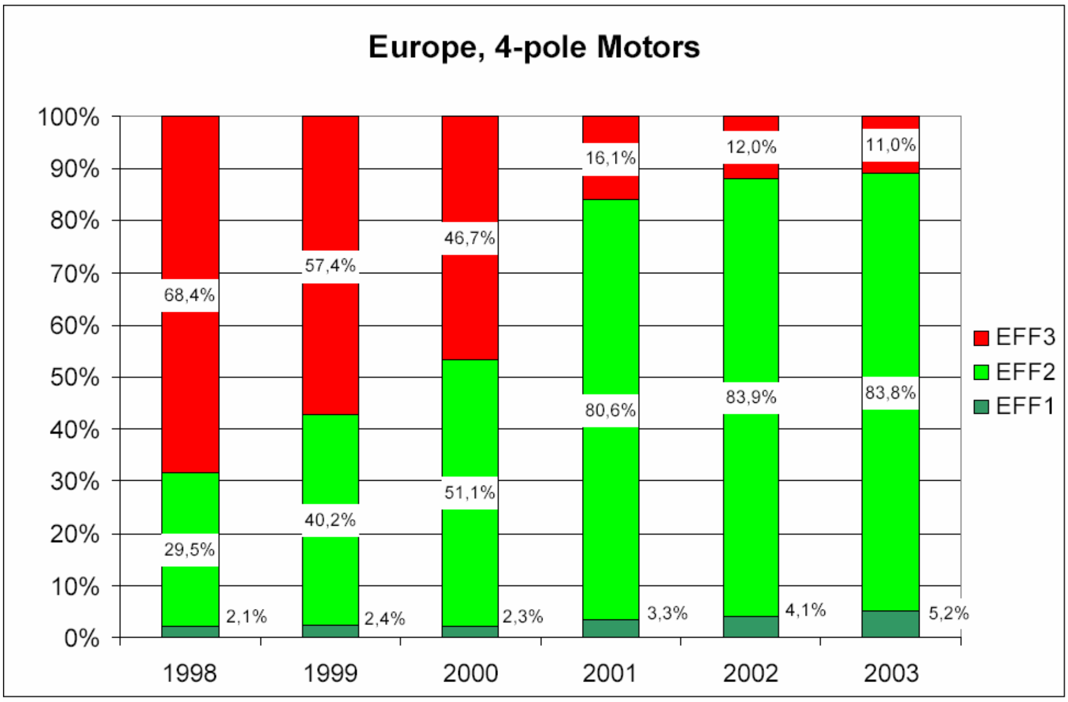


Fig. 3.14: Change of market share among the 3 motor classes (Source CEMEP [Cem 2004])

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 important to collect sales data for VSDs for future reports.

Detailed data on the efficiency of other end-use equipment in motor systems such as fans, compressors and pumps are not available. Moreover, the energy consumption depends more

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

on the overall systems design and operation than on the efficiency of the individual components. For some types of water pumps[11] a simple assessment system to verify the efficiency of the pump at the operation duty point has been developed and made available. This is based on the best efficiency points of the available efficiency of pumps of the market. With this instrument pumps can be classified in three categories for the specific operation point.

3.5 Conclusions

The energy efficiency policies implemented at EU level and described in the previous sections shall be evaluated on the basis of the annual electricity savings they have delivered and will continue to deliver in the coming years. While the various energy efficiency indicators for end-use equipment described in the previous sections are somehow 'relatively' easy to evaluate, it is necessary to build a stock model in order to evaluate the annual energy savings. 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 percentage of the installed equipment is replaced each year, the impact of energy efficiency polices will be relatively slow and modest at the beginning, though continually increasing over time. However, in a time span of 10 to 15 years, when the whole stock has been replaced and the full effect of the policy measure has taken place, annual electricity savings of tens of TWh are achieved for several types of appliances and equipment described in the previous sections. The annual savings resulting from each individual policy are calculated against the Business as Usual (BaU) scenario, which correspond to the most likely trend in consumption, if the policy was not introduced. The BaU scenario includes the natural efficiency improvements (due to the autonomous market and technology developments), and the autonomous trends in sales[12]. For some appliances although there is a positive impact due 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).

In particular standby consumption in entertainment electronic and ICT equipment is growing at a worrying rate. A lot of new equipment is added to the present stock (STBs, DVD players new TVs and surround sound systems, mobile telephones), while 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). In addition much equipment which did not 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.

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[11] The European Guide to Pump Selection and the Basic on Pump Efficiency; can be downloaded at http://energyefficiency.jrc.cec.eu.int/motorchallenge/tools.htm

[12] One of the possible policy options is to accelerate the replacement rate of old equipment, thus reducing the time for the complete turn over of the installed stock.

The European Commission estimated in its Communication on Standby Losses of 1999 that residential standby power consumption would increase from 36 TWh in 1995 to 62 TWh in 2010 without significant intervention [EC 1999]. Most recently the IEA has estimated the residential standby going from 46 TWh in 2003 to 66 in 2010 [Wai 2004]. Although new TVs, VCRs, and a few other appliances use significantly less standby power than older models as results of the voluntary agreement introduced in 1997, and TVs and VCRs new models are beginning to lower in-home standby power use, the simple number of appliances with standby power mode continues to increase world-wide. The net effect of these trends is likely to be a continuing increase in global standby power use.

In addition, TV reception platforms are rapidly moving toward digital broadcasting technology. As a result, set-top boxes (STBs) will likely be the source of significant new standby power demand in most economies in the near future. Some STBs introduced on the market stay in on-mode all the time, consuming up to 25–30 W of power. With the assumption of one STB per household by 2010, this is an additional electricity consumption of 33 TWh per year in the EU-15. 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 two converter boxes per household this will result in an additional 20 TWh per year. The EU Code of Conduct for Digital TV Systems, if successfully implemented halves this predicted consumption and thus will deliver about 25 TWh of annual electricity savings in about 10 years.

As far as the traditional white goods and other residential sector appliances and equipment are concerned electricity savings per year in the order of **22 TWh** to **27 TWh** have been achieved in the last decade. In particular it is worth to notice that the **65 TWh** to **75 TWh** will be saved per year by **2010** in total by the current polices already in place (appliances labelling, efficiency requirements, voluntary agreements, Code of Conducts, etc.). It is important to highlight that there is still a huge saving potential available if further cost-effective[13] measure 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%). Large saving potential is also available in residential **refrigeration appliances** (16 TWh), and **residential lighting** (10 to 20 TWh, in lighting with the current policies there will be a consumption increase of about 10%, the cost-effective technology CFLs is already in the market, bout 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 polices 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 **80 TWh** per year by year 2010 compared to the current policies scenario.

[13] Most of the energy efficiency measures are cost-effective. This means that they will results 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. In most cases there is an increase in manufacturing cost to manufacturers, which can be passed on the users or can be compensate by productivity gains. 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 90ies 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.

Table 3.11 Electricity consumption savings and trends in the residential sector EU-15 (sources [Wai 2004, Kem 2004])

	Electricity Savings Achieved in the Period 1992-2003 [TWh/year]	Consumption in 2003 [TWh/year]	Consumption in 2010 (with current policies) [TWh/year]	Consumption in 2010Available potential to 2010 (with additional polices) [TWh/year]
Washing Machines	**10-11**	**26**	**23**	**14**
Refrigerators and Freezers	**12-13**	**103**	**96**	**80**
Electric ovens	**-**	**17**	**17**	**15.5**
Standby	**1-2**	**44**	**66**	**46**
Lighting	**1 -5**	**85**	**94**	**79**
Dryers	**-**	**13.8**	**15**	**12**
DESWH[14]	**-**	**67**	**66**	**64**
Air-conditioners		**5.8**	**8.4**	**6.9**
Dishwashers	**0.5**	**16.2**	**16.5**	**15.7**
Total	**24.5-31.5**	**377.8**	**401.9**	**333.1**

Another important piece of equipment for electricity consumption and potential savings are **electric motors**, in particular the three phase industrial motors. Through the CEMEP agreement started in 1999 about 1 TWh was already saved until 2003. The saving potential of the current agreement when most of the motor stock will be 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. A recent report [ECI 2004] has calculated the total electricity cost-effective savings in motor systems to 200 TWh.

The "Ballast" Directive will deliver electricity savings of about 5 TWh by 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 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 Energy Star programme), and in the cooling and ventilation systems.

[14] 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). Larger electricity saving will be achieved by introducing solar thermal panel.

CHAPTER 4

BIOMASS

Niina Kautto

4.1 Introduction

Biomass as a renewable energy source holds great potential in responding to energy challenges of the future as well as meeting renewable energy targets set by the European Union. Many Member States have also identified biomass-derived energy as one of the ways to achieve Kyoto Protocol obligations. Biomass has multiple advantages over conventional energy sources:

- contributes to security of supply as a versatile and constant renewable energy source,
- reduces greenhouse gas emissions and improves air quality, depending on technology,
- creates employment opportunities and contributes to rural development and regeneration,
- its use can lead to numerous other environmental benefits, such as the use of wastes as feedstocks leading to the reduction of landfill waste or sustainable energy crop management leading to increased biodiversity.

Biomass is defined as all organic, non-fossil materials with biological origin, which have an intrinsic chemical energy content. This biomass resource originated from forest, agriculture or waste streams is the oldest form of renewable energy. Its characteristics define the scale of its use, as a source that is renewable only if exploited in a sustainable manner. Bioenergy, energy from biomass, is complex and varies both in resource type (various feedstocks) and form (solid, liquid, gaseous) whilst being influenced by technical, environmental and policy factors [IEA 2003a].

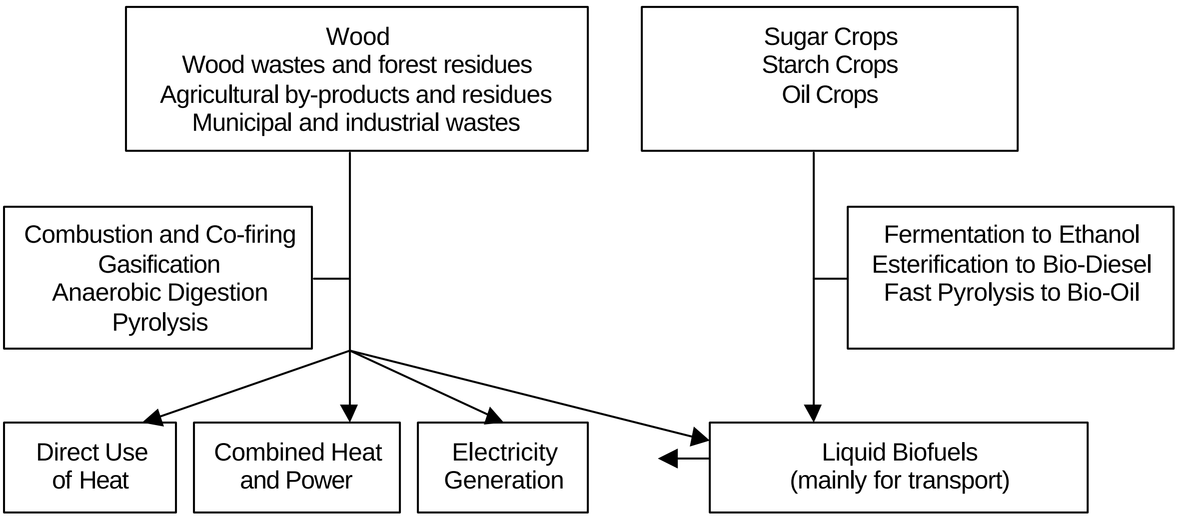

Fig. 4.1: Simplified overview of the main bioenergy usage paths (modified from [Jäg 2004] and [Ere 2004]).

Biomass can be readily stored and transformed into electricity and heat or used as a raw material for production of fuel and chemical feedstock [Ver 2002], see Figure 4.1 for an overview of the main bioenergy usage paths. Biomass serves as a multipurpose tool for electricity generation – in providing a base load capacity, which produces electricity in large volumes during times of peak energy demand[15] as well as a peak load and storage capacity. Indeed, the main advantage of biomass compared to most other renewable energy sources is its inherent energy storage, transportability and consequent availability-on-demand [IEA 2003a]. Biomass offers several applications for electricity generation, from centralised co-generation to distributed power production.

With over ten policy fields that are relevant to biomass[16], the complexity of bioenergy has to be set in the context of its strong dependence on numerous policy frameworks [Eur 2002]. Non-technical issues such as public acceptance, socio-economic as well as ecological externalities of biomass further obscure its benefits. The dependence of economics and logistical chain of a biomass system on both location and conversion technology explain why the most essential technical issues for bioelectricity relate to feedstock logistics and conversion technologies.

Energy generation from biomass has both positive and negative environmental impacts: burning of organic material can cause harmful emissions, while there is another benefit in the use of wastes[17] as feedstocks, as these are withdrawn from landfills. The European Commission's White Paper on renewable energy sources [EC 1997] has outlined the benefits of renewable energy use, including bioenergy, to different sectors.

The following part of the report concentrates on the use of renewable biomass as a source of electricity and combined heat and power.

4.1.1 Definition of electricity from biomass

Renewable electricity from biomass (i.e. biopower) is defined according to the RES-E Directive as the electrical energy generated from the biodegradable fraction of products, residues and wastes from agriculture (including vegetal and animal substances), forestry and related industries as well as the biodegradable part of municipal and industrial wastes [EU 2001]. In addition, dedicated energy crops or plantations can be used to generate electricity. Biomass can be a sustainable source of electricity only if it fills certain economic, environmental and social criteria. These are for instance that best available conversion technologies and logistics must be used to decrease harmful emissions, bioelectricity costs must be kept low to ensure economic efficiency and bioelectricity schemes have to be designed to benefit rural development and gain local public acceptance [Bau 2004].

A key difference between different definitions of bioenergy is the acceptance of electricity produced from waste incinerator plants as renewable energy. However, since the RES-E Directive entered into force in 2001, only the biodegradable fraction of industrial and municipal solid waste can be counted as a source of renewable energy. Most Member States define only organic waste as renewable energy.

Some deviating examples of the definition of renewable bioelectricity are provided by Lithuania and Finland. Lithuania regards all municipal solid waste and peat as renewable

15 For instance combined heat and power plants

16 Policies in the field of energy, industry, agriculture, environment, research, transport, social (employment), regional/rural, education, consumer, world development and international trade affect or are affected by biomass issues.

17 e.g.: municipal solid waste and slurry

[WWF 2004]. Finland classifies peat as a slowly renewable biomass fuel [Cri 2000] due to the long time span required for this resource to renew compared to wood. Also in Sweden, Estonia and Ireland peat is regarded as an important energy source [Ves 2001]. However, peat as organic material that originates from plants grown thousands of years ago is not explicitly considered as renewable energy source in the RES-E Directive and is thus disregarded by this report.

4.1.2 Biomass resources

Biomass resources are traditionally dispersed by nature and occur in numerous relatively small, local sources. With the exception of municipal and industrial wastes, these resources tend to be available in rural areas [IEA 2003]. The diversity of biomass is partly based on its wide range of feedstocks: biomass energy originates from forests, agriculture or organic waste streams. Main biomass resources are presented in Table 4.1.

Table 4.1 Main biomass resources [Ere 2004, Eur 2002].

Biomass resources	Examples
wood wastes	wood processing waste, sawmill waste, construction residues
forest residues	
short rotation forestry	willow, poplar, eucalyptus
sugar crops	sugar beet, sugar cane, sweet sorghum
starch crops	maize, wheat, corn, barley
oil crops	rape seed, sunflower
herbaceous ligno-cellulosic crops	miscanthus
agricultural by-products and residues	straw, animal manure
organic fraction of municipal solid waste	
sewage sludge	
industrial residues	e.g. food and paper industry residues

Energy crops for bioelectricity are likely to include woody crops (short, medium and long rotation crops) and perennial herbaceous (non-wood) energy grasses (such as miscanthus, reed canary grass etc) [Bau 2004]. As such, biomass resources can be classified according to source (animal or plant) or according to its form (solid, liquid or gaseous). They can be divided into the following principal categories:

- residues from primary energy production
- dedicated plantations
- by-products and wastes

The IEA classifies biomass as 'renewable combustible renewables and waste' (renewable CRW), including solid and liquid biomass, gases from biomass, and renewable municipal solid waste[18]. Wood, vegetal waste (including wood waste and energy crops), animal materials or wastes, sulphite lyes also known as black liquor and other forms of solid biomass such as produced charcoal can be classified as solid biomass. Category of gas from biomass includes landfill gas and sludge gas[19] and other biogas. Liquid biomass includes e.g. bio-

[18] Non-renewable CRW includes industrial waste and non-renewable municipal solid waste
[19] Sewage gas and gas from animal slurries

ethanol, biodiesel, and bio-oil [IEA 2003b]. Some waste[20] is excluded as biomass resources. Although representing a large potential source of organic material [Bau 2004]. Energy from waste should be used to produce electricity as long as it complements and does not replace waste prevention and recycling [EC 1997].

The total amount of biomass resources varies greatly from country to country, as well as the types of the most important resources. In Finland and Sweden the most significant resource is wood. Short rotation coppice, energy grass and straw constitute a large part of biomass resources in Germany and Poland, straw being the most important. Fruit and herbaceous biomass fuels contribute considerably to biomass supply in Southern and Central Europe [Ves 2001]. Waste from the pulp and paper industry (industrial black liquours) should be distinguished from previously mentioned resources, because it is an important bioenergy resource in some countries, such as Finland and Sweden.

4.1.3 Restrictions in bioenergy analysis

EUROSTAT Statistics as well as the International Energy Agency only introduced biodegradable part of waste into data collection in 1999. For the years 1990-1998 the IEA included all energy produced by means of waste generation[21]. Data presented for the years since 1999 often represents estimates rather than observations as the majority of production reported as renewable MSW should in fact be classified as non-renewable MSW. It should be noted, that biogas statistics are not available as complete until 1992 [IEA 2003b].

Bioenergy statistics, as well as other renewable energy statistics are more scarce from New Member States. This following part thus contains more detailed information on EU-15 Member States. As 19 of the 25 European Union Member States are part of the IEA (Czech Republic, Hungary, Poland and Slovakia in addition to EU-15 states), more statistical data are available from these countries. Accurate information regarding installed capacities, production and growth trends for bioelectricity is few and far between for new Member States. As the IEA statistics are currently one of the most complete and detailed sources of information, they are mainly used in this part of the report.

To enable comparison between different sources, it is essential to indicate the definition of biomass or bioelectricity. Definition of bioelectricity in this report is, ***if not stated otherwise***, electricity generated from solid biomass, biogas and the biodegradable part of MSW. However, because of the design of the statistics, bioelectricity capacities presented mostly include both biodegrable and non-biodegradable MSW in addition to solid biomass and gas from biomass.

4.2 Status of bioelectricity in the EU-25

The enlarged European Union (EU-25) consists of Member States with a variety of renewable energy mixes. Starting points of energy policies in Member States are often defined by domestic natural conditions, which differ largely across Europe. However, the differences between renewable energy use in Member States cannot be purely explained in terms of resource availability [Rei 2004]. Generally, New Member States have a considerable renewable energy and especially bioenergy potential [Gan 2004], though most of it has remained untapped.

[20] Industrial, commercial and municipal solid waste (MSW)
[21] In effect not distinguishing between biodegradable and non-biodegradable waste

4.2.1 *Current bioenergy use*

Leading renewable energy sources in EU-25 are hydropower and biomass, whilst other types of renewables still represent a small share in energy production. For both EU-15 and new Member States the most significant contribution to the share of renewables from gross inland consumption over the period 1990-2000 was that of biomass, 62 % and 83 % respectively [EUR 2003]. In the EU-25, like in most OECD countries [Bau 2004], production of bioelectricity is largely based on residues from forestry and wood processing industry. Agricultural residues and dedicated energy crops contribute significantly less to electricity production.

The installed capacity for electricity generation from renewables in EU-15 increased by 21.7% between 1990 and 2000, mainly by wind power and wood-burning plants (Fig. 4.2). Hydropower still clearly is the most dominant source of renewable energy, though the installed capacity of hydro plants has increased only marginally in EU-15 over the last decade. In New Member States other renewables than hydro represented just minimal or zero fraction of the installed capacity in the year 2000.

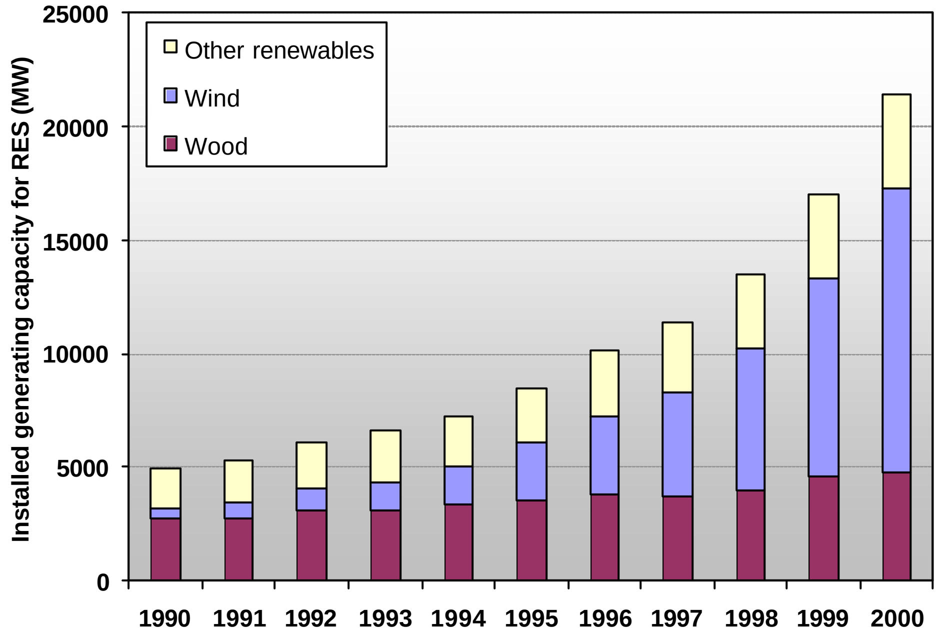

Fig. 4.2: Installed capacity for electricity production from wood, wind and other renewables (municipal solid wastes, biogas, geothermal and photovoltaic) in EU-15 in 1990-2000 [EUR 2003].

Leading bioenergy users in EU-15 are Finland, Sweden, Germany and France[22] [EC 2003]. The largest producers of electricity from biomass in 2001 amongst EU-15 were Finland, Germany, United Kingdom and France (Fig. 4.3) [IEA 2003b]. In new Member States, the biggest amount of bioelectricity is generated by Czech Republic and Poland, though quantities are significantly smaller than in EU-15 countries.

There is a great variation in all Member States regarding the use of biomass and as already mentioned this is not necessarily related to natural resources of the country. In the new Member States, biomass contribution to electricity generation is far less than to heat

[22] more particularly in 2001, based on gross inland consumption figures

production [Gan 2004]. Solid fuel wood is mostly used for heat production, e.g. in Latvia and Lithuania with small and generally inefficient domestic boilers [EC 2004a]. Electricity from biomass is mainly based on solid biomass and biogas, although its contribution to the total RES supply in each country is small. The majority of these countries have not yet established biofuel supply systems.

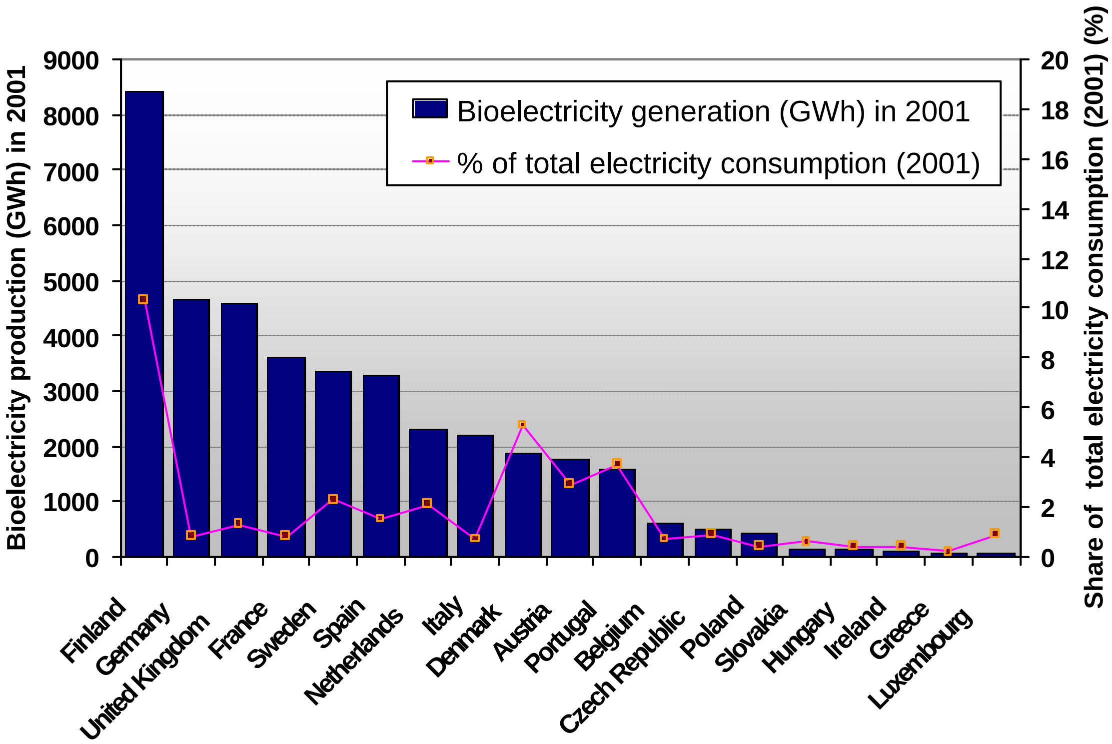

Fig. 4.3: Electricity production from biomass in nineteen Member States in 2001 [IEA 2003b].

4.2.1.1 Bioelectricity capacity and production in the EU

The installed biomass generating capacity in EU-15 was 8,733 MW in 2001 representing 6.0% of the total installed capacity for RES and waste[23]. Of the nineteen Member States, largest capacity for biomass electricity production have Sweden, Finland and Germany (Fig. 4.4). Bioelectricity capacity more than doubled amongst EU-15 between 1990 and 2001 (Fig. 4.5).

In 2001 bioelectricity production[24] in EU-15 amounted to 28.3 TWh; combined with generation in New Member States, of 1.2 TWh, bioelectricity in EU-25 thus totalled 29.5 TWh. Bioelectricity's share of total electricity generation was 1.0% and bioelectricity contributed 6.9% of the total electricity generation from renewables in EU-25 (430 TWh in 2001) [IEA 2003b, IEA 2004].

In EU-15, biomass categories can be differentiated further: if renewable MSW is included, bioelectricity generation in 2001 totalled 38.5 TWh (Fig. 4.3 shows per country account related to total electricity consumption in 2001), composition of which was 54.0% of solid biomass, 26.3% renewable MSW and 19.6% biogas.

[23] If only solid biomass and biogas are taken into account, the estimated capacity was 6,453 MW in 2001 or 4.4 % of the total (renewable and waste) installed capacity.

[24] including in this case only solid biomass and biogas

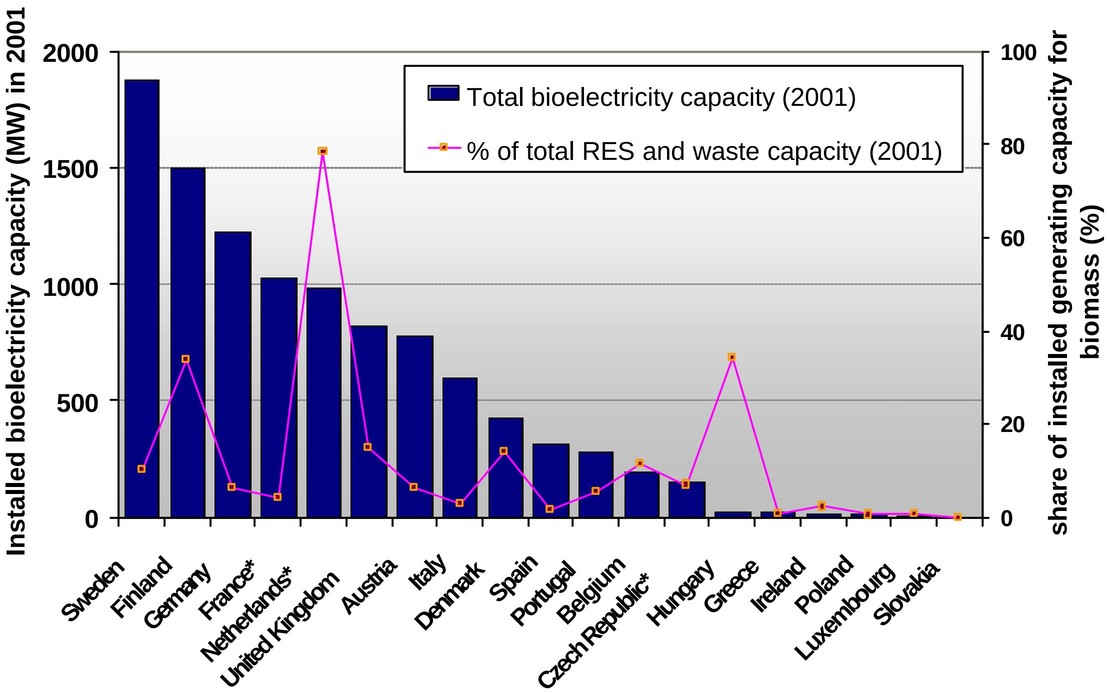

Fig. 4.4: Installed bioelectricity capacity by country in 2001 in nineteen Member States [IEA 2003b].
*) Bioelectricity capacity of these countries has been calculated through electricity production in that year and with a capacity factor of 40% [25].

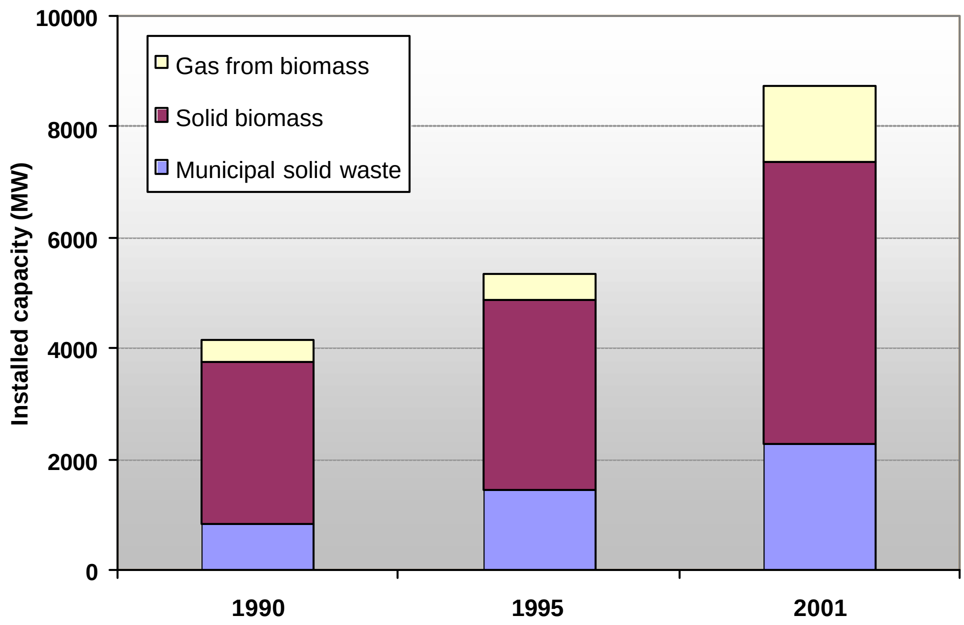

Fig. 4.5: Installed capacity for bioelectricity by source in EU-15 between 1990 and 2001 [IEA 2003b].

[25] This is because figures for the 'net generating capacity for renewable and waste products' in IEA 2003b might not be complete in the case of these certain countries. Note that capacity factor can be higher or lower depending on the country.

Electricity production from biomass steadily increased between 1997 and 2002. However, growth in EU-15 is 59% compared to 102 % in four new Member States (Czech Republic, Hungary, Poland and Slovakia). Absolute amounts of generated bioelectricity are still very small in new Member States compared to EU-15 production.

In industrialized countries (total OECD), bioelectricity currently represents only a small fraction of electricity production, 126.6 TWh or 1.3% of total electricity production in 2001[26], but has large growth potential [Bau 2004].

4.2.1.2 Solid biomass

Electricity generation from solid biomass grew in EU-15 from 10.2 TWh_e to 20.8 TWh_e between 1990 and 2001, with an annual growth of 6.7% (Fig. 4.6). Solid biomass accounted for 4.7% of renewable electricity generation and 54.0% of bioelectricity production in 2001. In the same year CHP plants produced most of the electricity from solid biomass (76.6%, electricity only plants therefore constituted 23.4%). The largest producer of electricity from solid biomass is Finland (8.2 TWh_e in 2001), where it represents 37.3% of renewable electricity supply.

The electrical capacity for wood has increased gradually during the last decade, Fig. 4.2 shows the trend compared to growing capacity of wind and other renewables in EU-15 between 1990 and 2000. Wood-burning capacity has grown by 74 % 1990-2000 [EC 2003], and average operating hours have simultaneously increased around one thousand hours[27]. This is at least partly due to the fact that the use of solid biomass has increased in CHP plants and the overall output of electricity has grown. Capacity for solid biomass has grown 5.2% per year (Fig. 4.5).

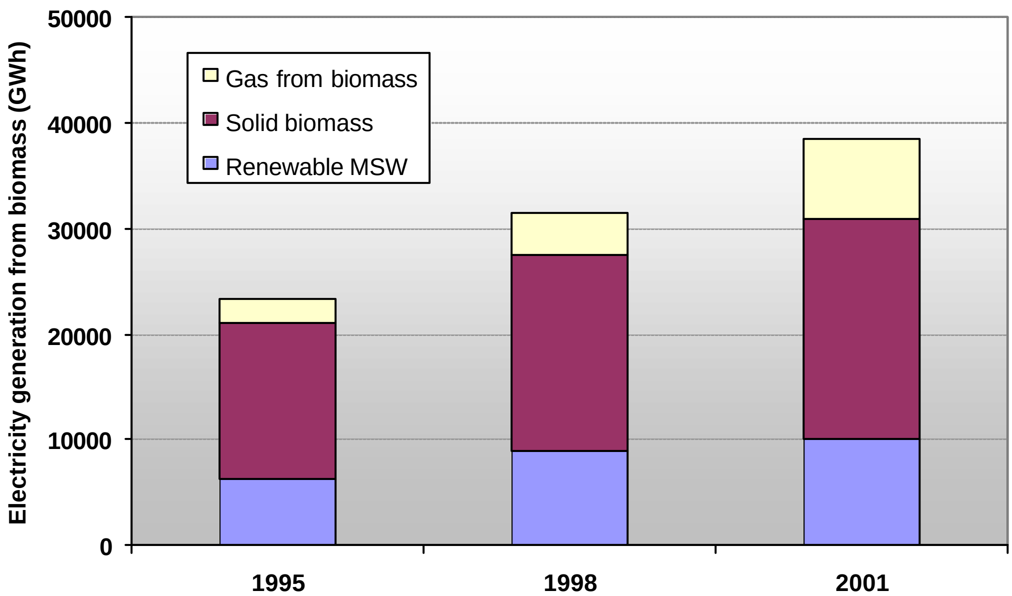

Fig. 4.6: Bioelectricity production by source in EU-15 between 1995 and 2001 [IEA 2003b].

[26] If only solid biomass and biogas are taken into account, bioelectricity generated in OECD countries in 2001 amounted to 93.2 TWh, which represented 0.9% to total electricity generation.

[27] when comparing the electricity production from solid biomass in 1990 and 2000, based on IEA 2003b figures

According to EurObserv'ER [EOb 2003] electricity generated from wood (in EU-15) was 25.3 TWh in 2002. This accounted for approximately 59% of biomass generated electricity. The wood energy sector delivered over half of the primary energy production from renewables (44.06 Mtoe) in 2002, a progression of 2.7 % compared to the previous year, and contribution of 12-14% of total electricity consumption in EU-15 countries.

Solid biomass is the leading source of bioelectricity in the four new Member States (Czech Republic, Hungary, Poland and Slovakia). Czech Republic and Poland produce the largest amounts of electricity from solid biomass, totalling 381 GWh and 402 GWh, respectively in 2001.

4.2.1.3 Renewable municipal solid waste

In EU-15, renewable municipal solid waste accounted for 2.4% of renewable electricity production and 26.3% of bioelectricity in 2001[28]. The installed capacity is estimated to have increased with an annual growth rate of 9.4 % (Fig. 4.5), from 845 MW in 1990 to 2280 MW in 2001.

Electricity production from renewable MSW in 2001 was 10.1 TWh_e[29] (Fig. 4.6). Germany is the largest producer of electricity from renewable municipal solid waste in the EU-15, with a total of 2.0 TWh (2001). The highest growth rates were experienced in Denmark and Italy between 1990-2001 at 32.8 % and 29.9 % per annum, respectively. In Luxembourg electricity from renewable MSW forms the largest national part of bioelectricity (solid biomass, renewable MSW and biogas included) in EU-15 with 86.4%, while generates 88.9% of its bioelectricity by renewable MSW. Generally, municipal solid waste is much less applied for electricity production in new Member States.

4.2.1.4 Gas from biomass

Electricity production from biogas among EU-15 Member States was an estimated 7.5 TWh in 2001, growing clearly from 2.3 TWh in 1995 [30] (Fig. 4.6). Biogas electricity capacity grew from 1992 to 2001 with an average growth rate of 12.4 % (Fig. 4.5), accounting for 19.6 % of the bioelectricity production, and 1.7% of total renewable electricity generation in 2001.

The United Kingdom represents the biggest biogas electricity producer in the European Union (EU-15), generating 2.9 TWh of electricity from biogas in 2001. The second largest producer is Germany with total of 2.0 TWh and third Italy, 0.7 TWh, with the highest growth rate per annum of 70.0 % from 1992 to 2001. As the IEA pointed out, most of the growth in the biogas occurred in the late 1990's and early 2000's and this increase is expected to continue in the near future.

In EU-15, 60% of biogas is used in electricity production and 40% in heat production. The total biogas production amounted 2.8 Mtoe in the EU-15 in 2002, which was 10% higher than in 2001 [EC 2004]). Amongst new Member States, Czech Republic produces the largest amount of electricity from biogas, 133 GWh in 2001 [IEA 2003b].

[28] Note that data on renewable and non-renewable municipal solid waste have been collected as distinct products only since 1999

[29] 14.2 TWh_e if all MSW is included

[30] Note that complete biogas statistics are available from 1992

4.2.2 *Reaching the targets*

The targets set by the White Paper for renewable energy sources and the RES-E Directive are the driving forces for bioenergy use in the EU. The latter in particular promotes the production of electricity from renewable energy sources. The White Paper set the objective for the entire biomass sector (wood energy, biogas and biofuels) at 135 Mtoe[31] [EC 1997].

EU-15 used 56 Mtoe of biomass for energy purposes in 2001 whilst an achievement of the targets for 2010 would require an additional 74 Mtoe, of which 32 Mtoe in electricity generation [EC 2004]. The White Paper projected the electricity production from biomass for the year 2010 to be at 230 TWh (8.0% of the total electricity production, and equivalent to an installed capacity of 44 GW). Figure 4.8 shows the substantial increase necessary to reach this target by EU(-15) Member States. In summary, the White Paper targets imply that between the years 1995 and 2010 a 3-fold increase in biomass energy, and a 10-fold increase in biomass electricity is required.

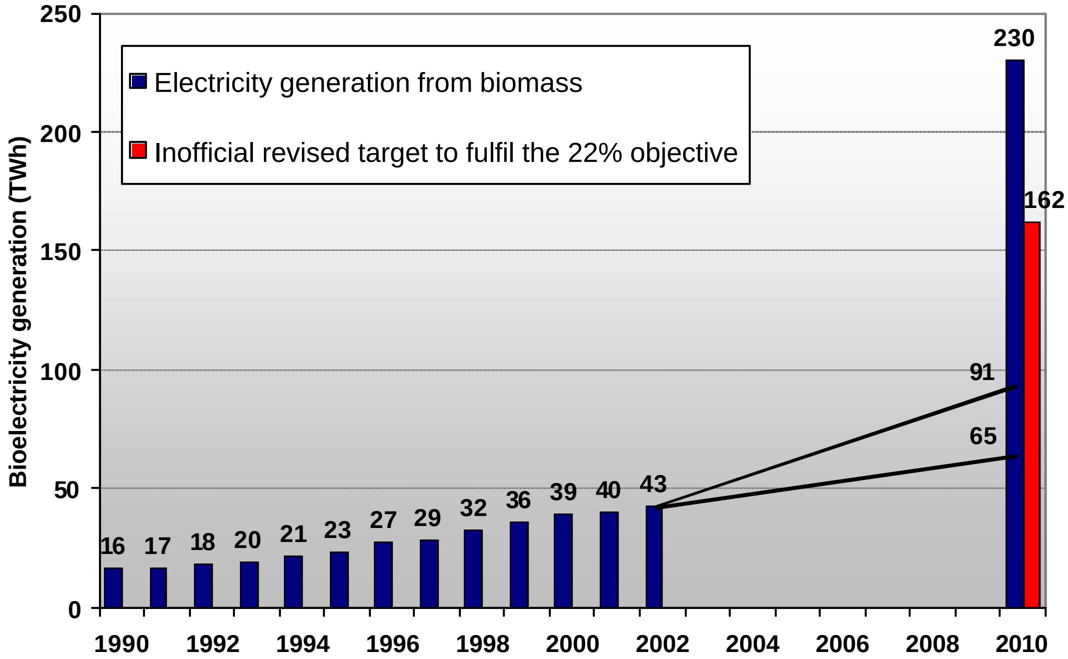

Fig. 4.7: Electricity generation from biomass in EU-15 in 1990-2002 and the EU targets for 2010 for electricity production from biomass [Ala 2003, EC 1997, EC 2003 and EC 2004] (unconsolidated figure for 2002). Figure also shows the variation of estimated bioelectricity production in 2010.

The RES-E Directive has the target to increase the share of renewable electricity from 14% to 22% in EU-15 in 2010[32]. Several studies have shown that the RES-E Directive targets in the EU will not be met with current policies [e.g. ECO 2002, Uyt 2003, WWF 2003]. The European Commission in its recent Communication assessed the state of the development of

31 It was estimated that the bioenergy sector should contribute 90-100 Mtoe, projected additional bioenergy use consisting of biogas exploitation (15 Mtoe), agricultural and forestry residues (30 Mtoe) as well as energy crops (45 Mtoe)

32 Objective is not detailing the contribution of different sources of RES-E

renewable energies in the European Union [EC 2004]. The assessment of electricity from biomass calls for additional effort to reach the targets and indicates that in order to reach the target, electricity from biomass will need to grow from 43 TWh in 2002 to 162 TWh in 2010 (Fig. 4.7). Therefore, the required growth rate for the bioelectricity would be 18% a year.

Electricity from biomass has grown 9 – 10% for the past 4 years (between 1999 – 2003), and is expected to increase with a rate of 6 to 10% over the period of 2003–2010. Estimation of the total amount of bioelectricity produced in 2010 varies between 65 – 91 TWh at the current trend and without implementation of additional policy measures [Pre 2002, EC 2004, EOb 2003]. Therefore, the growth rate has to be accelerated in the European Union.

To fulfil the target of electricity production from bioenergy, it is suggested that the use of biomass should be increased especially in large-scale applications, meaning co-firing with coal or other fossil fuels [Ala 2003]. However, considering the dispersed nature of biomass resources and the large quantities of fuel required, the most economic solution would be to build smaller decentralized bioelectricity plants, which are seen to play an important role in reduction of greenhouse gases and dependence of fossil fuels [Hei 2003]. Many technological solutions are under development for small- and micro-scale electricity production, whilst large-scale technology options are already partly available. In new Member States, decentralised bio-heat plants are more easily established than large-scale biopower plants, which require large fuel volumes [Gan 2004].

Meeting the targets of the White Paper on Renewable Energies by 2010 for biomass requires immense efforts on biomass production and processing into heat, electricity and liquid fuels. The technology is likely to be available but necessary incentives for industries are still missing. The European Biomass Association, AEBIOM, calls for financing of the conversion of land to energy crops as well as financing of processing units to convert biomass into different energy forms. The fulfilment of targets for biomass will require a concerted effort from in particular from those Member States showing large biomass potential, as well as from the Commission. Successful national programs should be studied and improved technology and norms demonstrated.

In order to provide a clear approach to secure bioenergy supply throughout Europe, the European Commission has committed itself to bring forward a coordinated biomass plan by the end of 2005, with specific attention to new Member States [EC 2004].

4.2.3 Biomass potentials

4.2.3.1 Defining the potentials

In evaluating biomass resource potentials it is important to clarify the type of potential, be it economic, technical or other potential. Theoretical potential of biomass refers to overall plant growth driven by solar radiation[33]. Technical or technological potential has several categories, and describes how much of the theoretical potential is technically exploitable, e.g. cultivation. Social potential overlaps with technological potential, whilst economic potential presents the portion of technical potential that could be exploited cost-effectively and at competitive prices[34]. Market potential represents the willingness or readiness of markets to exploit the potential and does not take into account the external costs as they are borne by society so far.

[33] As part of this, solar radiation represents physical potential and biological potential describes how much plants can take in the radiation in photosynthesis.

[34] Economic potential includes external costs of energy production.

Economic and market potential must be bridged by way of support mechanisms whilst they should also be converged with technical potential (borders being dynamic). In general, the potentials presented in literature represent a combination of all types of potentials which complicates a comparison of different estimations. We thus refrain from further defining potentials.

Resource availability usually relates to technical or theoretical potential. It is suggested that in some cases it would be better to talk about resource mobilisation instead of resource availability [Sie 2004]. Sustainable management and delivery of energy to the place of demand are also considered to be more crucial issues than availability of biomass resources [WEC 2001].

4.2.3.2 Biomass potentials on a global and European Union level

One of the main advantages of biomass is its widespread availability, but there are also competing options for the use of land (e.g. livestock production and recreation) and for the biomass resource itself (e.g. food production and liquid biofuels production [Kav 2004])). There are numerous studies assessing the future biomass energy potential. For instance, it is estimated that the future global potential of biomass energy is extremely large, ranging from 85 EJ to 1130 EJ[35] (in 2050) (Table 4.2). This potential is depending for instance on the future population development, type of diet consumed and also the productivity level of forests and sustainable harvest levels [Hoo 2002].

The IPCC Third Assessment Report (TAR) [IPC 2001] estimated that potential biomass contribution to global primary energy supply would be 2–90 EJ and 52–193 EJ by 2025 and 2050 respectively. In comparison, current use of biomass energy globally is approximately 55 EJ [WEC 2001]. For industrialised countries (OECD) the estimations vary for 2025 5–21 EJ and for 2050 9–31 EJ. Table 4.2 shows the variation of different biomass potential scenarios on a global level.

Table 4.2 Examples of global biomass potential scenarios.

Global biomass potentials	**2025**	**2050**
IPCC TAR 2001 (global)	2-90 EJ	52-193 EJ
IPCC TAR 2001 (OECD)	5-21 EJ	9-31 EJ
Hoogwijk et al. 2002		85-1130 EJ
WEA 2000 (OECD +Central Eastern Europe, newly independent states of the former Soviet Union		276-446 EJ

Biomass has one of the largest growth potentials of renewables in the EU according to the White Paper on renewable energies. One estimate for the current and available biomass resources in the EU-15 is presented by the EUREC Agency in Table 4.3. It can be seen that by-products of other production activities constitute the main part of biomass sources, but in the long term energy crops have the potential of becoming the primary biomass feedstock.

Global energy potential from residues alone is estimated to be 70 EJ, and 5.8 EJ in the EU-15. The estimate from energy plantations totals 1.5 EJ for EU-15 [Bau 2004], see Table A.2 in the Annex. Figure 4.8 shows the vast unexploited potential of biomass for electricity in the EU when comparing the estimated energy potential from residues and energy plantations to current production of electricity from solid biomass.

[35] 1 EJ = 10^{18} J = 277.8 TWh

Table 4.3 Biomass resources and potential in the EU-15 (source [Eur 2002]).

Raw material	Current resources Mt (dry)/year	Future resources Mt (dry)/year
By-products of other activities:		
Wood wastes	50	70
Agricultural residues	100	100
Municipal solid wastes	60	75
Industrial wastes	90	100
Dedicated land for biomass:		
Short rotation forestry	5	75-150
Energy crops	-	250-750
Total biomass	200	1000
Total bioenergy (Mtoe) *	80	400
% current EU primary energy	5-6%	25-30%

*) In 2001 bioenergy (renewable combustible renewables and waste including solid biomass and liquid biomass, renewable MSW and biogas) contributed to the primary energy supply of EU-15 51 Mtoe [IEA 2003b]

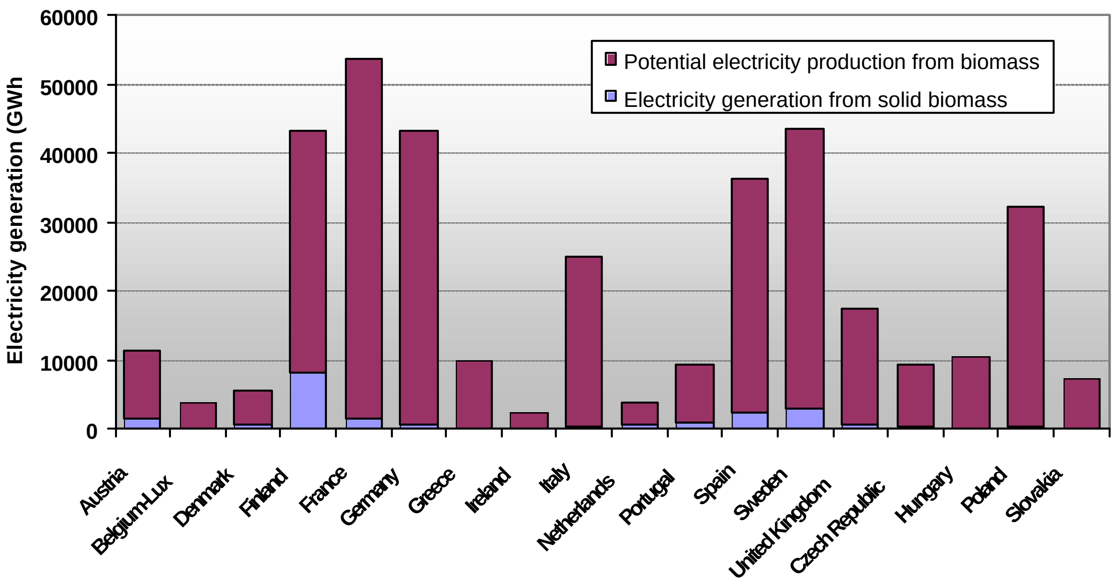

Fig. 4.8: Bioelectricity potential vs. actual use in 2001 [Bau 2004, IEA 2003b]. Biomass potential include energy potential from residues and energy plantations (25% residues + 5% of crop, forest and wood land at 150 GJ/ha (10 t/ha per year) and an electrical efficiency of 35%).

A more recent study estimates the availability of biomass resources in EU-15 to a total of 131 Mtoe/yr for the year 2000, growing to 172 Mtoe/yr in 2020 (Table 4.4). Taking into account new Member States (plus Bulgaria and Romania) total availability of bioenergy in the EU is expected to grow from 160 Mtoe/yr up to 210 Mtoe/yr (2000-2010). Most of these biomass resources are so called ‘tradeables’ i.e. clean types of biomass whilst smaller share is formed by ‘non-tradeables’, those bioenergy resources, which are addressed by waste management policies [Sie 2004]. Largest growth is to be expected in tradeable biomass resources , consisting mainly of the growing use of solid agricultural residues as well as forestry by-products and refined wood fuels. Energy crops are seen to play only a small role [36].

Table 4.4 Availability of bioenergy in Europe [Sie 2004, modified].

Availability of bioenergy in EU-25 + Romania and Bulgaria	2000 [Mtoe/yr]	2010 [Mtoe/yr]	2020 [Mtoe/yr]
Tradeables	107	115	125
Non-tradeables	47,1	62,4	79
Transport fuels	5,7	5,7	5,7
Total bioenergy	160	183	210

Note: Total bioenergy numbers rounded.

The AFB-net, European Bioenergy network in their study (1999-2000) mapped biomass resources in 20 European countries [37], and concluded that available resources would be 4500 PJ/a (107 Mtoe/a) compared to the current use of 1800 PJ/a (43 Mtoe), or 40% of the resources. This estimation mainly takes into account those resources which are easily accessible and economically feasible [Ves 2001].

Mid-term technical potential for biomass use in continental new member countries (8 of 10) is estimated to be over 7,200 MW in 2020, while the biomass sector enjoys some of the largest potential for investment compared to all other RES sectors. According to the study of the European Bank for Reconstruction and Development, long-term potential for RES is extremely large in the region, including Russia and other Eastern European countries [Bla 2003].

According to the Commission’s Communication, there is an important potential for the use of biomass for both electricity and heat generation in most new Member States (for all but the two Mediterranean islands). Great unexploited potential for electricity generation is described as particularly striking in Hungary, the Czech Republic, Slovakia, Latvia, Lithuania and Estonia [EC 2004a]. The use of biomass [38] could more specifically be doubled in Slovenia [Jää 1999].

Energy crops are regarded as an essential source for RES-E production in new Member States, notably for CHP plants, due to the fact that these countries have great areas of arable land. Changing into more efficient agricultural production would present an opportunity to release some of the arable land from food production for energy purposes. Poland and Czech Republic are considered to have the greatest bioenergy export potential for energy crop development [Gan 2004].

Technological potential for electricity from RES in EU-15 Member States is estimated to be more than double that of the total estimated demand for 2010 [Haa 2003]. Projections for the year 2020 estimate the potential electricity production from biomass in EU-15 at 3 EJ or 290 TWh [39] (Table A.2 in the Annex) [Bau 2004]. There is thus significant potential for the

[36] According to scenarios of this study, biomass based transport fuels have a small share in 2020 and the targets of the “Biofuel Directive” are not met. Similar to other studies, this emphasizes that figures are indicative and based on certain conditions.

[37] 19 of the EU-25 countries, excluding Luxembourg, Cyprus, Czech Republic, Hungary, Lithuania and Malta

[38] Including heating purposes

[39] In 2001 39 TWh (IEA 2003b)

increase of electricity generation from biomass. Based on the assessment of certain feedstocks, a study presented by WWF International and the European Biomass Association (AEBIOM) suggests that achieving the proposed target of 15% for bioelectricity in OECD countries by 2020 would be possible[40].

The quantification of the biomass resource and its potential are foreseen to be accurately assessed in the whole EU-25. Further assessment of biomass potentials is needed in particular in terms of land availability, land use for various biomass applications and the difference in benefits that these applications might have.

4.2.4 Biomass conversion technologies

Biomass conversion technologies include combustion, gasification, pyrolysis, mechanical compression and pressing, esterification, anaerobic digestion as well as ethanol fermentation[41] [Eur 2002]. The most relevant technologies in relation to electricity generated from biomass are [IEA 2003a]:

- combustion
- co-firing
- pyrolysis
- gasification
- anaerobic digestion

Whilst biomass plants are faced with similar issues as fossil fuel plants emitting for instance CO_2, nitrogen oxides or particulate matter, wood combustion results in lower SO_2 emissions than, for example, coal. Emissions thus strongly depend on the technology used: modern and well-designed technology can lead to considerable environmental and health gains. Taking into account the life cycle of biomass, such emissions have a much lower net impact on the environment than fossil fuels.

4.2.4.1 Combustion and co-firing

Combustion is the main option in this field: burning biomass produces heat and/or steam, which can be used directly for cooking, space heating and industrial processes, or indirectly for the generation of electricity through a steam turbine. The majority of biopower plants consist of direct-fired boilers[42] that, due to small scale and economic trade-offs, typically range from 20 to 50 MW with rather low efficiency, rates in the 20 % range [Eur 2002, IEA 2003, Bau 2004]. Low efficiency is further explained due to the fact that biomass fuel typically entails lower heating value and higher moisture content compared to that of coal [Bla 2003].

Dedicated bioelectricity plants are generally of moderate scale (below 50 MW_e) due to the dispersed nature of biomass feedstocks, their low energy density as well as consequently high transportation costs. There have been large improvements in combustion efficiencies (> 30%), in the development of CHP plants as well as in reduction of emissions [Ver 2002].

An example of greater efficiencies with CHP plants is the 38 MW_e CHP plant using circulating fluidised bed combustion in Växjö, Sweden (electrical efficiency 30%, total efficiency 87%). For instance, the share of CHP plants in electricity production in Sweden was 7% in the

40 The 15% suggested is more than a vision than a target. It is a suggestion of what the OECD could be aiming at by 2020, and of what may be achieved under conditions favourable to bioelectricity development (personal communication with A. Bauen).

41 Production of bioethanol

42 With fixed or travelling grates or with fluidized beds

year 2001[43], while in Denmark 70% of electricity is produced by CHP plants [Kir 2004]. In EU-15 countries, electricity from solid biomass is mainly produced in CHP plants, electricity from biogas and renewable MSW is generated mostly in 'electricity only' plants.

Main development has been experienced with fluidised bed combustion (FBC) technology, which has high efficiency and these combustors can burn mixtures of fuels, also with high moisture content (up to 60%). The importance of this technology during production of heat and electricity is steadily increasing, due to its economical and environmental advantages.

Co-firing is co-combustion of biomass in existing power plants with conventional fuels, mainly coal but also with peat, upgraded urban waste fractions (=RDF) and other fuels. This technology allows for conversion of energy in biomass to be more efficient, in the range of 33-37 % and offers a moderately low-cost and low-risk way for power plant managers to add biomass capacity [IEA 2003a].

Combustion of landfill gas, i.e. landfill gas recovery (LGF), has the benefit of converting, what would due to methane content otherwise be a significant source of greenhouse gas emissions, to less harmful CO_2. Landfill gas can be burnt as fuel by reciprocating engines or small gas turbines, internal combustion engines are the most common technology used [Bla 2003]. In the UK, the use of landfill gas is wide-spread and the technology is fully commercial. Landfill gas is also recovered in Germany and to a lesser extent elsewhere in Europe [EUR 2000].

4.2.4.2 Gasification

Gasification is described as the process of converting the organic fraction of biomass at higher temperatures and with existence of air, into a gas mixture, which has fuel value and more variation than the original solid biomass. This gas can be burnt to produce process heat and steam, used in internal combustion engines or gas turbines to produce electricity, as well as a transport fuel [Eur 2002]. The production of the electricity via gas turbines combined with steam cycles is the most effective and economical use of the gaseous product [Ver 2002].

Several biomass gasification processes are developed or under development for electricity generation, that offer advantages over direct burning like higher efficiency and cleaner emissions. Gasification systems are currently at demonstration stage, and the development of these efficient systems for electricity production is essential: BIGCC (biomass integrated gasification and combined cycle) and BIG-STIG (biogas integrated gasification steam injected gas turbine) plants can achieve efficiencies of 42–47%. Significant developments have been made over the past fifteen years in the field of biomass gasification, especially in the area of medium- to large-scale electricity production [Mor 2003]. Gas cleaning to improve the quality of gas is a crucial issue in both combustion and gasification systems, and measures needed are, e.g. reduction of emissions and removing of particulates and tars [EUR 2000].

4.2.4.3 Pyrolysis

Pyrolysis is the process of decomposition at elevated temperatures (300–700 °C) in the absence of oxygen, and the products of pyrolysis are solids (char, charcoal), liquids (pyrolysis oils) or a mix of combustible gases. Production of pyrolysis oils has received attention in recent years because they are easier to handle and they have a much higher energy density than solid biomass. Mostly charcoal is produced (through slow pyrolysis), but pyrolysis liquids (or bio-oils) can be obtained through a fast or flash pyrolysis at moderate reaction

[43] The low share is due to the large share of available nuclear and hydropower in Sweden

temperatures, and oil yields can be up to 80% by weight. These bio-oils can be substituted for fuel oil in direct combustion in boilers, engines or turbines for heat and electricity generation [Eur 2002, IEA 2003a].

The main advantage of fast pyrolysis is that fuel production is separated from power generation. Flash pyrolysis is still at demonstration scale. Bio-oil upgrading processes, which are needed to overcome unwanted features, e.g. corrosivity and poor heating value, are at much earlier development stages. Pyrolysis processes can be of interest in conjunction with existing systems for large-scale electricity production.

4.2.4.4 Anaerobic digestion

Anaerobic digestion (AD), as a biological process by which organic wastes are converted to biogas (i.e. a 40–75 % mixture of methane and carbon dioxide) in the absence of air, is a well-developed technology for waste treatment. During AD typically 30 to 60 % of the input solids are converted to biogas and it can be used to generate heat and electricity using e.g. otto (gas) or dual fuel diesel engines, gas turbines or fuel cells at capacities of up to 10 MW_e. Most of the biogas resources come from landfills or when treating municipal wastewater, but AD can be used also for biogas production from e.g. animal manure [Eur 2002, IEA 2003a].

Anaerobic digestion has several environmental benefits. It can for instance prevent groundwater contamination when anaerobic digesters provide reliable treatment systems for organic wastes and manure, remove odour problems and decrease methane emissions from atmospheric decomposition of manure [Bla 2003].

Larger digesters treating MSW and other residues have been built in Denmark, Italy, France, Germany and Belgium with numerous industrial and farm-based digesters dotted around Europe [EUR 2000].

4.2.4.5 Development of conversion technologies

Other new technologies in addition to gasification of biomass are Stirling engines and organic Rankine cycles (ORC), but they have not yet become technically efficient or economically feasible [Kir 2004]. Overall, different biomass conversion technologies are in development, and they are characterized by conversion efficiency and a factor of capital cost. Large R&TD programmes are being carried out and their focus is both on the economic and on technical feasibility [Sie 2004], with main tasks in the field of co-combustion [Ver 2002]. Technical problems of emerging technologies (e.g. gasification and advanced combustion) and promising technologies, e.g. pyrolysis, should be addressed through for instance standardised solid biofuels, agro-residues and energy crops as well as gas cleaning and bio-oil refining, thus further minimising environmental impacts [IEA 2003a].

4.3 Background of the RES-E and bioenergy legislation

Early evaluation of the implementation of the White Paper objectives showed that RES overall made little progress between 1997 and 2000, but experienced a significant boost in certain countries and specific sectors. It was concluded that biomass had not been given enough attention despite its immense potential and available technologies [EC 2001].

The Campaign for Take-Off (CTO), as one of the community support programmes for RES between 1999-2003, set objectives for the end of year 2003 for biomass: 10,000 MW_{th} generated by cogeneration installations from biomass, 1 million homes heated by biomass, 1000 MW_e generated by biogas installations and 5 million tons of liquid biofuels consumed annually [EC 1999]. Biomass is obviously lagging behind the stated objectives, although it should be noted that the EU Directives likely to promote the use of biomass were adopted just recently. After the CTO, the programme called "Intelligent Energy – Europe" has taken place and it is setting objectives for the period 2003-2006. According to its work programme, RES electricity is one of the vertical key actions [IEE 2003].

The EU legislation concerning bioenergy and bioelectricity consists of two key Directives: Directives on electricity generated from renewable energy sources [EU 2001] and on biofuels [EC 2003]. In addition to the RES-E Directive, the "biofuel Directive" or the Directive on the promotion of the use of biofuels or other renewable fuels for transport is another example of transforming the White Paper objectives into concrete efforts. According to this Directive, an increase of the market share of biofuels to 2 % should be achieved by the end of 2005 and 5.75 % market share by the end of 2010. Directive of co-generation [EU 2004], "the revised electricity market Directive" [EU 2003c] as well as Directive on structuring energy products and electricity taxation [EU 2003d] are all contributing to the development of bioenergy.

Target setting is an important policy instrument and is seen as the foundation on which other RES policies are built. The European Conference for Renewable Energy – Intelligent Policy Options in January 2004 stated that the target value of at least 20 % of gross inland energy consumption by 2020 for the EU is feasible [Ber 2004]. According to the EREC projections, biomass could contribute with a share of 24 % to RES electricity generation in 2020 in EU-15, its share being approximately 9% in 2001 [Ere 2004a]. An acceleration of the implementation of renewable energy policy is necessary in order to reach the targets set for 2010 this includes the creation of a level-playing field as well as the tackling of administrative and grid-access barriers, through the strict enforcement of regulatory frameworks at local, national and international levels.

Member States' (EU-15) national targets adopted in 2002 were consistent with the objective of the RES-E Directive. The Commission's recent report however indicates that practical measures Member States have put in place so far are estimated to deliver a share of green electricity of only 18-19% (EC 2004a). New Member States adopted the green electricity directive just recently. Their national targets were set in the Accession Treaty and the total renewable electricity target for the enlarged European Union is 21 % of total electricity consumption by 2010 [EU 2003e].

4.4 Bioelectricity support policies in the EU-25

To encourage the development and investments in the production of renewable electricity, there are several policy instruments and support mechanisms in use in Member States. The RES-E Directive does not indicate which kind of policy measures would be favourable, due to which Member States continue to develop their own national mix of policy instruments to stimulate renewable electricity [Vri 2003] at least until the end of 2005, when a common mechanism for RES-E support might be suggested by the Commission. All Member States of EU-15 have implemented policy instruments to support the use of biomass. At least eight of them have set national targets for its use [Pre 2002], though only a few have indicative targets for production of electricity specifically from biomass. National schemes should evolve towards convergence for the single liberalized electricity market in 2007 [Ere 2004a].

4.4.1 Bioelectricity support schemes in the EU

The dominating support mechanisms or schemes for bioelectricity (if not stated otherwise), are listed in Table A.1 in the Annex. Support mechanisms here principally refer to economic support mechanisms and do not include other policy instruments such as research and development, targets or environmental programs. As seen from the table, majority of Member States have at least partial feed-in tariff schemes promoting electricity from biomass whilst four have adopted the combination of green certificates and obligation quota system. Poland and Latvia are the only countries which do not apply green certificate systems that support their quota. Ireland has developed a tendering/bidding scheme as the main instrument and Finland with its energy tax refund complemented with investment subsidy is a unique example of its promotion scheme in the EU.

Feed-in tariffs are in place as a dominating instrument in eighteen Member States (18/25)[44], and their current tariff margins can be seen in Table 4.5 (further details see Table Table A.1 in the Annex). Most of these countries have a technology specific payment for RES and at least a short-term guarantee for payment. The degree of support might generally not be high enough to stimulate bioelectricity production in these countries[45]. It has to be noted that all EU-15 states have at least so called weak feed-in laws although there are no prices set. This is because of the RES-E Directive and it's Article 7 [IEE 2003]. Although feed-in tariffs are widely in use throughout the Member States, the mechanisms of these schemes vary significantly. As seen from Table 4.5 bioelectricity prices alone differ greatly between countries, and tariffs depend on issues such as: date of start-up, source of electricity or the type of technology, size of facility or a time of generation. The key issues especially in the case of new Member States are that the prices do not adequately cover the costs and guarantee period is too short to ensure price security for investors [WWF 2004].

There is evidence that those countries which have chosen to implement stable, long-term feed-in tariffs also have the highest RE deployment rates [IEA 2002b]. Quoted more than once as an excellent example for providing a strong incentive for renewable electricity, the feed-in law in Germany has supported bio-power since 2000. At present, fairly high feed-in tariffs are combined with reasonable investment subsidies and exemption from environmental tax, and these have generated a considerable RES market in Germany [EC 2004a].

Biomass use in power stations is also said to be benefiting from feed-in laws, although the use of biomass has essentially increased in Finland and Sweden even without this measure. It has to be noted that in Finland this has occurred even without governmental support measures because of the cheap price of wood waste in electricity production[46]. This clearly shows that biomass development is coupled with other success factors, such as availability of financial support, because biomass installations still generally need capital subsidy to be financially feasible[47] [EEA 2001]. In these two countries heavy taxation of competing fossil fuels, electricity taxes and quota-based system (in Sweden) are seen to be the most effective policy instruments promoting bioenergy, and their experience may direct the way also for other EU countries [Eri 2004].

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44 In Belgium the system of feed-in tariffs exist in addition to a green certificate scheme.

45 This is based on the evaluation of the degree and duration of support in EU-15 states (EC 2004b). For new Member States favourability of payment is assessed based on personal communication with national experts as well as a combination of certain level of tariffs and the guarantee. However, for instance according to Spanish Renewable Energy Association assessments [App 2004], feed-in tariffs in Spain are far from the 8.5 € cents/kWh necessary to ensure profitable investments in biomass.

46 On the contrary Finland's case is an example of favourable development without promotion measures from government

47 With exceptions, like Finland

Table 4.5 Feed-in tariffs in the EU countries for bioelectricity [source: EC 2004a, Rei 2003 & 2004, Vri 2003, WWF 2004, App 2004 and other national RES-E law documents, personal communication].

Country	Tariff margin € cents/kWh [1]	Technology specific payment [2]	Guarantee [3]	Favourable payment [4]
Austria	3,0-16,5	X	X	X
Belgium	2.0-2.5	X	X	(X)
Denmark	1,0-4,0	X	X	
Finland	No feed-in tariff			
France	3,5-5,5	X	X	(X)
Germany	6,6-9,9	X	X	X
Greece	7,0-7,8		-	(X)
Ireland	No feed-in tariff			
Italy	No feed-in tariff			
Luxembourg	2,5	X	X	
Netherlands	2,9-8,2	X	X	X
Portugal	6,2	X	-	
Spain	6,7-7,1	X	X	
Sweden	No feed-in tariff			
United Kingdom	No feed-in tariff			
Cyprus	6,3	X	-	-
Czech Republic	6,2-7,7	X		(X)
Estonia	(4,9-) 5,2		X	
Hungary	7,3		X	(X)
Latvia	5,0-5,9	X	X	(X)
Lithuania	5,7-5,8	X		
Malta	No feed-in tariff			
Poland	No feed-in tariff			
Slovak Republic	3,0-3,5			
Slovenia	6,8-7,0	X	X	(X)

[1)] Tariff margin includes the price variation for bioelectricity inside the country and in some cases variation based on different sources (e.g. Belgium, Estonia), not including premiums

[2)] Technology specific among other RES

[3)] Guarantee does not necessarily mean long-term security

[4)] Favourable payment i.e. is the degree of the support considered high enough to stimulate bioelectricity (cost-covering), (X) = probably favourable

– data not available

Industrial policies can have a great influence on the use of biomass and the production of bioelectricity. Black liquor and other concentrated liquors originating from the pulp and paper industry[48] in Finland contribute considerably to the consumption of renewables, 42 % in 2001 [Sta 2002] and solid biomass accounted for 11% total electricity production in the same year [IEA 2003b]. This source of biomass has a significant potential also elsewhere, e.g. in

48 included in the category of solid biomass according to IEA definitions

Germany. When comparing the pulp and paper production as well as the electricity production from solid biomass in these two countries (see Fig. 4.9), we can see that there is a large unexploited potential in Germany to use black liquor as an energy source[49] [EUR 2003a, IEA 2003b]. In Europe, Finland and Sweden are leading the energy use of industrial black liquors (135 PJ/a and 125 PJ/a, respectively), this resource reported as zero in Germany [Ves 2001].

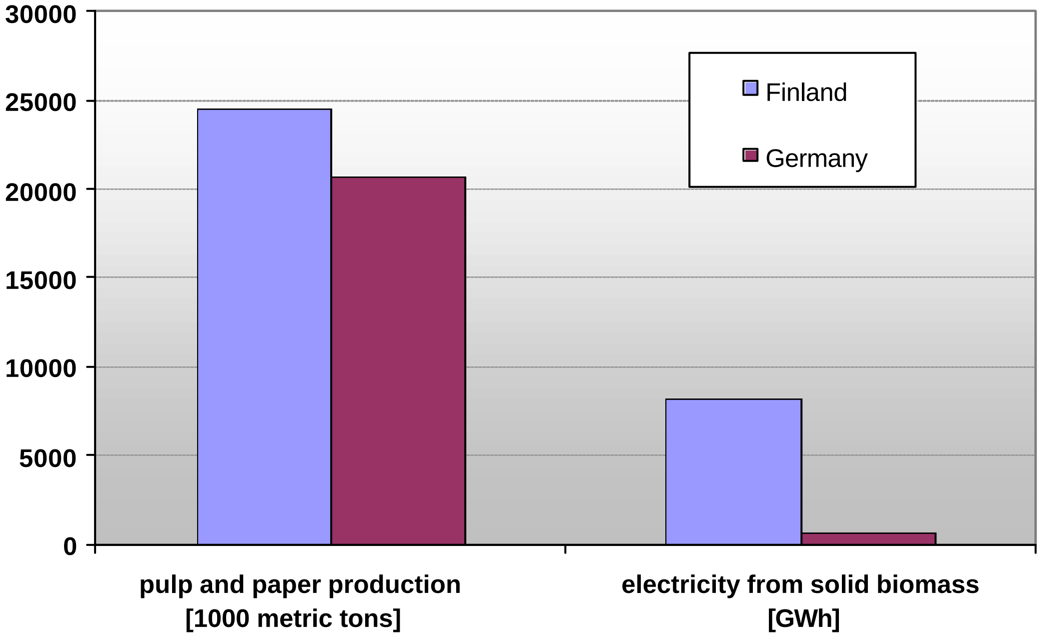


Fig. 4.9: Comparison between pulp and paper production and electricity from solid biomass in Finland and Germany shows a large unused energy potential for industrial biowastes in Germany [EUR 2003a, IEA 2003b].

Power generation is not the primary focus for sectors outside the energy industry. However, other industrial candidates for power production from biomass in addition to the pulp and paper industry or other forest product industries are municipal wastewater treatment plants (biogas recovery) as well as district heating by biomass and landfills (biogas) [Bla 2003].

Effective use of biomass for energy purposes depends not only on market developments but also on a successful integration of energy, environment and in particular agricultural and forestry policies as well as waste, industry, rural development and trade policies. Bioelectricity promotion schemes must thus take these into account [EC 2004a, Bau 2004].

4.4.2 Effectiveness and cost of policy support for bioelectricity

Member States face the challenge of encouraging technology progress and market growth while reducing the costs of policy support for renewables. This can be achieved by directing renewables to those markets in which they are the most cost-effective, so as to say to their most competitive niches. Bioelectricity can be competitive especially where biomass resources are abundant, pre-treatment requirements are moderate and bioelectricity is produced in plants with proven conversion technologies and concepts, e.g. co-firing or CHP [IEA 2003a].

[49] It has to be noted that this comparison is only suggestive since there is no exact information on black liquor energy use from Germany.

A Czech study raises an important question in terms of subsidy schemes for renewable energy sources and whether it is more efficient to support the use of biomass primarily for heat production or for combined heat and power generation instead of for electricity production only. Effectiveness refers here to the relation of economic efficiency and environmental effects: CO_2 reductions might be achieved at the same level and with lower costs via biomass co-firing compared to electricity production only [Kna 2004].

The overall efficiency of any type of biomass power plant is essentially increased if the heat produced is also used [EUR 2000]. The Directive 2004/8/EC on the promotion of cogeneration states, that good quality cogeneration of heat and power (CHP) saves at least 10% of primary energy consumption compared to separate production [EU 2004]. Average savings in primary energy are likely to be in the region of 20-25% [EC 2004], leading also to larger CO_2 emissions reductions than in separate production of heat and power.

In many cases incentives for bioelectricity have not promoted the most efficient solution, as most existing plants have electrical efficiencies between 15-25%. It is estimated that in order to electricity from biomass to become widespread, it may need support of 10 – 40 €/MWh [Bau 2004].

4.4.3 Support for biomass feedstock

Support for biomass feedstock supply is fundamental to the development of bioenergy industry. In the EU-15 around 8 % of arable land was categorised as set-aside land and not used for food production in 2001 (Fig. 4.10) [EUR 2002, Bau 2004]. The share of 16% of set-aside land was dedicated to non-food crops, mostly aimed at the production of biofuels [Bau 2004]. If assumed that only 10% of the total arable land in the Member States will be set-aside land in the coming decades, the total estimated set-aside land in the EU-25 would total 9.8 Mha [FAO 2004, Gan 2004]. Presuming further that half of the set-aside land is dedicated to energy crops (4.9 Mha), energy potential of these crops would be 706 PJ or 17 Mtoe annually[50] [Gan 2004].

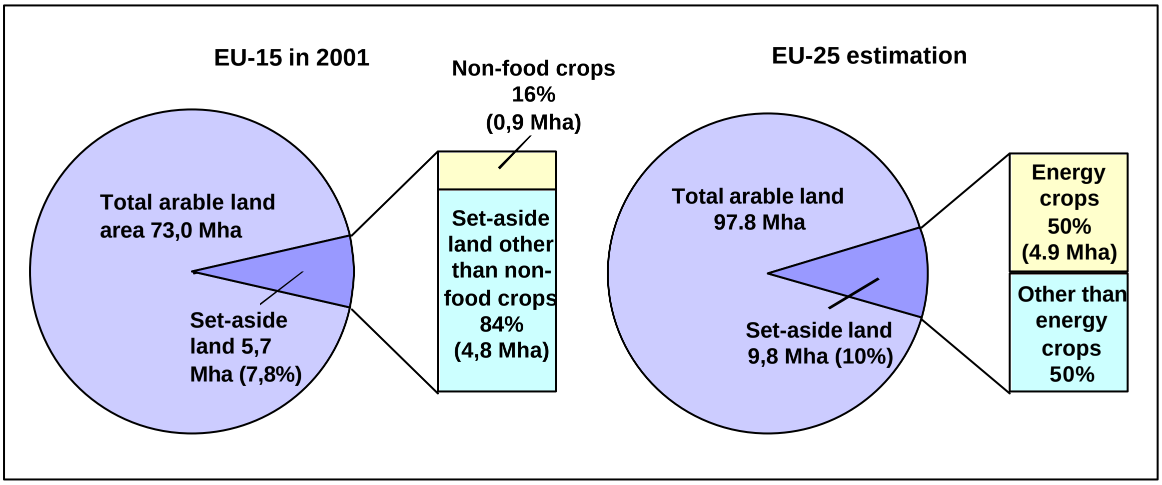


Fig. 4.10: Arable land and set-aside land in EU-15 in 2001 and the estimation for energy crop production in EU-25 [EUR 2002, Bau 2004, FAO 2004, Gan 2004].

50 estimated energy crop yield 8 tons dry matter/ha/year

The Common Agricultural Policy (CAP) has been revised[51] and the latest CAP reform introduces several measures for the development of non-food crops. An area-based energy crop payment of 45 €/ha was introduced (not crop specific), which became available from the beginning of 2004[52] [EU 2003f], and it can provide an attractive incentive on a cultivated area basis. However, there has to be sufficient pull from elsewhere in the bioelectricity supply chain in order to stimulate energy crop production [Bau 2004, EC 2004]. For comparison, assuming that all the annual energy potential of future set-aside land in the EU-25 could be used for electricity production, the electricity price can be calculated to be around 0.11 € cents/kWh based on the area-based energy crop payment of 45 €/ha.

4.4.4 Assessment of support policies

As previously stated, biomass has the principal share of electricity produced by all renewables alongside hydro power and is seen as one of the most important means to reach the targets. The use of biomass is estimated to grow provided that the policy ambition level increases. Biomass fired CHPs and co-fired facilities are envisioned to benefit more from the introduction of a green certificate system than other biomass technologies. The largest increase in this case is expected to be in agricultural and forestry residues [Uyt 2003].

The ADMIRE REBUS tool, which has been created to analyse the development of the European renewable electricity market under different policy scenarios, demonstrates that ambition level of national governments and the Commission will be one of the key factors determining the deployment of RES-E and that the countries should apply a combination of several strategies. Another study suggests that regardless of which strategy is chosen, the basic criteria for success should apply at least a clearly defined time horizon and predictability as well as enhancement of competition between generators [Haa 2003].

4.5 Bioelectricity economics and competitiveness

Bioelectricity can be considered to be more expensive than other electricity from renewable sources, but can compete with electricity from conventional sources especially if environmental costs are taken into account [Bau 2004]. However, wood waste can be competitive even compared to old large-scale hydro power in some cases. It should be noted also that different technologies serve different markets and depend on varying situations. Biomass supplies a wide range of applications from baseload to peak demand of electricity.

4.5.1 Bioelectricity costs

Considering electricity from biomass, the cost of bioelectricity depends on the biomass feedstock price, the power generation technology as well as the scale of operation, the investment of the power plant and the extent to which retrofit is possible, e.g. in the case of co-firing with fossil fuel. Table 4.6 shows the principal technologies for bioelectricity and competing options with their efficiencies. Current costs of biopower from new dedicated combustion plants vary between 60-120 €/MWh (=6-12 € cents/kWh). CHP plants using MSW are estimated to have costs as low as 30 €/MWh, though wood-burning CHP plants in Finland have already generated electricity at lower prices than that, e.g. 12 €/MWh in 1998

[51] adopted in 26 June 2003
[52] different elements of the reform will enter into force in 2004 and in 2005

[Jyv 1999]. Estimations of future bioelectricity costs from dedicated plants using energy crops are in the range of 50-60 €/MWh [Bau 2004].

Table 4.6 Capital costs and efficiencies of the main bioelectricity and competing conversion technologies [Bau 2004].

Technology	Capital costs in 2002 (€/kW$_e$)	Electrical efficiency (%)
Existing coal – co-firing	250	35-40
Existing coal and natural gas combined cycle - parallel firing	700	35-40
Grate/fluifised bed boiler + steam turbine[1]	1500-2500	20-40
Gasification +diesel engine or gas turbine (50 kW$_e$ - 30 MW$_e$)[1]	1500-2500	20-30
Gasification +combined cycle (3 - 100 MW$_e$)	5000-6000	40-50
Wet biomass digestion + engine or turbine	2000-5000	25-35
Landfill gas + engine or turbine	1000-1200	25-35
Pulverized coal - 500 MW$_e$	1300	34-40
Natural gas combined cycle - 500 MW$_e$	500	50-55

1) smaller scale systems will be characterised by higher costs and lower efficiencies indicated in the value ranges where as larger scale systems will be characterised by lower costs and higher efficiencies indicated in the value ranges

The IEA estimates bioelectricity generation costs to range between 1.6-9.8 € cents/kWh in 2010 (Table 4.7) [IEA 2003a]. The study of European Bioenergy Networks (EUBIONET) has showed that wood fuel prices in Finland, Sweden and Denmark averaged 1.2 € cents/kWh in 2002 Finland boasts the lowest prices being in of 0.7 € cents/kWh [Ala 2003].

Investment costs can vary considerably, for instance co-firing investment levels are site specific and are affected by the available space for storing biomass feedstocks amongst others. The range of present and future investment costs can be seen in Table 4.7.

Feedstock costs differ depending on the type of biomass, pre-processing prior to the use in power plant and transportation distance. The most economical condition occurs when the energy is consumed near or at the place of production. Wastes are generally available at negative or low cost, whereas dedicated energy crops will incur the highest costs [Bau 2004].

Table 4.7 Ranges of investment and generation costs for bioelectricity in 2002 and 2010 [IEA 2003a].

Low investment costs [€/kW]		High investment costs [€/kW]		Low generation costs [€ cents/kWh]		High generation costs [€ cents/kWh]	
2002	2010	2002	2010	2002	2010	2002	2010
410	330	3250	2440	1,6-2,4	1,6	8,1-12,2	6,5-9,8

Note: Discount rate is 6% and amortisation period is 15-25 years
(calculated from USD with a rate of 1€ = 1.23 USD)

4.5.2 Cost reduction opportunities

Example of feedstock cost reduction in the case of energy crops is that their price currently being around 4.4–5.4 €/GJ[53] in the EU-25 (plus Bulgaria and Romania) [Sie 2004] would have cost reduction potentials possibly as low as 2–2.5 €/GJ under good crop management and fuel supply logistics conditions [Bau 2004]. Biomass feedstock costs can further be lowered through improvements in yields. As a comparison, most residues in the EU-25 are estimated to be available at the cost of 1.6–2.5 €/GJ[54] [Sie 2004], whereas coal import price for OECD countries is approximately 1.6 €/GJ and natural gas import prices 1.5–3 €/GJ [Bau 2004].

Cost reduction opportunities in bioelectricity costs are typically achieved through improvements in technology. However, it is difficult to determine precisely bioelectricity costs and price reductions due great diversity of technologies, conversion processes, fuel types and system designs let alone industrial patterns and local climate. In addition to changes in plant technology, improving fuel supply and its chain are fundamental ways to increase the efficiency and cost-competitiveness of biopower [IEA 2003a].

Co-firing has low generation costs compared to higher generation costs of gasification plants [IEA 2003a]. Typically, lower costs result in landfill gas and co-firing applications, when large quantities of biomass can be supplied to existing coal plants. The economic viability of bioelectricity could be achieved by technologies such as combined heat and power (CHP) through higher efficiency and gasification technology that offer cost reduction potential [Ere 2004].

4.5.3 Experiences and prospects for bioelectricity

The upper limit for the bioelectricity plant generally ranges from 30 to 100 MW, mostly depending on geographical context as well as on biomass fuel sources [IEA 2003a]. There are, however, already bigger plants available and the concept is proved to be working. The largest biomass-fired plant in the world commenced operation in Finland in 2002: Alholmens Kraft has an electricity power output of 240 MW_e and uses wood-based biofuels (45%), peat (45%) and coal as a reserve fuel (10%) [Nic 2002].

Reasons for Nordic Member States to become main producers and exporters of equipment and services for bioelectricity generation are multiple: in addition to their vast domestic fuel supply and national policies favouring bioenergy, their timber, pulp and paper industries have strong market positions. The access to low-cost biomass supplies enhances power producers' competitiveness in the market (as seen e.g. in Finland), and especially in the short term when co-firing biomass with coal.

Large-scale use of biomass for district heating as well as abundant supply of forest residues and recycled wood with the control on waste and energy in Northern Europe has changed the pattern of using biomass in the same region in which they are produced. Bioenergy trade has expanded rapidly during the past ten years and consists of various types of wood materials and other substances. Traded biomass includes mostly refined wood fuels (pellets and briquettes), industrial by-products (sawdust, bark and chips) and wood waste [Ves 2001].

Inside Europe largest amounts of biomass are traded from the Baltic countries (Estonia, Latvia, Lithuania) to the Nordic countries (Sweden, Denmark and Finland) and some biomass

[53] 1 GJ = 0.278 MWh

[54] Referring here to average supply costs (delivered to end-user) of solid industrial residues. The costs of dry agricultural residues vary from 2.1 to 3.0 €/GJ.

volumes are also traded intercontinentally. The estimated amount of total volumes in the international biomass trade is at least 50 PJ. However, national biomass market is generally not yet developed well enough for organised international trade.

The electricity market has changed considerably in the last ten years, leading to the reform of the energy sector to complete the internal electricity market and increasing competition reducing electricity prices. In the near future (2005) the European Emissions Trading Scheme (EU ETS) will be adopted and will create CO_2 emission allowances as a new commodity. This is expected to give additional incentives for bioelectricity production and to offer further opportunities for bioenergy development in addition to national implementation schemes (see chapter 2.1.3) [Ere 2004, Ott 2003].

4.6 Barriers and success factors for implementation

The availability and continuous subsidy of fossil resources are considered major obstacles to the deployment of RES in Member States. On the other hand, phasing out the utilisation of nuclear power and dependence on the external supplies of fossil energy sources as well as energy intensive industry can function as promoters of RES [Rei 2003].

4.6.1 Bioelectricity barriers

In general biomass faces the same barriers as other sources of renewable electricity, two of the most critical being grid access and administrative procedures. Insufficient and inadequate support systems as well as the lack of integration of various biomass-related policies are hindering growth for their own part. In order to enhance biomass energy use, support schemes and policy refinements should be improved to take into account biomass potentials at regional and national levels [EC 2004]. The main barriers for increasing the electricity production from biomass in OECD are more commercial and policy related rather than technological barriers [Bau 2004].

As the ATLAS study[55] indicated in 1996/1997, the market barriers for electricity from biomass can be categorised more specifically into informative, risk and financial obstacles as well as environmental and legislative barriers. There still seems to be a lack of knowledge andappreciation by decision makers and the general public of the the use and benefits of biomass for electricity especially outside Nordic countries. Political or public support is fairly low and therefore financial support is also generally low [Atl 1997].

Uncertainties related to the supply of biomass are included in the barriers specifically for bioelectricity. The large capital investments do not occur unless there is a proof of reliable long-term income to attract private investors and presently biomass use is based on industrial by-products and wastes which build up only slowly. Uncertainty of future energy politics is seen by decision makers as a great risk: the risk for investor is that incentives can change before the investment has paid off. The limited guarantee periods particularly in new Member States do not ensure the price security for investors [WWF 2004]. Incentives are not coordinated between countries and experiences of advantages and problems related to different support schemes are not shared between states.

Bioenergy is not environmentally friendly by definition alone, and the use of appropriate technology is crucial to keep the emissions low. The use of biomass results in several

55 The project under the European Commission's 4th Framework Programme for Research and Technological Development (RTD)

environmental benefits on a local level. Energy crops can have increased biodiversity compared to arable or pasture land and create recreational habitats. Sustainable use of biomass reduces CO_2 emissions and this will act as an added marketing value, most importantly in the coming EU ETS.

In addition to complex and long-lasting administrative procedures generally hindering renewable electricity development, there are many legislative problems affecting biomass, agricultural and forestry sectors, several of them related to CAP. It should be further developed and made flexible for supporting biomass for energy generation, including norms for the use of set aside land and agricultural and forest residues for energy. There is a need for an EU wide forestry policy. Consistent policies and continuity of incentives are necessary to secure a long-term market to guarantee return on investment, as well as technology development and demonstration projects.

As already highlighted, co-operation forms between different fields related to biomass need to be developed more efficiently. Energy crops are taken into account in the newest reform of the Common Agricultural Policy, but the whole bioelectricity supply chain has to work together in order to boost energy crop production more widely. Major EU policy adjustments, which would include energy crops to be in balance with food crop policy, might be required to make energy crop production competitive.

Technical hurdles for bioelectricity can be insufficient technological development and complicated conditions for the connection to the grid [Rei 2003]. For energy crops current problems are associated with the cost of production and difficulties in harvesting and storing. There are few technical barriers to building biomass-fired facilities at any scale: in addition to availability and cost of the fuel supply, areas of concern are lower capacity and generating efficiency compared to fossil fuel systems as well as problems related to multi-fuel options. Main objectives for gas producing technologies (anaerobic digestion, pyrolysis and gasification) have been to improve the gas quality by reducing tars and to handle ash as well as to improve stability and reliability of gas production [EUR 2000].

Competing uses of biomass resources are typically constraining the expansion of bioelectricity production. Specifically limiting the biogas resource potential is the EU Directive on waste deposits, which limits organic wastes in landfills to 25 % by 2010.

4.6.2 Success factors

There are several success stories that demonstrate how to overcome the barriers for renewables. Examples have proven that when the right mix of policies and measures was set up, renewables developed successfully. Proactive governmental support linked to subsidy schemes and communication strategies, introduction of carbon and energy taxes and considerable research and development support are mentioned as key success factors [EEA 2002].

There are large variations between EU-15 states in relation to RE technology breakthroughs: e.g. Finland and Sweden contribute 60 % of new generation from biomass-fuelled power plants. As a result of the European Environment Agency study [EEA 2001] it can be concluded that no single factor but rather the cumulative benefits of a series of supportive measures were discovered to be responsible for success of RES deployment. These measures include e.g. long-established RES policies and administrative support especially on local and regional levels, feed-in laws or other financial support mechanisms as well as the support of all renewable technology stages and increasing public acceptability at local level.

It is seen that financial incentives for renewables do not alone substantially help RE development especially in the new Member States. The most essential incentives for the development of RES are likely to be political stability and the general economic condition of a country. As seen from the study of the European Bank for Reconstruction and Development, one of the best ways to overcome barriers is to develop, finance and build demonstration projects that simultaneously lead to positive environmental, economic and socio-economic benefits [Bla 2003].

4.6.3 Future outlook

In evaluating renewable biomass in the enlarged European Union, it is clear that biomass enjoys a leading role in reaching the renewable electricity targets. The use of biomass in energy purposes varies greatly between the Member States, especially following enlargement. New Member States are expected to be the largest biomass suppliers in the EU-25, while EU-15 countries can offer advanced and efficient technology and know-how [Gan 2004].

There is a vast potential to increase bioenergy and notably bioelectricity production throughout the EU. However, a lack of estimating better future availability of land resources excists, especially in the case of energy crops. Agricultural overproduction, large share of arable land as well as possibility to increase crop yield offer opportunities for energy crops production, particularly in new Member States [Gan 2004]. Adequate financial incentives in the agriculture are needed in order to implement energy crop production on a large scale, also in the case of EU-15 Member States.

Barriers for bioenergy development are complex and require a comprehensive approach as well as cooperation among all Member States. Efficient support schemes need to be put in place to promote bioenergy projects and barriers have to be removed so that biomass can fulfil expectations given to it.

CHAPTER 5

WIND ENERGY

Arnulf Jäger-Waldau

Amongst the three discussed renewable energy sources, Wind Power is the most mature and cost competitive one. The European Wind Energy Association[56] (EWEA) provides quite a lot of up to date data about the status of wind technology developments, the European wind industry and installed wind turbine capacities.

5.1 Resources

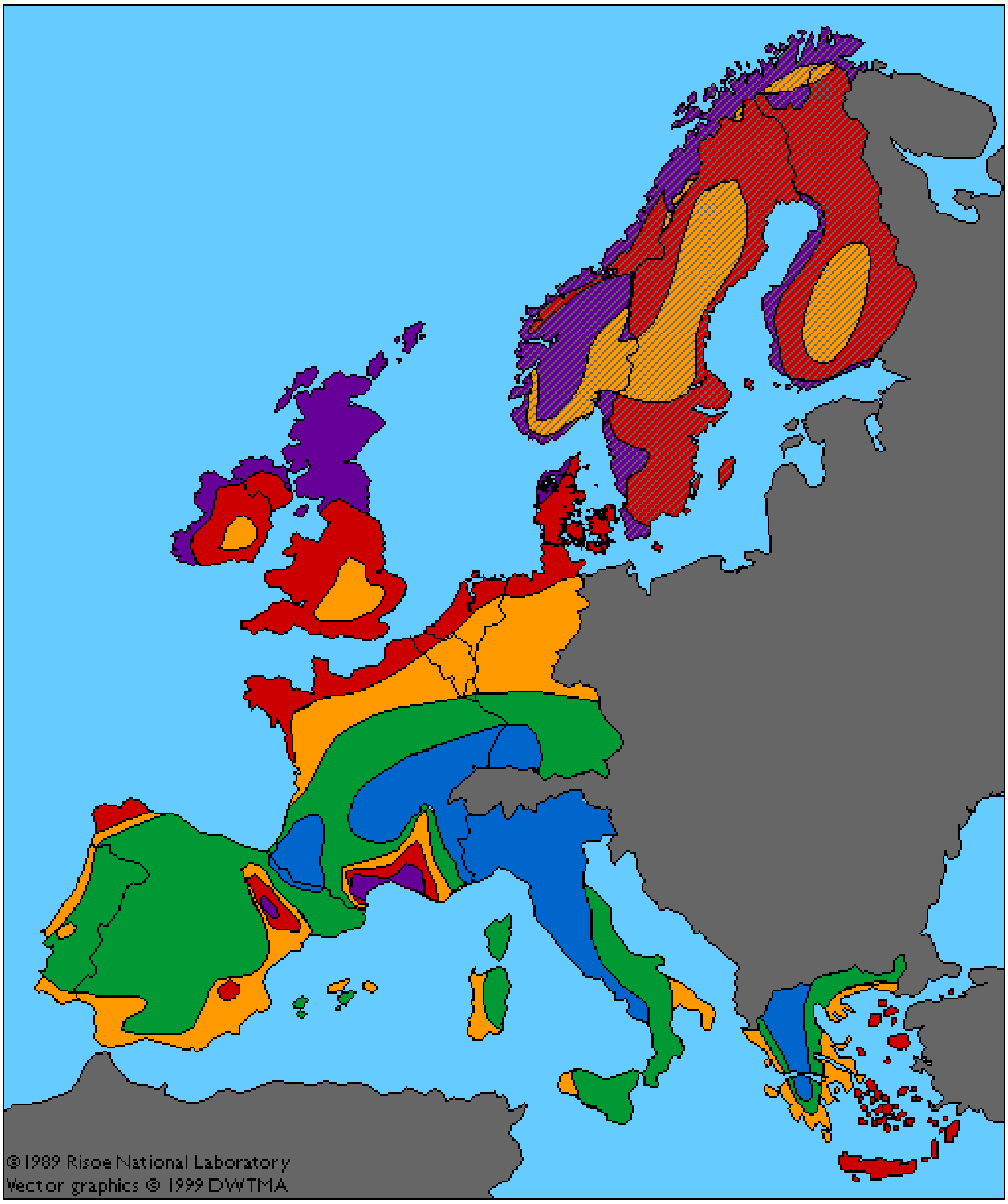
Wind energy is a significant and powerful renewable energy resource. The resources are plentiful, globally speaking more or less equally distributed and offer both – decentralised and centralised (mainly off-shore) – power generation. Several resource assessments have been carried out by various institutions. One important tool to conduct these assessments are wind resource maps, which indicate the different average annual wind speeds. Figure 5.1 shows the EU15 wind resource map. Despite the fact, that wind resource maps are already available for some of the New Member States a complete map for the whole of Europe is still missing.

The general methodology used in such studies is to assess the area of land available with average annual wind speeds of more than 5–5.5 metres per second at a height of ten metres above ground level. At such average wind speeds it is considered feasible to utilise wind power cost effectively at current generation costs. In order to account for constraints of land use such as high population density, infrastructure etc., the total available land resource is reduced by 90% or more. At the end of this process one can calculate how many TWh of Electricity could be generated using "state of the art" performance of commercially available turbines.

Though this type of resource assessment is rather conservative, it should be noted that it remains a "theoretical" potential and generally only takes into account socio-economic limitations such as public perception of wind turbines. Nevertheless, wind resource maps are a valuable tool to show that technical resource availability is unlikely to be a limiting factor for the utilisation of wind energy for electricity production. One study cited by EWEA estimates the world's wind resources to be 53,000 TWh with 4,800 TWh in Western Europe and 10,600 TWh in Eastern Europe including the former Soviet Union [Gru 1993]. The IEA predicts an increase of electricity consumption worldwide of 2.4% until 2030 [IEA 2003], which would correspond to a world wide electricity demand of 31,000 TWh in 2030 or 58.4% of the estimated wind energy resources.

In comparison, a study carried out by the University of Utrecht in 1993 [Wij 1993] had a very restrictive approach predicting around 550 TWh "exploitable onshore resources" for EU15. The reason for this approach was to take into account Europe's high population density and large infrastructure elements such as roads, airports and railways. However, it has to be noted, that this study was carried out when the average size of a new wind turbine ranged from 250 to 300 kW.

[56] European Wind Energy Association, www.ewea.org



Wind resources at 50 meters above ground level for five different topographic conditions:
1) Sheltered terrain, 2) Open plain, 3) At a coast, 4) Open sea and 5) Hills and ridges.

	m/s	W/m^2	m/s	W/m^2	m/s	W/m^2	m/s	W/m^2	m/s	W/m^2
	>6.0	>250	>7.5	>500	>8.5	>700	>9.0	>800	>11.5	>1800
	5.0-6.0	150-250	6.5-7.5	300-500	7.0-8.5	400-700	8.0-9.0	600-800	10.0-11.5	1200-1800
	4.5-5.0	100-150	5.5-6.5	200-300	6.0-7.0	250-400	7.0-8.0	400-600	8.5-10.0	700-1200
	3.5-4.5	50-100	4.5-5.5	100-200	5.0-6.0	150-250	5.5-7.0	200-400	7.0-8.5	400-700
	<3.5	<50	<4.5	<100	<5.0	<150	<5.5	<200	<7.0	<400
			>7.5							
			5.5-7.5							
			<5.5							

Fig. 5.1: European Wind resource map © Risø National Laboratory (Vector graphics map by courtesy of the Danish Wind Turbine Manufacturers Association)

In 2003 the average size of newly installed wind turbines was 1.2 MW, which means that today's "state of the art" is much more advanced and hence new calculations are necessary. In the 1993 University of Utrecht study the technical potential of Germany was stated as 24 TWh. In comparison, Kaltschmitt and Wiese made an analysis for the onshore potential of Germany under the assumption that if 1.2 MW wind turbines were to be used and a total capacity of 87.9 GW to be installed, the potential would total 128 TWh [Kal 1995]. However, whilst the later study is too conservative in number of availability hours it does not sufficiently take into account acceptance limitations.

Offshore wind potential around the coastline of Europe is considerable. Under the European Union Framework programme various studies were carried out that took into account not only the theoretical potentials but also the limitations due to water depth, distance to shore and visual concerns. The results therefore vary substantially from over 3,000 TWh if water depths up to 30 m and 40 km distance from shore were to be included [Mat 1993] to 317 TWh if all water depths over 20 m were to be excluded and limitations due to visual concerns, adequate spacing between wind farms and expenses for power cables were to be introduced [EWE 2004].

Nevertheless, even the lower estimates predictwind energy resource in the European Union to an extent that on- and offshore wind could potentially contribute about 20% of the electricity in 2020. These examples show, that for an evaluation of available wind resources in the European Union to be realistic it is necessary to take into account latest technological developments as well as socio-economic factors.

5.2 Market and Implementation

According to the European Wind Industry Strategic Plan for Research & Development, First Report [EWE 2004], European wind turbine manufacturers have currently a world market share of approx 75% (Fig. 5.2). The global industry turnover in 2002 and 2003 was around € 7 billion, creating around 95,000 jobs.

The top 10 suppliers in the world maintained their position supplying almost 95% of the 2003 installations. In total there are about 25 companies worldwide manufacturing wind turbines. The 15 companies beyond the top 10 shared 5.3% of the world market in 2003. Vestas Wind Systems (DK) maintained its market leader position with 21.7% in 2003 and strengthened it in a merger with NEG Micon the 5th largest producer announced in December 2003 [Ves 2003] and completed in May 2004. GE Wind Energy (US) could achieve the highest relative growth in market shares rising from 5th position to 2nd position in 2003. Out of the top 10 producers only three could increase their market share in 2003, namely GE Wind, REpower and Mitsubishi Heavy. All other manufacturers lost market shares in 2003 compared to 2002.

At the end of 2003 more than 40,000 MW of wind power were installed world-wide up 8,344 MW from the previous year [EWE 2004a]. These installations provide enough electricity to supply about 19 million European households or 47.5 million people. Despite the fact that the European market declined, the major share of new installations with 66.5% took again place in Europe. The largest increase could be observed in the Asian markets with more than 60% growth compared to 2002 with India and Japan leading. Of the total cumulative installed capacity about 75% are in Europe and the 5 biggest installer countries, Germany, Spain, USA, Denmark and India make up for more than 80%. This uneven contribution leads to hope and concern at the same time. What happens if the leading installers slow down? What happens if the other countries catch up?

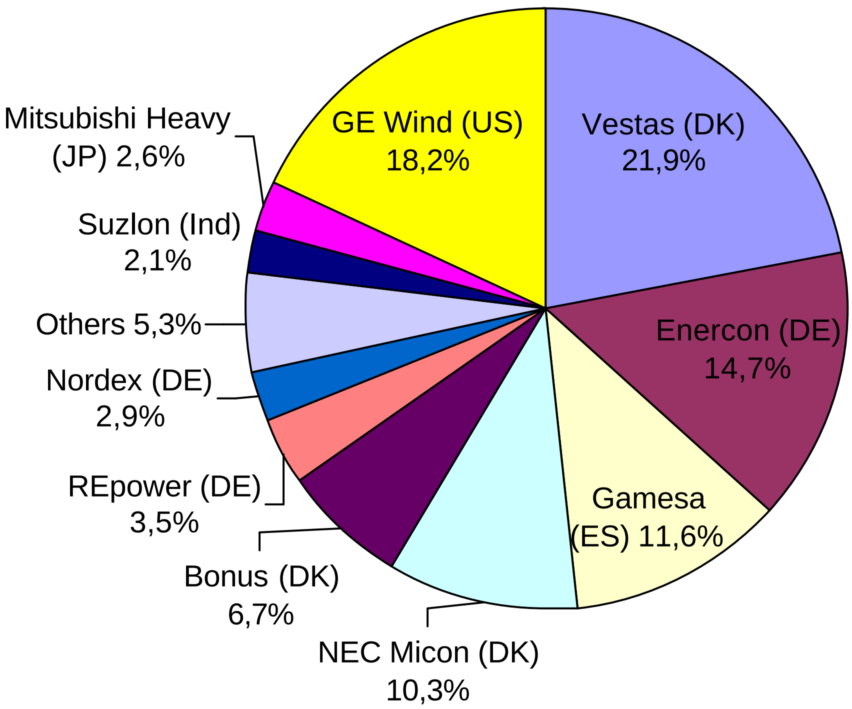


Fig. 5.2: Top ten wind turbine suppliers in 2003 (source: BTM Consult ApS, March 2004 [BTM 2004])

The promising outlook is that almost 50 countries world wide are already installing wind power and contribute to the global growth. In addition to the traditional wind market a new segment is about to emerge: offshore wind farms. In the seas around Northern Europe wind farms with more than 20,000 MW are already being proposed. Similar considerations are under way in the shelf areas along the American Atlantic cost.

The enlargement of the European Union on 1st May 2004 added 10 new Member States with currently 103 MW of wind power installed increasing the total in EU25 to 28,503 MW at the end of 2003. The White Paper target of approx. 40 GW wind turbine capacities installed in EU15 in 2010 can already be exceeded in 2005 if current growth rates can be maintained. Most of the European Union's Member States have plans for an increased use of wind energy to reach the White Paper targets. In 2010 the installed capacity in the European Union is estimated[57] at approximately 87,500 MW, which could provide around 175 TWh or 5.97% of electricity.

2003 was a wind year below average, and the deviation from the 10 years median in Germany was 15.8% for costal regions and 18.2% for inland regions. Despite this fact, generated electricity amounted to 18.5 TWh or 3.3% of the total electricity used in Germany.

If one looks at the situation in Europe (Figure 5.3), it becomes obvious that the increase in installations is not directly correlated with the natural resources, but with policy support for renewable energies. The pathways to support renewable energies and here in particular wind energy are somewhat different in Germany, Spain and Denmark, but the most important issue is the creation of investor confidence to reclaim their investment costs.

[57] Source: UCTE/EWEA, EREC, DTI, Swedish Institute, National Climate programme (FI), Sustainable Energy Ireland

The big breakthrough for the German market came in 1991, when the Stromeinspeisungsgesetz - Electricity Feed-in Law (EFL) - was passed by parliament. This legislation guaranteed all renewable energy producers up to 90% of the domestic sale price of electricity for every kWh they generated. The law which has proved to be administratively simple and effective in practice was based on the argument that clean energy sources need encouragement both to establish a market and to compete with historically subsidised fuels like coal and nuclear. In 2000 the Renewable Energy Law (revised in 2004 [EEG 2004]) was passed which recognised varying energy generation cost for different renewable energy sources and set guaranteed feed-in tariffs for the specific renewable energies over a certain number of years. In addition, the increasing competitiveness of wind led to an introduction of a decreasing feed-in price after five years of a turbine's operation.

A similar system of feed-in tariffs was introduced in Spain when in 1994 [Spa 1994] all RES-E electricity producers were entitled to sell their output power to the grid. The amount paid to the RES-E producers must be between 80 and 90% of the average electricity price estimated each year by the government. At the end of 1998 the Royal Decree 2818/1998 which went into force on 1 January 1999 strengthened the implementation of renewable energies. It confirmed the targets set by the European Union for Spain of 12% total energy and 29.4% electricity from renewable energy sources in 2010. The royal decree has given RES-E producers the option for a fixed price or a "market price + premium". The main difference to the German system is that the price is not fixed for a certain number of years but is decided on a year to year basis. For 2003, the government agreed price was 6.2 €ct./kWh, making wind quite an attractive investment.

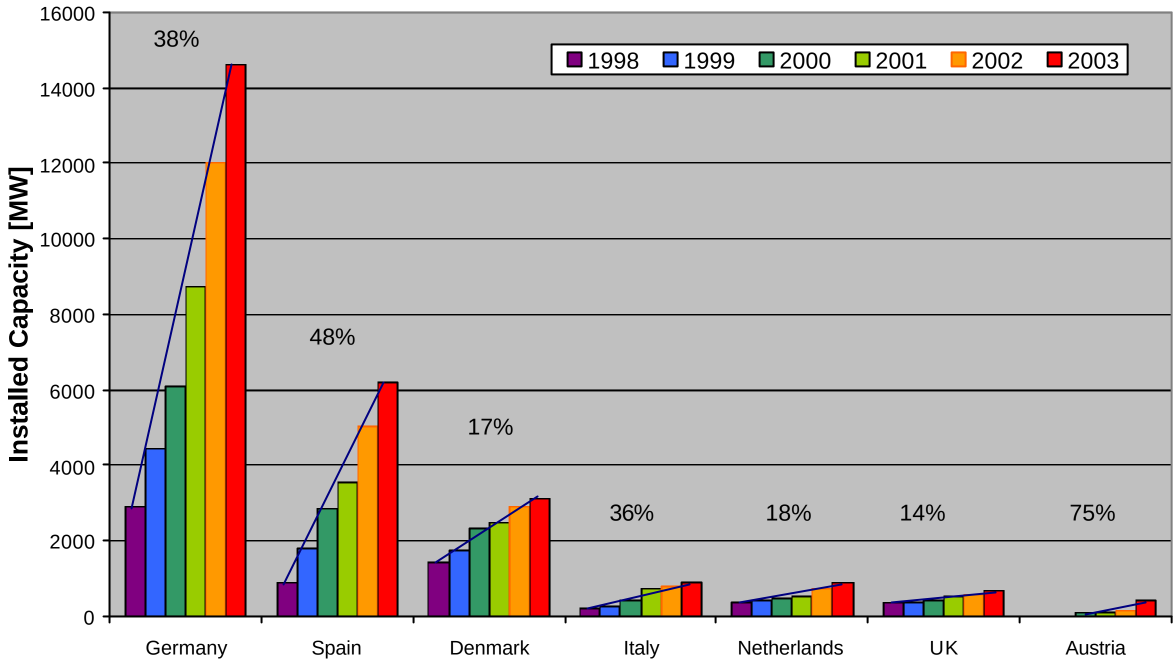


Fig. 5.3: Installed Wind Energy Capacities in EU Top 7 and average growth rates during these 6 years

Denmark chose the pathways of national energy plans in which already the first Danish energy plan as early as 1981 set a goal that 10% of electricity consumption should derive from wind energy in 2000. This target was accomplished in 1997. The new "Energy 21" plan set massive CO_2 reduction targets (20% cut in the 1988 emission level by 2005 and a 50% cut by 2030). If this were to be achieved with renewable energies, more than a third of all energy should be renewable and most of it will likely to be wind. This policy also led to the creation of a new wind industry, which at present provides more than 20,000 jobs in Denmark – more than the entire traditional energy sector – and over 4,000 jobs abroad.

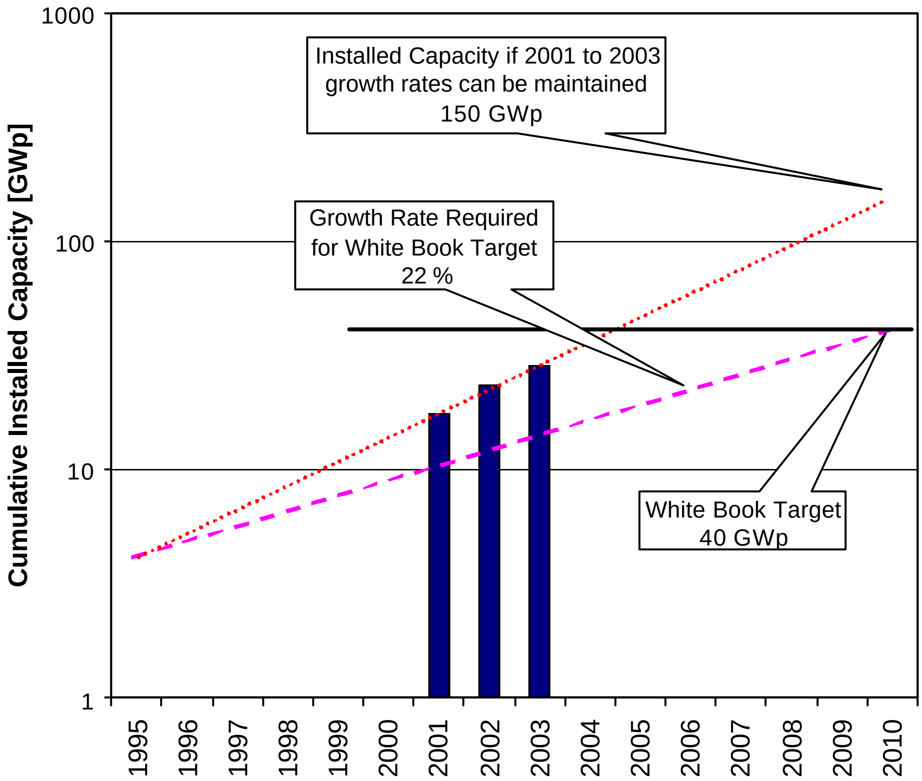


Fig. 5.4: White Book target growth rate and estimates based on 2001 to 2003 installations

Wind Energy is very much on track to fulfil the White Book targets (Fig. 5.4). If the growth rates of the last three years could be maintained, the total installed wind energy capacity could reach 150 GWp in 2010 providing around 300 TWh or roughly 9.5% of the electricity in the European Union. To achieve this goal a stable policy frame is indispensable as shown earlier for the cases of Germany, Spain and others.

5.3 Technological Developments

Besides the political framework the other important driving force is technological development. As shown in Figure 5.5 the energy convention chain for wind energy starts at the mechanical step. The most common configuration is the horizontal axis, three bladed turbine with an upwind positioned rotor - located on the windy side of the tower, even if a number of other variations are continued to be explored [Eur 2002]. Major improvements are being made in the ability of the machines to capture as much energy as possible from the wind at the lowest cost. The options are thus more powerful rotors, larger blades, improved power electronics, better use of composite materials and taller towers.

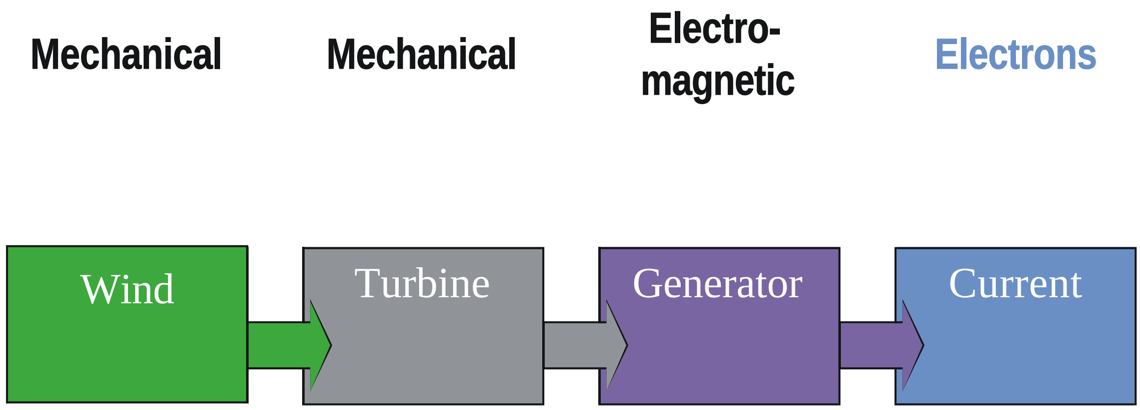


Fig. 5.5: Wind Energy Conversion Chain (Figure: courtesy of H. Ossenbrink)

The most dramatic improvement has been realised in the increase of size and performance of wind turbines, which had a direct impact on generated electricity cost (Figure 5.6). In 1982 the average machine size was 25 kW, which rose to 200 kW (35 m rotor diameter) in 1992 and reached a commercial size range in 2003 between 750 kW and 2,500 kW (80 m rotor diameter on 70 to 100 m high towers). In 2003 the average capacity of new wind turbines installed in Germany was 1,600 kW. Bigger machines with 3,000 to 5,000 kW, specifically designed for offshore applications, are currently under development. In 2003 Enercon installed a 4.5 MW wind turbine prototype on a 112 m high tower.

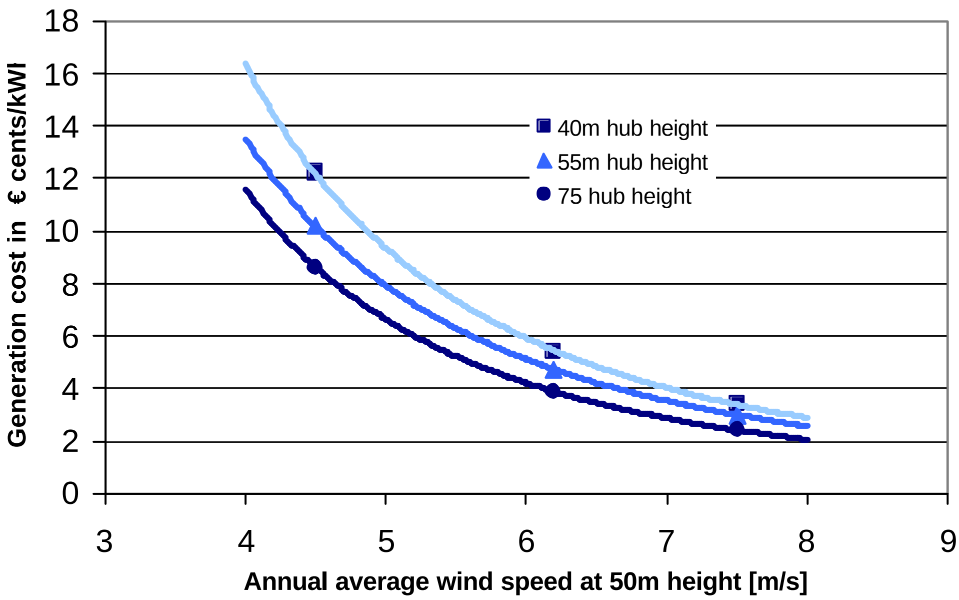


Fig. 5.6: Generation cost compared to hub height of wind turbine [Eur 2002]

At the time of finalisation of this report, REpower AG is completing the foundations for the REpower 5M turbine near Brunsbüttel, Germany, a 5 MW wind generator with a rotor diameter of 126 M and a hub height of 100 to 120 m. This development is co-financed by the German state Schleswig-Holstein and the European Union, within the frame of the European project "5MW Innovative Wind Turbine Suitable for on Land and Offshore Installations".

A second 5 MW prototype is being developed by Multibrid Entwicklungsgesellschaft mbH, Neumarkt, a 100% subsidiary of PROKON Nord Energiesysteme GmbH. The rotor diameter is designed to be 116 m and the hub height for off-shore applications will be 85 M. The plan is to erect the prototype in Bremerhaven-Speckenbüttel in the summer of 2004.

The key to achieving these, and even higher power output capacities in the future lies in the capability to build large lightweight and efficient but sufficiently strong turbine blades. One possibility is fibreglass-reinforced composite technology, however, increasing length will imply that technology limits need to be pushed even further. The challenges associated with large blades do not increase in simple proportion to their length. While the swept area increases by approximately the square of blade length (an exponent of 2), the blade weight will grow approximately with the *cube* of length (an exponent of 3). In practice, weight increases have been eased by refining designs and employing manufacturing methods that optimize the structural properties. Studies have shown actual weight increases by an exponent of 2.35. However, the real challenge lies in developing a large blade that incorporates the best possible combination of capacity, weight and price.

Additional developments are aimed at optimising the rotors for low noise emission and the use of pitch control. Asynchronous generators, often without reduction gear have gained an approximate market share of 30%.

Prices for wind turbines and consequently prices for kWh electricity generated by wind energy have decreased significantly over the last couple of years. The “state of the art” wind turbine in 2003 required an investment of € 804 per installed kW and electricity costs of 3.79 €ct./kWh [EWE 2004b]. The design lifetime of wind turbines is now in the range of 20 to 25 years. Operation and maintenance costs are typically in the order of 3% to 5% of initial investment costs and per year. The “Wind Force 12” study predicts a further decrease of costs due to an improvement both in average size of turbines and in their capacity factor. By 2010 the study expects costs of 3.03 €ct./kWh, assuming a cost per installed kilowatt of € 644/kW and 2.45 €ct./kWh with an installation cost of € 512/kW by 2020. The latter is a substantial reduction of 36% compared to 2003.

In addition, the following development trends can currently be seen to be contributing to the above mentioned price reductions.

- **Weight-reduction, advanced Materials**
- **Improved suspension of oscillations (blade + tower)**
- **Flexible components, (blades, hubs)**
- **Reduction in component number**
- **Passive alignment, “Downwind” Rotor**
- **More precise forecasting (EnviSat Experiment)**
- **Control of large Wind-farms**
- **Off-shore systems, siting**

5.4 Further Challenges

The further expansion of wind energy and the concentration in large wind farms will require changes in physical grid networks. This is very often cited as an additional cost driver and the extension of the grid should be paid by the wind farm operators. However, as already pointed out in the introduction, the IEA predicts that the European Union will have to invest close to

$ 40 bn year-on-year in order to maintain and expand its electricity grid and generation capacity. Instead of maintaining the current centralised distribution network, new investments should be made to build up an intelligent distribution network capable of integrating various kinds of decentralised electricity generation facilities.

It is often cited that since wind is a variable energy source, the utilities have to have additional power units in reserve in order to take precaution for times of little or no wind.

Up to the point where wind generates about 10% of the electricity that the system is delivering in a given hour of the day, this is not an issue. Enough flexibility is built into the system for reserve backup, varying loads, etc., for there to be a negligible difference between such a system and a system with 0% wind. Variations induced by wind are much smaller than routine variations in load (customer demand). Much more significant is, in fact, the degree to which, capacities of other power plants like nuclear (cooling water) or hydro vary when water resources are low as experienced in the Nordic member countries over recent years.

At the point where wind generates 10% to 20% of the electricity that the system is delivering in a given hour, this is an issue that can be resolved with precision wind forecasting (which is fairly accurate in the relevant time frame to utility system operators), system software adjustments, and other changes. Once wind is generating more than about 20% of the electricity that the system is delivering in a given hour, a strong and intelligent European grid will be necessary to balance demand. However, this means that additional expenses will occur due to the need to procure additional equipment that is solely related to the system's increased variability.

These figures assume that the utility system has an “average” amount of resources that is complementary to wind’s variability (e.g., hydroelectric dams, solar, etc.) and an “average” amount of load that can vary quickly (e.g., electric arc furnace steel mills). Actual utility systems can vary quite widely in their ability to handle as-available output resources like wind farms. However, as wholesale electricity markets grow, fewer, larger utility systems are emerging. Therefore, over time, more and more utility systems will look like an “average” system.

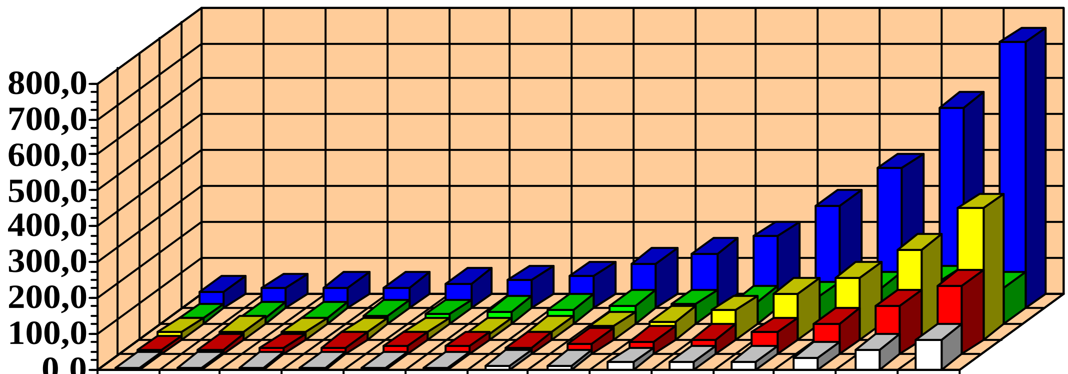
CHAPTER 6

PHOTOVOLTAIC

Arnulf Jäger-Waldau and Harald Scholz

6.1 Introduction

In 2003, the photovoltaic industry delivered some 744 MWp [May 2004] of photovoltaic generators (Figure 6.1) and has become a € 4.5 billion. business. PV has enjoyed an extraordinary growth during the last few years with overall growth rates between 30% to over 40% making further increase of production facilities an attractive investment.



	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Rest of World	4,7	5,0	4,6	4,4	5,6	6,4	9,8	9,4	18,7	20,5	23,4	32,6	55,5	83,8
Europe	10,2	13,4	16,4	16,6	21,7	20,1	18,8	30,4	33,5	40,0	60,7	86,4	135,1	193,4
Japan	16,8	19,9	18,8	16,7	16,5	16,4	21,2	35,0	49,0	80,0	128,6	171,2	251,1	363,9
United States	14,8	17,1	18,1	22,4	25,6	34,8	38,9	51,0	53,7	60,8	75,0	100,0	120,6	103,0
Total	46,5	55,4	57,9	60,1	69,4	77,6	88,6	125,8	154,9	201,3	287,7	390,2	561,8	744,1

Fig. 6.1: World PV Cell/Module Production from 1990 to 2003 (data from PV News [May 2004])

Besides the exponential increase of the world market that led to a rising interest of institutional investors, the rapid increase of the Japanese production capacities is of particular interest. Within 5 years from 1995 to 1999, Japan has propelled itself to the position of the market leader both in terms of supply and demand for solar cells. Four of the top 10 PV manufacturers were Japanese in 2003. In total Japanese producers provided 48.9% of the world production, followed by producers in Europe with 26%.

Since 1999 European PV production has grown in average by 50% per annum and reached 190 MW in 2003. During the same period, European market share from 20% to 26%, and the US share decreased due to a weak home market. The European PV industry must continue its high growth rate over the next years in order to maintain this level.

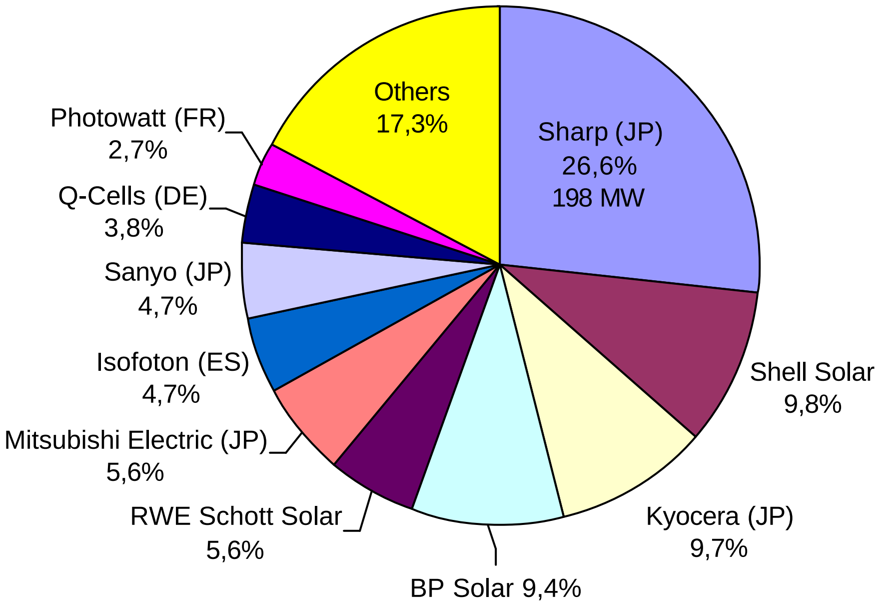


Fig. 6.2: Top 10 PV producers in 2003.

However, different solar cell technologies have grown with different growth rates and over 85% of the current production is based on silicon wafer or silicon ribbon. This is a well-established technology, which achieves sufficient efficiency over at least 20 years of lifetime and constitutes a low-risk investment with high expectations for return on investments. In addition, the HIT-solar cell of Sanyo (*H*eterojunction with *I*ntrinsic *T*hin Layer), a heterostructure between a silicon wafer and an amorphous silicon thin film has about 4% market share. In the last 15 years the market share of thin film solar cells has decreased from approx. 30% in 1987 to less than 6% in 2003.

Should the growth of photovoltaics continue as in the past years, the supply of cost-effective silicon feedstock might limit the achievable cost reduction, especially if feedstock costs cannot be kept below about 0.50 €/Wp. In the last years this problem was often mentioned as the bottleneck for further growth of the silicon wafer based PV industry. However, in March 2003 Solar Grade Silicon LLC announced the full production of polycrystalline silicone for PV at the Moses Lake facility with an initial capacity of 2000 metric tons [Sol 2003]. This indicates that the silicon producers have recognised PV as a full-fledged industry, which provides a stable business for a silicon industry that had traditionally been highly dependent on the demand cycles of the microelectronic industry. Therefore, it can be expected that adequate silicon feedstock will be available to accommodate further growth of the PV industry.

Similar to learning curves in other technology areas, a new generation of devices will develop and steadily increase its market share. This thin film technology, after years of research and technology - and also lawsuits - is readily available and currently in a transition phase from pilot to industrial production. Equally competitive technologies are amorphous Silicon, CdTe and $Cu(In,Ga)(S,Se)_2$. The growth of these second generation technologies will be accelerated by the positive development of the PV market as a whole and there are many indications that the required scale-up to manufacturing units of 50 MWp annual capacity will soon join 1st generation silicon devices in satisfying demand. However, the growth of thin film production capacity within this decade must be at least 50% to achieve a market share of 25% in the photovoltaic production of 2010, assuming that total PV growth continues at a constant 27% per year. By then, Silicon technology would deliver about 3,000 MWp per year, requiring probably 24,000 metric tons of Si-feedstock, about the same amount as today's entire world production of Silicon. This implies that in order to maintain such a high growth rate, material use for silicon wafers has to be reduced more rapidly and thin-film technologies have to grow at a faster rate. Further cost reduction will depend not only on the scale-up benefits, but also on the cost of the encapsulation system, as efficiency will remain limited below 15%, stimulating strong demand for very low area-proportional costs.

However, thin film PV technologies still have to overcome some major hurdles to realise this vision. The following issues are common ones for all thin film solar cells:

- Currently thin film solar cells have less than 10% market share.
- Large plants with high yield and throughput required for significant cost reduction.
- Efficiencies of thin film modules in production are not yet above 10%.
- Most of the thin film modules still have to solve the problem of long-term stability (20 to 25 years of lifetime), which is very much related to encapsulation issues.

But:

- Excellent for Building-integration; more flexible in appearance, size and design.
- Enormous potential for growth and investment, in particular for pilot lines

If photovoltaics are to contribute significantly to the energy supply of the future, new developments for solar cells with higher efficiencies than the current average efficiency for modules made from wafer silicon solar cells (10 to 15%) and somewhat lower for thin film modules (6 to 12%) are needed. There has to be an evolution of the current silicon wafer technology to thinner wafers, ribbon or multicrystalline material and more advanced cell technologies. However, an important message from Prof. Martin Green at the University of New South Wales is, that future photovoltaics has to be thin film, whether conventional, concentrator-type or novel ideas, in order to meet the price targets shown in Figure 6.3.

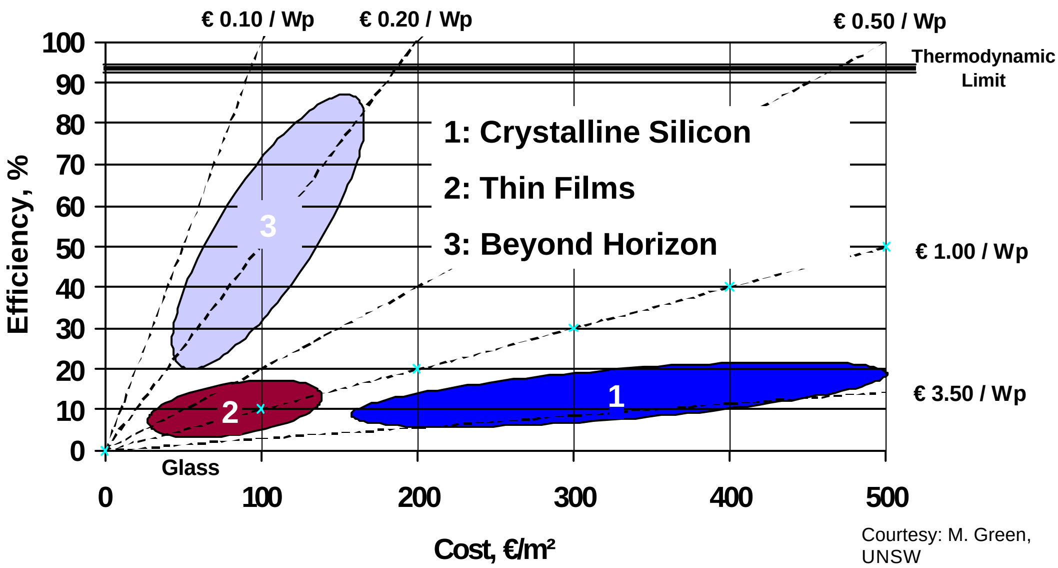


Fig. 6.3: 1st, 2nd, and Future Generation Solar Cells or *"which price for what efficiency*?"

6.2 Technology issues

In principle the Photovoltaic Energy Conversion Chain appears very simple and appealing (Figure 6.4), however, in reality it is quite challenging to design and manufacture a cheap solar cell. The reasons for this are mainly the area costs and different loss mechanisms in the current solar cell concepts.

Fig. 6.4: Photovoltaic Energy Conversion Chain (Figure: courtesy of H. Ossenbrink)

In Figure 6.5 the different loss mechanisms are shown for the example of a laboratory prototype and a commercial crystalline silicon solar cell.

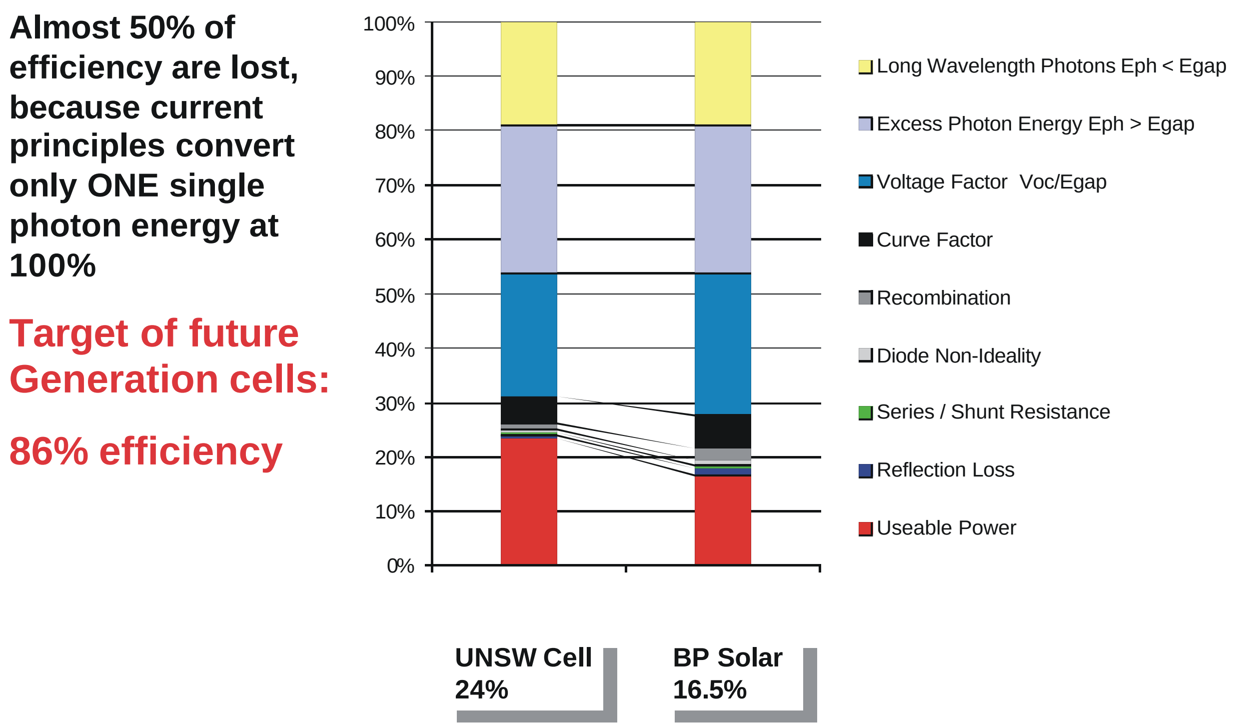


Fig. 6.5: Loss mechanisms in prototype [UNSW} and commercial [BP-Solar] crystalline silicon solar

To reach the goal of higher efficiencies, several options are currently discussed such as:

♦ ***"Multiple threshold" or multi-junction devices***

Two main losses in the single junction solar cell are due to the fact that all energy of photons smaller than the bandgap ($E_{ph} < E_g$) cannot be converted into electricity and that the fraction of the energy above the bandgap of photons with $E_{ph} > E_g$ is lost as well. If the solar spectrum is split into narrow wavelength bands and converted in separate solar cells with appropriate energy bandgaps, the energy conversion efficiency can be increased. The theoretical efficiency limit for an infinite number of stacked solar cells for direct sunlight is 87%. However, it is clear that this limit can not be reached for a real stack. Nevertheless, a stack with three or four solar cells can increase the efficiency considerably and reach efficiencies well above 35%.

Such a stack is engineered in a way that the solar cell with the highest bandgap is on top and those with the lowest at the bottom. The uppermost cell will then absorb the high energy photons it is able to convert, passing photons of energy below its bandgap through to the underlying cell, where the process continues.

These multi-junction devices are in general used in combination with a concentrator technology, i.e. the sunlight is concentrated onto the solar cell, in order to save on the solar cell material.

♦ ***Quantum Mutiplication***

This can be realised with up- or down-conversion. In the case of up-conversion, two sub-band-gap photons, which would not be absorbed by the solar cell, are transformed to one larger energy photon, which is absorbed by the solar cell. This process can also be reversed to down-conversion, where 1 large energy photon, with energy larger than twice the band gap of the solar cell is down-converted into 2 photons, with energy just above the band gap.

The photon conversion takes place in a material outside the solar cell, which is in good optical contact, but not in electrical contact with the solar cell. The photon converter must have the desired optical properties, however, good transport properties are not required.

♦ ***Intermediate Bandgap Solar Cell***

In this concept an energy level between the valence and conduction bands in the absorber material provides additional transitions at lower energies. In addition to band-band transitions, electron-hole pairs can be generated in a 2-step process, when an electron is first excited from the valence band to the intermediate level and then by a second photon from there to the conduction band. Such an intermediate level cell is equivalent to 3 cells in a tandem, where a series connection of the 2 cells represented by the transitions involving the intermediate level is connected in parallel to the third cell, which represents the band-band transitions.

♦ ***Hot Carrier Cells***

The thermalisation of photoexcited carriers with the atoms in the crystal lattice is one of the main loss mechanisms in conventional solar cells. The concept of a "hot carrier" cell seeks to avoid this loss. It can be done if the electrons and holes leave the absorber through semi-permeable membranes before they are thermalised by scattering with phonons. However, cooling of the energy carrier down to the temperature T_0 of the environment is an important step in the conversion process. As this cooling should not occur in the absorber, it must happen in the semi-permeable membranes. In order to avoid thermalisation losses there, only monoenergetic electrons (or holes) are allowed to pass into the membranes, due e.g. to a narrow conduction band (or valence band).

♦ ***Thermal Approaches***

Thermophotovoltaic (TPV) power generation is a process where the solar radiation is absorbed by an intermediate absorber/emitter combination, which is heated to high temperatures and emits near monochromatic radiation towards a solar cell, either by virtue of its own selectivity or through a filter. In such an arrangement, all thermalisation losses in the solar cell are avoided and the unsuitable photons are not lost, since they are either not emitted or they are reflected back onto the intermediate absorber/emitter by the filter, which helps to maintain a high absorber-temperature.

All these options require serious research consideration. The highest efficiencies for photovoltaic devices today are realised with mechanically stacked InGaP/GaAs/InGaAs 3-junction cells. Multi-junction cells based on III-V-semiconductor materials are a realistic path to ultra high efficient solar cells. The most recent result was reported by SPECTROLAB at the end of July 2003. NREL has confirmed a 36.9% efficiency multi-juction concentrator device [Spe 2003]. In combination with concentrator technology these cells are a near future option to play an important role in the future energy market.

6.3 Market and Implementation in the EU

Between 2001 and 2003 the EU15 wide PV installations doubled, mainly due to the German programme, which accounted for more than 70% of total EU PV installations. However, Spain and Austria also doubled their installed PV power, whereas Luxembourg propelled itself to World Champion and leads statistics in terms of installed PV with 8Wp ***per capita.*** If the enlarged European Union as a whole would follow this example, 3.63 GWp installed PV or about 3.6 TWh per year could be achieved. (Figure 6.6).

It is interesting to note that 16 out of 25 Member States have already introduced feed-in tariffs (see Annex Table A.4). 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, its 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 there, where 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.

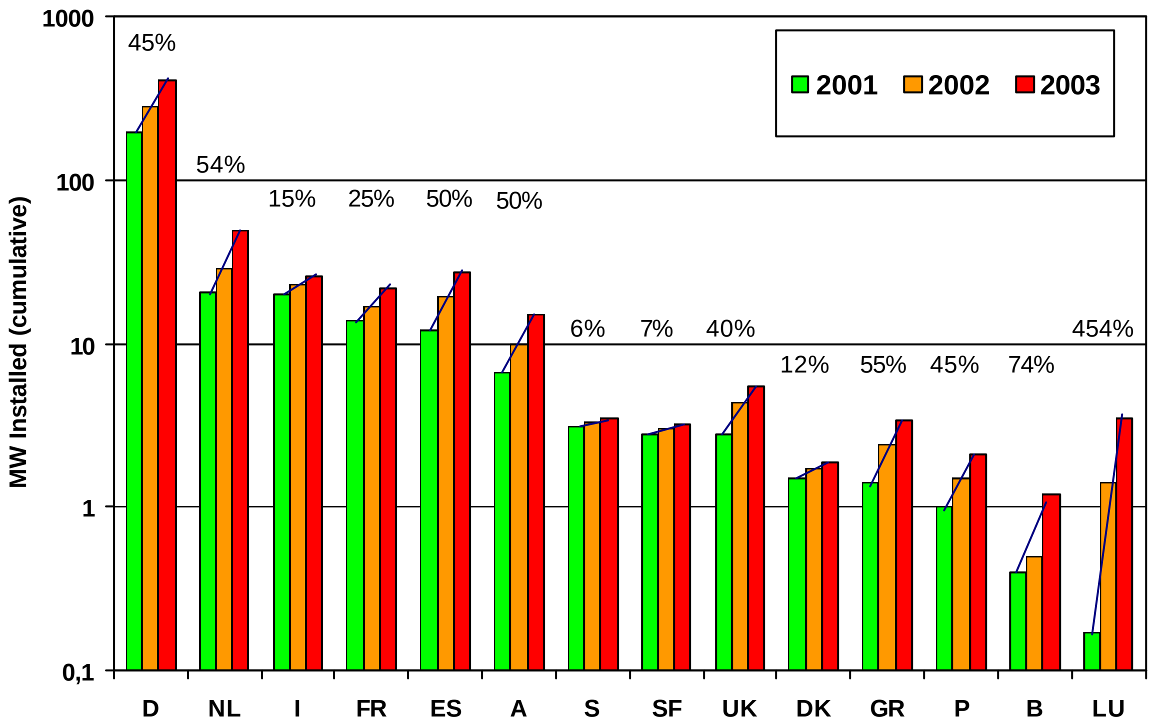


Fig. 6.6: Cumulative installed grid connected PV capacity in EU15 from 2001 to 2003 and average growth rates
Note that capacities do not seem to correlate with solar resources (Fig. 7.3)

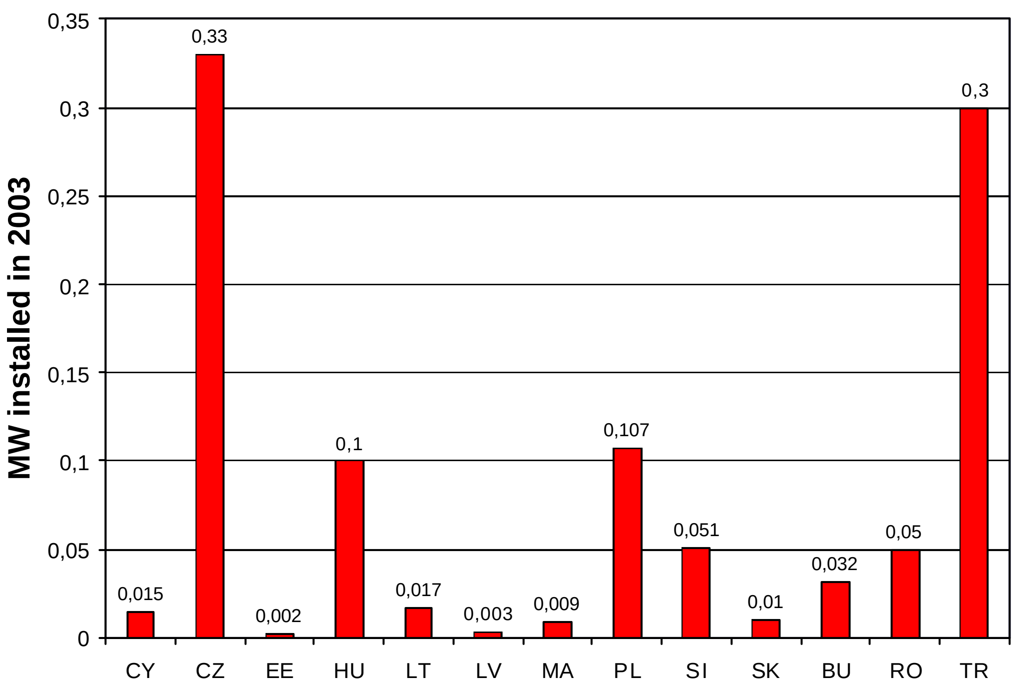


Fig. 6.7: Cumulative installed PV capacity in the New Member States and NAS in 2003 [Rei 2003, You 2003, Pie 2004].

The New Member States and Candidate Countries still have much lower installation figures (Figure 6.7) despite good to very good solar resources is some states with up to 1,600 kWh/kWp (Cyprus, Malta, Romania, Bulgaria, Southeast Hungary). But 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 (see Figure 7.3).

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 (Figure 6.8).

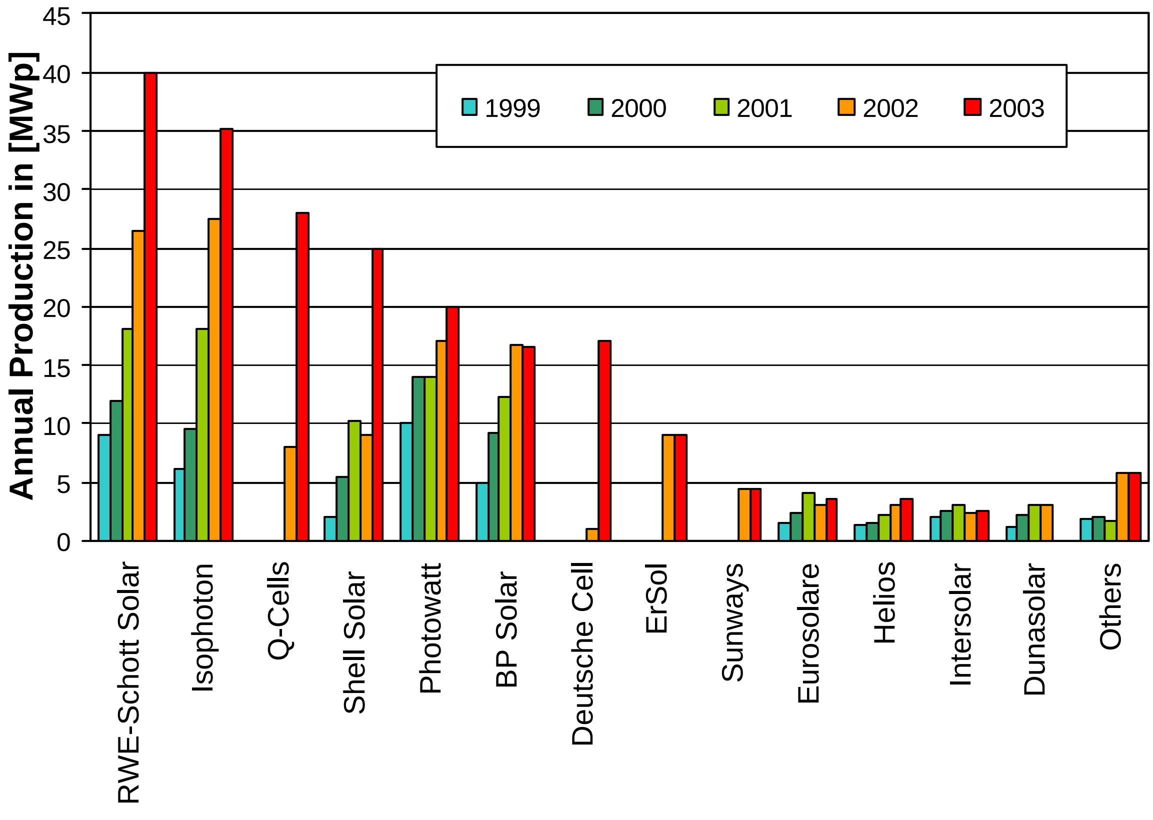


Fig. 6.8: Annual production of the European PV manufacturers with sales larger than 2 MWp in 2003 [May 2004 and 2004a]

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 2003 could be maintained in the next years, the White Book target would already be achieved in 2008 (Figure 6.8). In 2010, total installations would then exceed 7 GWp or approx. 16 Wp per capita, which would still be less than half of the Japanese target per capita. The adoption of the Japanese target of 38 Wp per capita would result in 17.25 GWp installed in 2010, which would generate around 17.25 TWh. The PV installation growth rate curve in the European Union exactly mirrors that of wind power, with a delay of approximately 12 years.

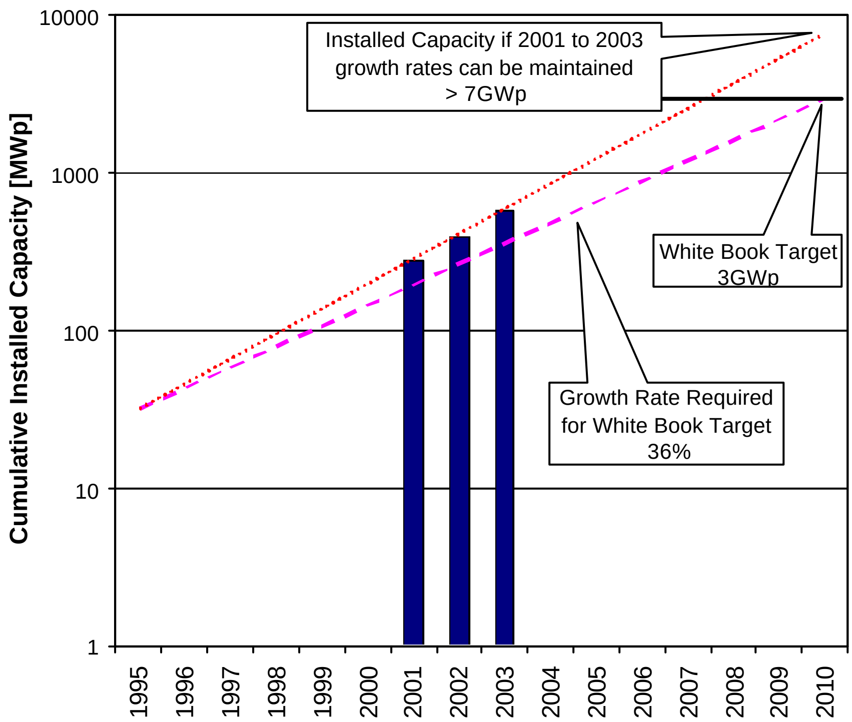


Fig. 6.9: White Book target growth rate and estimates based on 2001 to 2003 installations

The introduction of the German Feed-in Law in 1999, and a number of countries following up on this trend, led to a significant improvement in the frame conditions for investors. Since then, European PV production grew on average by 50% per annum and reached over 190 MW in 2003 [May 2004]. With this industry output and for the first time, Europe has produced as many solar cells as PV systems were installed in Europe. European world market share increased in the same time from 20% to 26%, whereas US share decreased due to a weak home market. In consequence the Japanese share also increased to 49%.

The European PV industry has to continue this impressive growth over the next years in order to maintain its strong market position. This will only be achieved , if reliable political framework conditions are created that 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.

According to the European Photovoltaic Industry Association, the PV industry now provides approximately 15.000 jobs in Europe. 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.

The recent implementation of a feed-in law in Italy and the changes to the feed-in law in Spain are encouraging signs. They give rise to the hope that over the next years, these markets will grow as dynamically as the German one thus leading the way to a European wide PV boom.

CHAPTER 7

PV ELECTRICITY POTENTIAL IN EU25 MEMBER STATES

Marcel Šúri, Thomas A. Huld, Ewan D. Dunlop

A successful integration of solar energy technologies into the existing energy structure depends strongly on better knowledge of the solar resource. An increase in the uptake of photovoltaic (PV) systems in the energy market in turn depends on public support schemes that should consider climatic variability within regions of Europe. Spatially-distributed databases help to understand the geographical and time distribution of the solar energy resource and the potential performance of the PV systems. This chapter provides estimates of the PV potential in the 25 Member States of the European Union and it analyzes its regional differences.

7.1 European Solar Radiation Database

Solar radiation is a key factor, determining electricity produced by photovoltaic (PV) systems. Within the project PV-GIS a solar radiation database of Europe was developed in the geographical information system (GIS). The GIS database has a grid resolution 1 x 1 km and it includes the data representing a period 1981-1990. It consists of monthly and yearly average values of the global irradiation on horizontal and inclined surfaces, as well as climatic parameters needed for an assessment of the potential PV electricity generation (Linke atmospheric turbidity, the ratio of diffuse to global irradiation, an optimum inclination angle of modules to maximize energy yield). Geographically, the database covers the European subcontinent, plus surrounding areas.

The details of the computational approach and information about the quality of the data can be consulted in works [Šúri et al. 2004a, 2004b]. To provide an access to the database to anyone interested, we have developed web-based interactive applications. Any location in Europe can be chosen by browsing and clicking on a map, choosing a country and city from a list, or by directly setting latitude/longitude values. The monthly and yearly values are displayed in a separate window. For a selected module inclination and orientation a user can get also a daily profile of clear-sky and real-sky irradiances for a chosen month. The web applications can be accessed at: http://re.jrc.cec.eu.int/pvgis/pv/imaps/imaps.htm.

7.2 Potential of a 1 kW_p PV Configuration

The developed database enables to estimate PV potential electricity generation over Europe for solar irradiation incident to horizontal or inclined surfaces.

An overview picture of the geographical variability can be got by calculating the annual total electricity output from a grid-connected PV system, installed within the existing building infrastructure, E [kWh]:

$$E = 365\, P_k\, r_p\, G \qquad \text{(equation 7.1)}$$

where P_k (in kW) is the peak power installed (1 kW in our case), r_p is the system efficiency (analogous to the performance ratio, typical value for a roof mounted system with modules from mono- or polycrystalline silicon is 0.75) and G is the annual mean of daily global irradiation on a horizontal or inclined surface of the PV module.

Assuming that the most of PV installation will be located within the built-up residential areas the potential was calculated only for residential areas (filtering-out all the rest from the analysis). The statistical values of the PV electricity generation potential in individual countries and their regions were calculated at the level of administrative regions (NUTS, level 3): average, minimum, maximum, standard deviation. The results are shown in Figure 7.1 (optimum angle) and Figure 7.2 (regional average of the PV electricity generation at an optimum angle). Assuming the irradiation at the optimum angle provides an image of the highest yield possible.

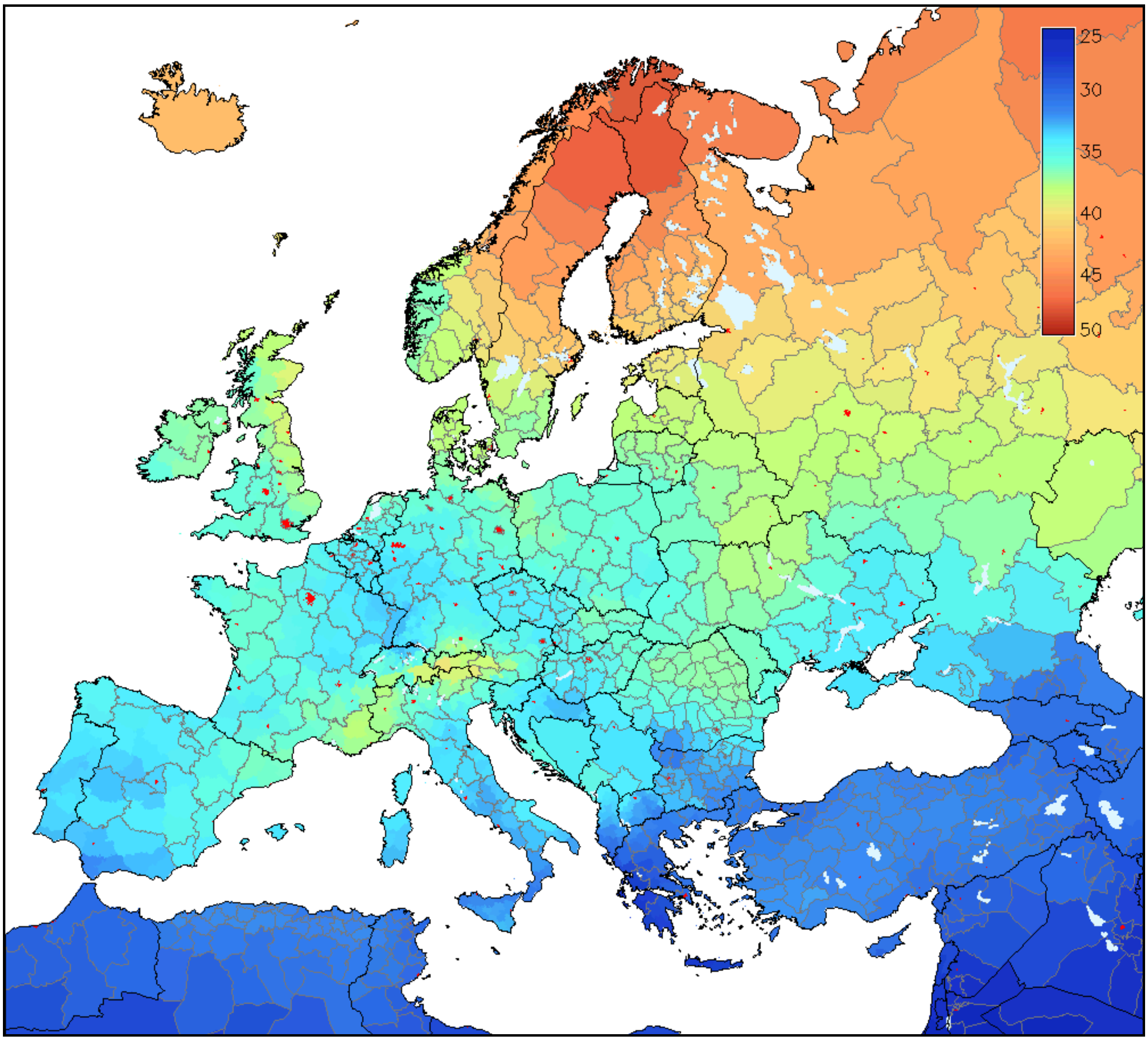


Fig. 7.1: Optimum inclination angle for a south-facing surface, i.e. the angle at which the PV module receives the largest amount of total yearly global irradiation [degrees]

The regional data were summarized to compare the potential between the countries and also their internal geographical heterogeneity. Figure 7.3 shows the national average of the PV potential electricity generation in the residential areas. The extremes of the dash line show the minimum and maximum value, while the upper and lower edges of the boxplot delineate occurrence probability of 80 %.

The results reveal significant regional differences, determined by latitude, continentality, terrain and local climatic variations within the EU25 states. It is obvious that the highest energy potential is in the Mediterranean region with a lot of sunshine in summer (Malta, Cyprus, Portugal, Spain, Greece, Italy and Southern France). Quite good conditions are in the rest of France and in most regions of Central Europe (in Hungary, Austria, Slovenia and Slovakia). The northwest Europe, the Baltic states and the most northerly regions, have the least favourable conditions. The yearly PV electricity generation in the Baltic region is (due to the long daylight in summer) almost the same as in the much lower latitudes of Western Europe where the climate is influenced by the Atlantic Ocean.

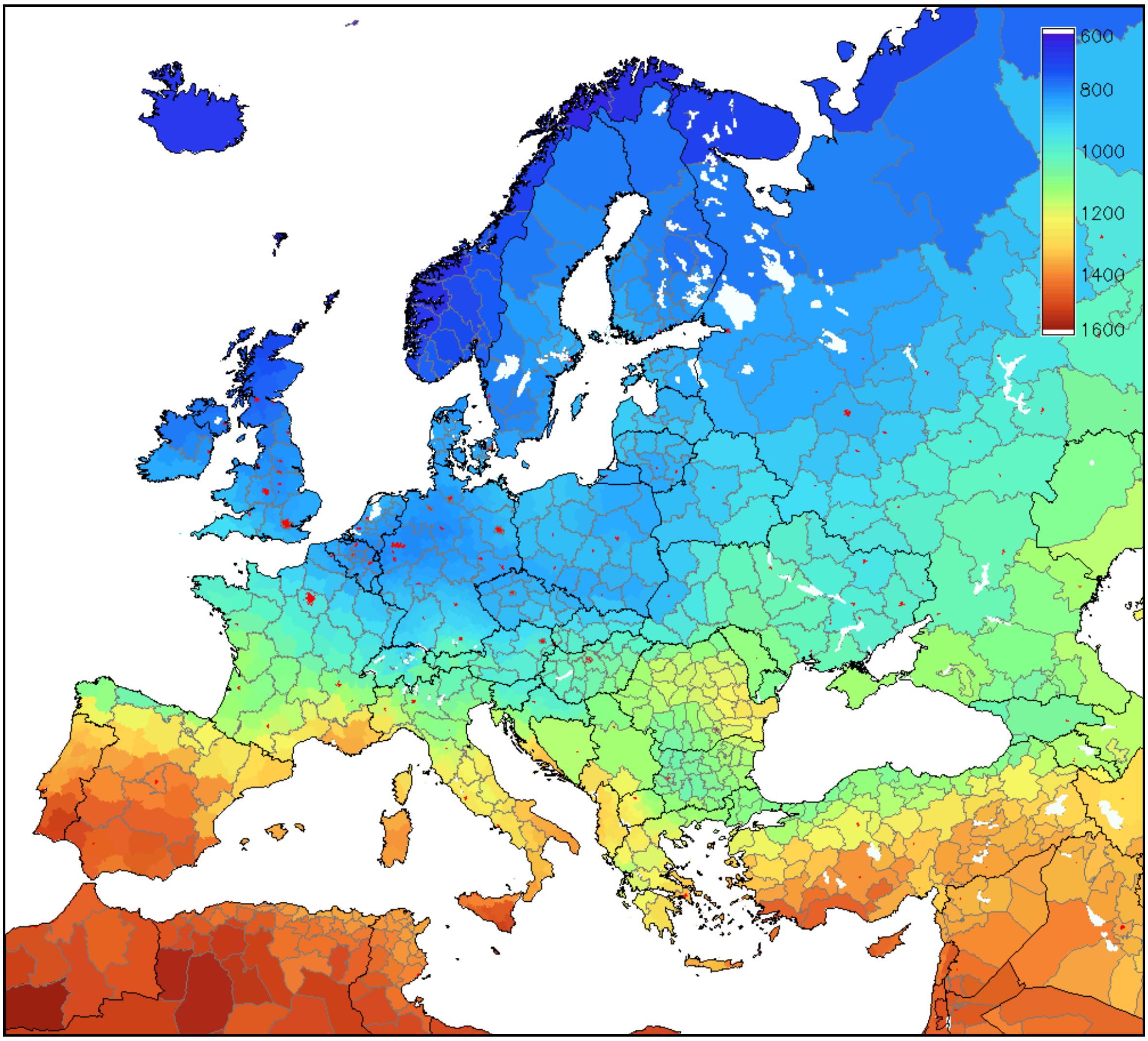


Fig. 7.2: Regional averages (at NUTS level 3) of yearly sum of the electricity generation for a 1 kW_p PV configuration with modules inclined at an optimum angle [$kWh.year^{-1}$]

The PV potential of a 1 kW_p PV system (calculated from equation 7.1) for horizontal surface in the residential areas of the EU25 countries ranges from 510 (in Northern Finland and Sweden) up to 1360 kWh/year (Southern Sicily, Portugal and Spain, Cyprus, Malta and Crete); 2.7 times more in Sicily than in the north Scandinavia). Besides Northern Scandinavia, quite unfavourable conditions are also found in Scotland. Less favourable conditions are found also in Northwestern Germany and Benelux.

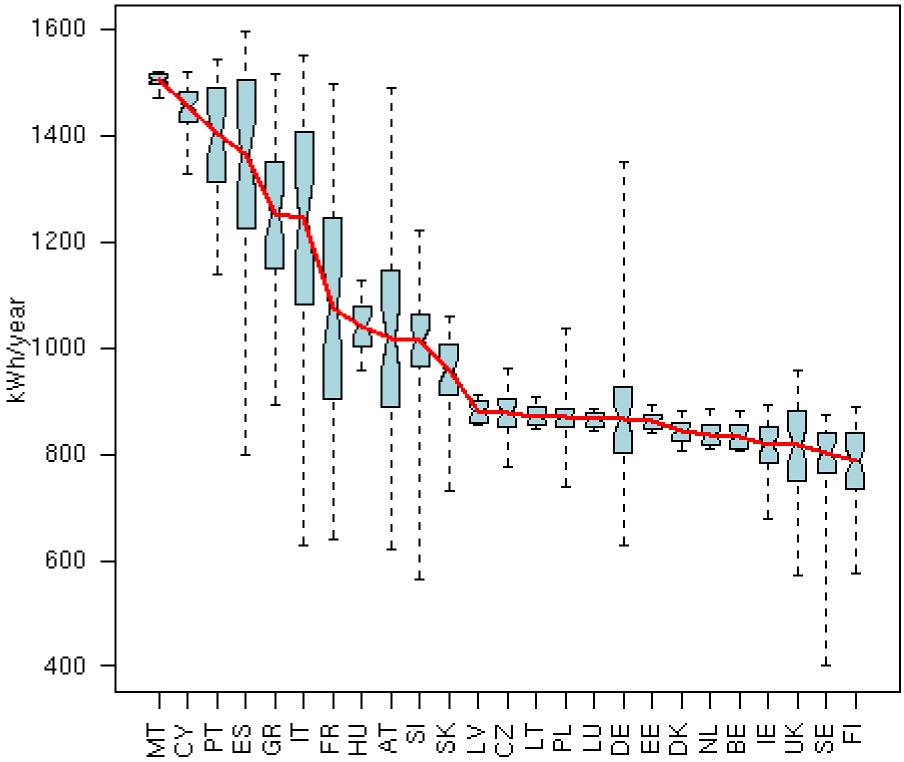


Fig. 7.3: Yearly sum of the electricity generated by a typical 1 kW_p PV system in the residential areas of the EU25 Member States [kWh/year]. The values show: maximum, maximum of the 80% occurrence, average, minimum of the 80% occurrence and minimum for optimum angle conditions.

The optimum inclination angle of the PV modules within Europe ranges from 27° in Western Peloponnesos to 49° in Northern Scandinavia (Fig. 7.1). In large parts of EU25 (mainly between latitudes 45-55°), the latitudinal gradient is weak and optimum angle oscillates between 33 and 36 degrees, depending on regional climate variation and terrain shadowing.

Inclining the PV modules to harvest maximum global irradiation within a year increases the yearly PV electricity generation to 600 (in Northern Sweden) up to 1540 kWh (in Sicily; 2.6 times more). The most electricity from a vertical surface (PV facades) can be generated (up to 970 kWh per year) in Southern Spain, Portugal and Sicily and also in Southern France (Provence). The worst conditions for the vertically-positioned PV modules enable to generate only 420 kWh (Scotland and Southern Sweden).

In general, inclining the PV modules from the horizontal to the optimum angle will increase the yearly electricity yields at 8 to 29 %. The lowest contribution from the inclining from horizontal to optimum position can be expected in Greece (8-10 %), but it is quite low also in the border regions between Germany, France Benelux and in the Czech Republic (11-13%) with high share of diffuse radiation. The highest benefit can be obviously reached in Northern Scandinavia.

Compared to the PV modules in the horizontal position, the facades produce up to 33 % less solar energy in Greece (as the extreme case), but will give yearly yields only 15% less in

Scandinavia and Eastern regions of the UK. Lower differences compared to the horizontal modules can be expected also in the Alps, Carpathians and in Northern Europe. An advantage of vertical PV is the well-balanced seasonal profile (Figure 7.4).

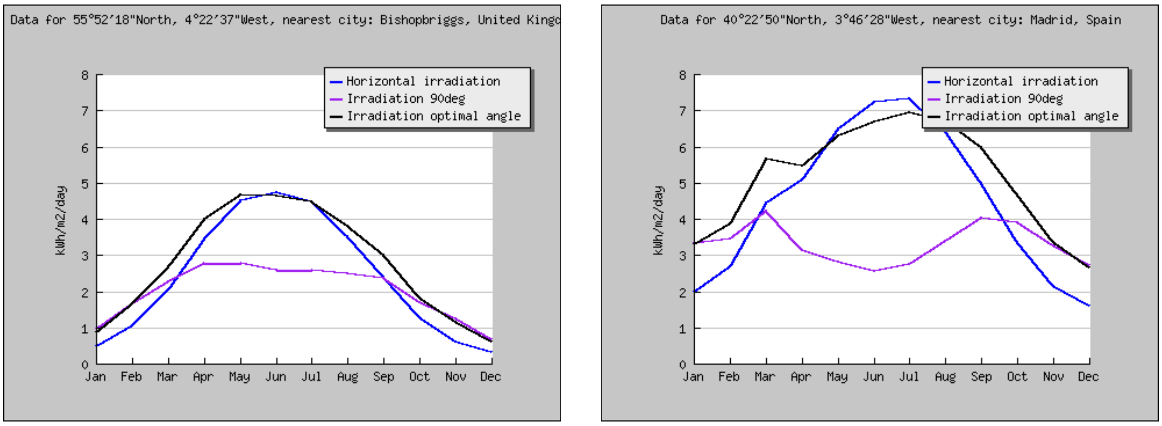


Fig. 7.4: Seasonal variation of global irradiation in Glasgow and Madrid

The largest diversity of the solar electricity generation at the national level can be seen in Spain, France and Italy. This is due to the geographical extent of these countries as well as the climate transition from the Atlantic (in case of Spain and France) and the Alpine (in case of Italy) to the Mediterranean in South. The variation in the solar electricity generated in 80 % of the residential areas of the geographically 'extreme' regions in France goes up to 340 and in Italy 320 kWh per year from each installed kW_p. This indicates a significant regional disparity that should be considered in the national PV-support policies. For example the difference in PV electricity generation between the Spanish provinces Huelva and Asturias for a $1kW_p$ system can exceed 450 kWh per year. In financial terms (on condition that the feed-in tariff is 0.40 €/kWh), this means 180 Euro/year. The variability of the regional PV potential in countries such as Portugal, Greece, Austria, Germany and UK is smaller, though not insignificant.

A typical feature of the solar energy systems is their seasonal variation. In Europe the 1 kW_p system produces during four summer months May, June, July and August 44 – 72 % of the yearly electricity (Fig. 7.4). The seasonal variability increases from the South to the North; it is also lower in the mountains than in the neighbouring lowlands. The similar variation can be observed within a day. Taking into consideration the daily electricity-production, peaks in early afternoon, the PV can contribute to eliminate peak load problems, such as those originating from the demand of the air-conditioning systems. The variation of the solar electricity generation within the regions of individual countries can be seen on the Figure 7.5.

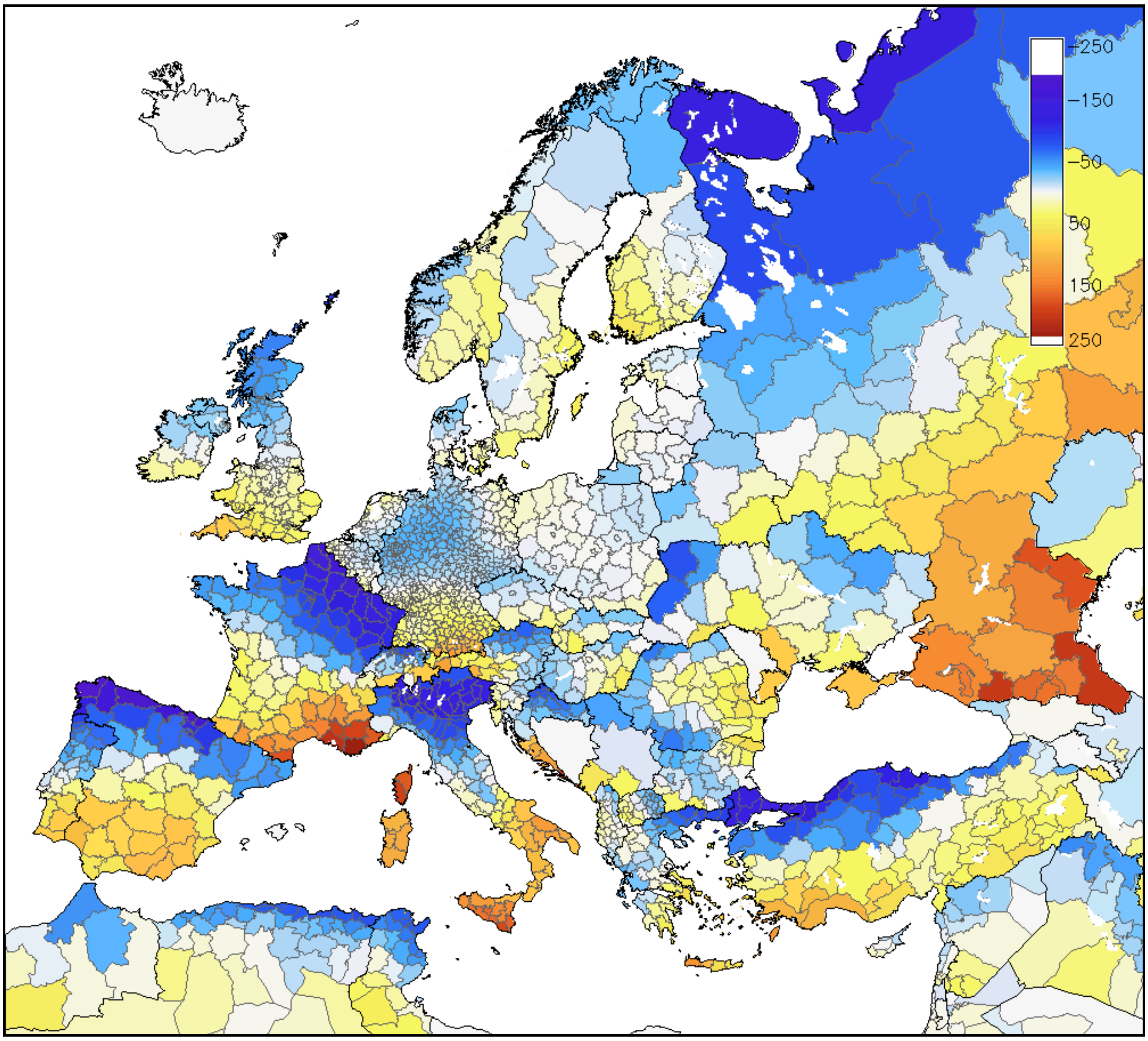


Fig. 7.5: A difference between regional averages in the individual countries, calculated as: 'regional average – national average' [kWh/year]

7.3 PV Electricity in Residential Areas

The PV electricity will come from a large number of small power generators that are distributed dominantly in the residential areas. There are various figures showing the theoretical potential of PV. Our approach was based on geographically distributed data. The density of the residential areas was recalculated to a coarser grid 5× 5 km. To show the distributed electricity generation pattern in the European countries where the CORINE Land Cover data are available, the total yearly yield was calculated (Figure 7.6). In the calculation, it is assumed that in each 1 square kilometer of the residential areas the PV capacity of 1 MW_p has been installed with modules inclined at the optimum angle with assumed overall system performance ratio of 0.75. (The practical consequence of such an assumption can be demonstrated on the example of Slovakia, where average building density is about 400 per 1 km^2 of the residential area. In that case it would mean that each building had installed a 2.5 kW_p PV system.) Coming out of these considerations, the total yearly electricity production of all PV systems within each 5 × 5 km grid cell is determined by the solar radiation potential and the surface of the residential areas. Therefore the most productive cells in the map are generally those with high urban density and favourable climatic conditions.

The summarization of the previous assumptions at the national level (Fig. 7.7) gives an overview of the potential PV capacity and electricity production in the EU25 (with exception of Malta and Cyprus). The calculation shows that covering of only 0.8% of the residential areas, the contemporary available building-integrated PV technology may increase the share of renewables in the electricity supply in the EU25 countries by 1.5-14 percent. Especially in economies with lower electricity consumption per capita (Latvia, Lithuania, Poland, Hungary), this potential is quite high.

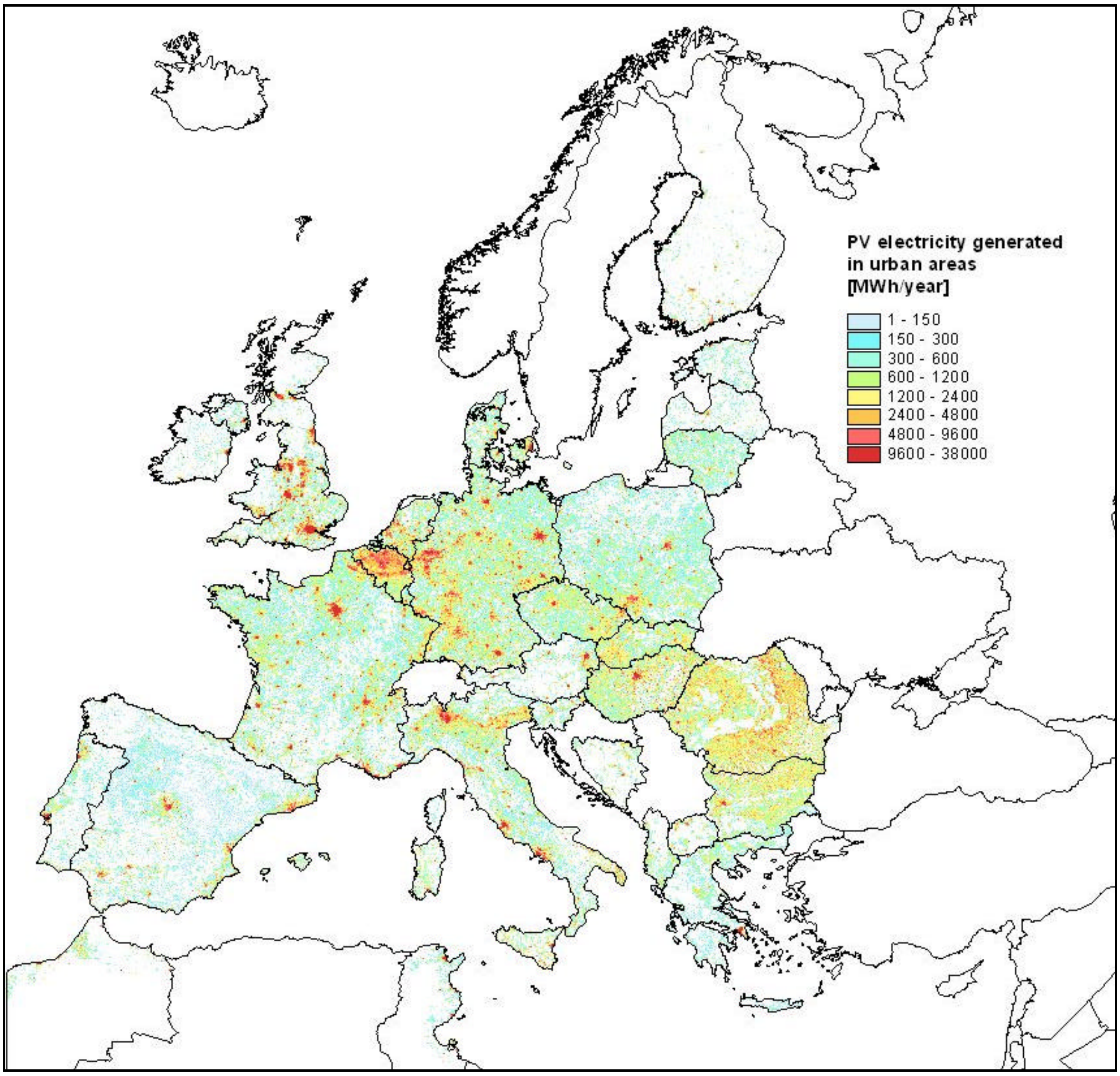


Fig. 7.6: Total PV electricity generation calculated for a grid cell 5 × 5 km, assuming installed capacity of 1 MW_p per each square kilometre of the residential areas [$MWh.year^{-1}$]. Considering the contemporary technology, PV modules of 1 MW_p capacity would cover 0.8% of the surface of residential areas. (The map shows only countries for which the CORINE land cover data were available.)

7.4 PV Capacity Needed to Generate 1% of the National Electricity Consumption

The average electricity generation of a typical 1 kW_p PV configuration in the residential areas (see Figure 7.3) was used to estimate the installed PV capacity that would be needed in each country to reach a share of PV at the national electricity consumption by 1 % (statistics by IEA 2003 [IEA 2003]).

For comparison, in the year 2003, the installed capacity in Germany reached 408 MW_p (see Chapter 6). With the exception of the extreme electricity consumption per capita in Sweden, Finland and Luxembourg (due to energy-intensive industry), the target of reaching 1 % of the electricity consumption from PV in EU25 countries would mean an installation density of about 0.2 – 0.9 m^2 modules per capita (Figure 7.8). This corresponds to what we regularly see installed on roofs, façades and balconies in the form of TV reception dishes.

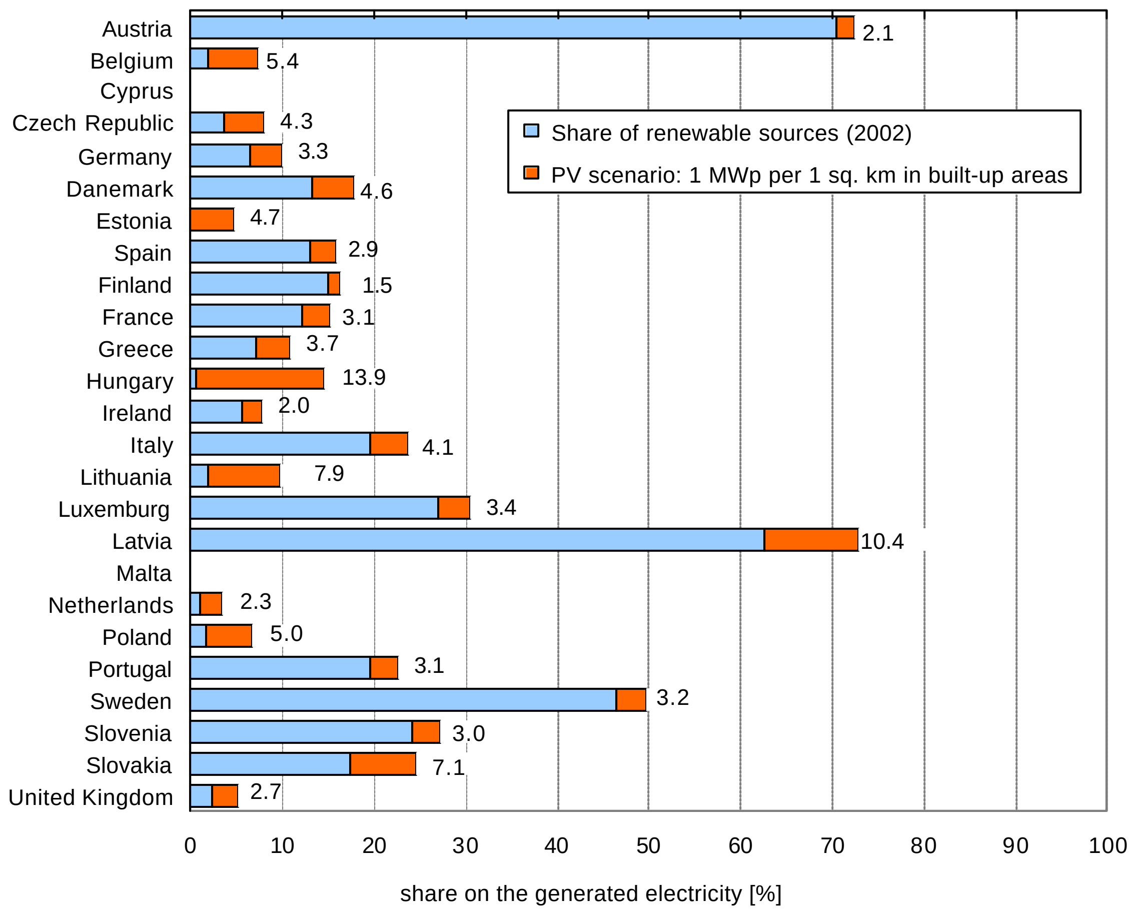


Fig. 7.7: Share of PV electricity in the national electricity consumption for an assumption of 1 MW_p installed capacity per each square km in the residential areas

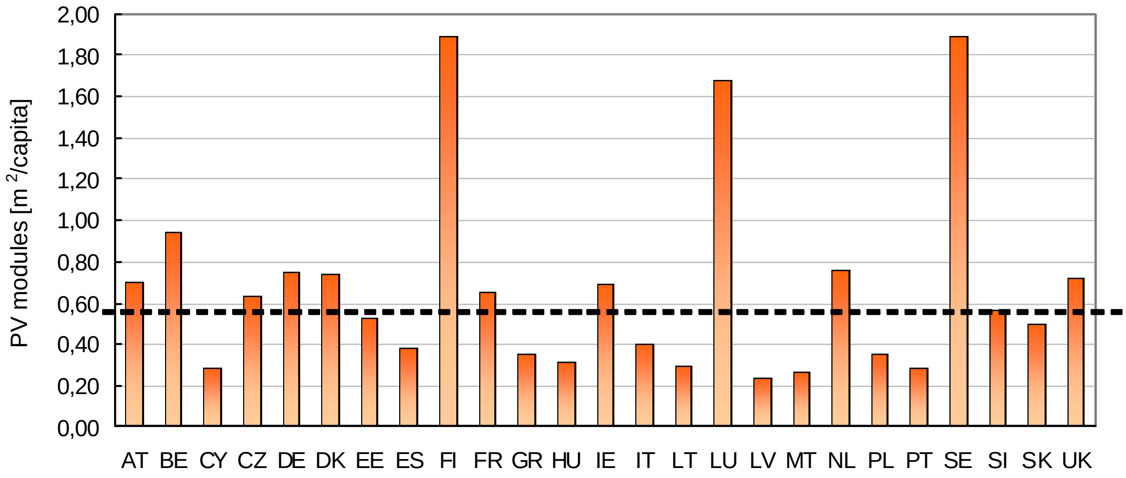


Fig. 7.8: Surface of the modules [m^2 per capita] needed to reach a PV share of 1 % on the national electricity consumption. (The dashed line is an equivalent of an 85 cm diameter satellite dish per capita.)

An installation of PV-modules of the size between 0.25 and 0.9 m^2 per citizen in the European Union would already generate 1% of the national electricity demand. In financial terms this would correspond to an investment by each citizen of the European Union between € 120 and € 430 based on an average module price of 4 €/Wp.

More information, maps and data can be accessed at: http://re.jrc.cec.eu.int/pvgis/pv/.

CHAPTER 8

OUTLOOK AND CONCLUSIONS

Harald Scholz and Arnulf Jäger-Waldau

The analysis of the progress data 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, notably systematically including the New Member States. 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.

8.1 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 ambitious goals of the White Paper [EC 1997]?

Figure 8.1 shows the planned development to reach the White Paper targets on renewable electricity and the actual status for 2003. 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. The following methodology was used to determine the 2003 "status quo" values for the generated electricity:

- Biomass: Here the data availability is very scarce and the 2003 value is an extrapolation of the 2002 value reported by the Communication of the Commission on the 'The share of renewable energy in the EU' [EC 2004].
- Wind: The installed nominal rated capacity of 2002 + 50% of the additional installations for 2003 are multiplied by 2000h 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 2002 + 50% of the additional installations for 2003 are multiplied by 950h of operation.

Table 8.1: 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	2003	2010	1995 to 2010	2004 to 2010
Biomass	23	45	230	17% (actual 9%)	27%
Wind	4	50.8	80	22% (actual 37%)	7%
Photovoltaic	0,03	0,48	3	36% (actual 41%)	30%

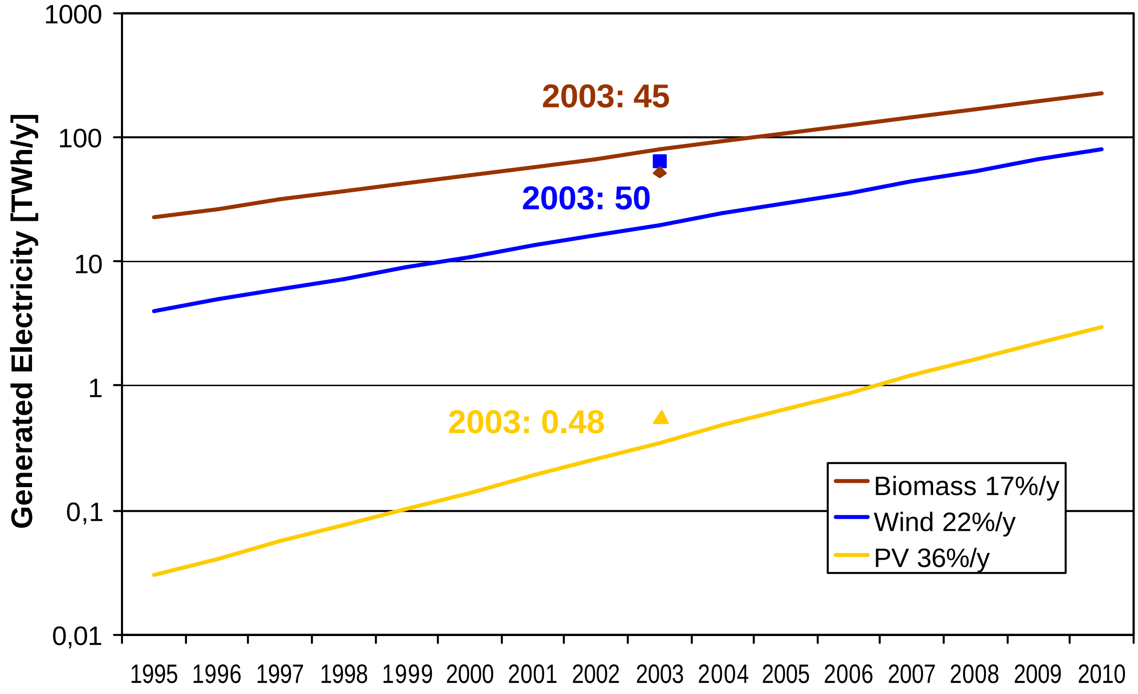


Fig. 8.1: Pathway to reach the White Paper targets and values for 2003. In order to reach the targets biomass must increase by an average of 17%/year (9% until now), wind by 22% (37%) and PV by 36% (42%).

Wind and photovoltaic are well on track to reach the White paper targets by 2010. For wind it can be even expected that it will reach the target already before 2010. However, the main concern is the electricity production from biomass as shown in Table 8.1. Here a major change in the implementation policies is needed in order to come even close to the set targets. As concluded in chapters 2.1.3 and 4.5.3, with the new European Emissions Trading Scheme (EU ETS) coming into force from the beginning of 200 onward, CO_2 emissions from biomass (including biomass co-firing, proportionally) are exempted from the need to use or buy CO2-allowances. This is expected to give an additional incentive also for bio-electricity production and bio-fired CHP in addition to national implementation schemes. The question remaining for the next years is how effective the price development of these allowances will further sustainable energy production, and how much national schemes will use it as an excuse to halt their own support measures.

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 a less output. If these measures are taken biomass could be brought on track for the White Paper targets.

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. The Commission has to bring forward a coordinated biomass plan, with a clear approach to securing adequate supplies of biomass through European, national and regional/local action across them all. The plan must orientate and optimise Community financial mechanisms re-direct efforts within the policies concerned and tackle the obstacles to biomass deployment for energy purposes. 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 at the brink 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. California, where the pricing already reflects the true value of peak-load energy. 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 (see table 2.1), only considering the domestic market. The results suggested that around 530,000 jobs may 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.

8.2 Global

The world-wide growing energy and electricity demand could be supplied by renewable energies as shown in Figure 8.2. 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.

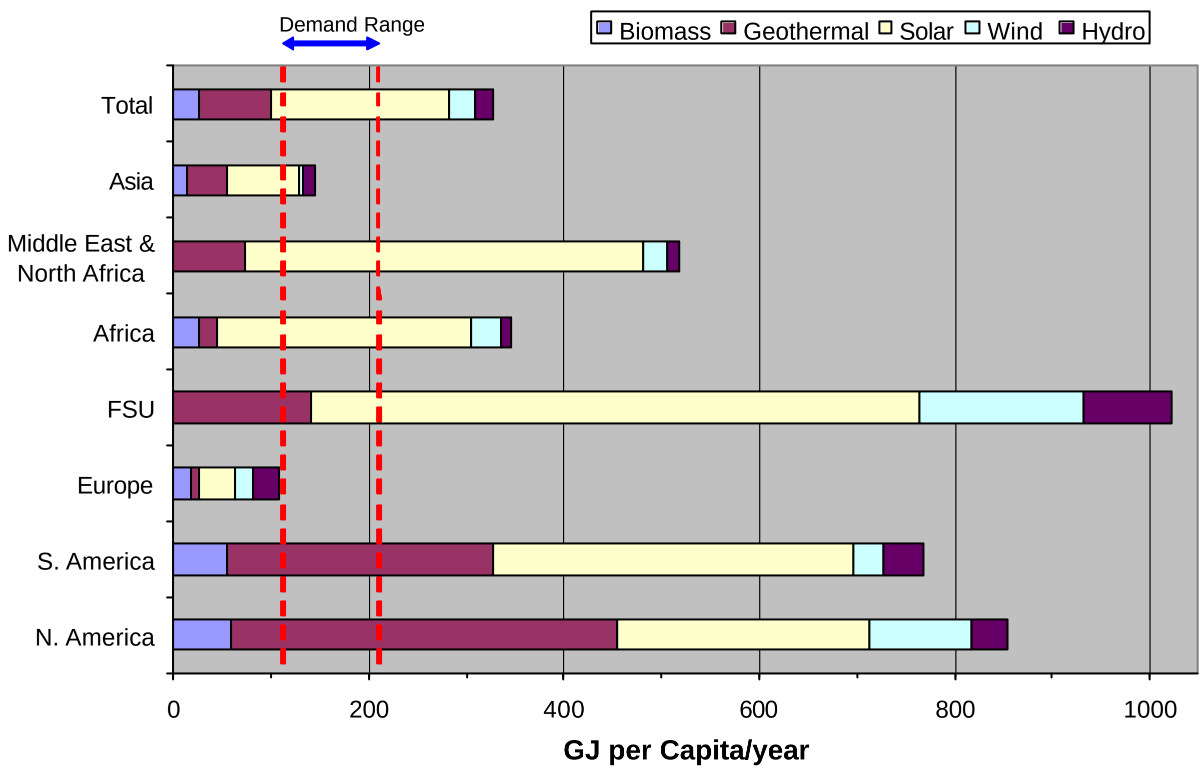


Fig 8.2: Potential of usable renewable energies calculated for a world population of 10 billion people [Joh 2002]

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 2004b] 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.

At the Conference's plenum, EU Commissioner Wallström gave the current analyses of the development versus the White Paper targets; the EU would arrive at only 18%…19% of renewable electricity by 2010, if no further action would be done. She promised more action, though, notably in the biomass field, in order to achieve the targets in time. Moreover, she gave assurance scrutinizing the proposed Berlin-Conference [Ber 2004] target of a 20% share of all renewables in the EU consumption.

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

KEY ENERGY FIGURES

Gross Inland Consumption 2001 [IEA 2003d, EUR 2004]

World	EU 25	EU15
10 029 Mtoe	1 688 Mtoe	1 486 Mtoe
419.9 EJ	70.7 EJ	62.2 EJ

Total Final Consumption 2001 [IEA 2003d, EUR 2004]

	World		EU 25		EU 15	
	[Mtoe]	**[EJ]**	**[Mtoe]**	**[EJ]**	**[Mtoe]**	**[EJ]**
total	6 995	292.9	1 095	45.8	971	40.7
Industry	2 201	92.2	309	12.9	270	11.3
Transport	1 802	75.4	336	14.1	312	13.1
Domestic/other	2 992	125.3	450	18.8	389	16.3
Energy Branch	548	22.9	75*	3.1*	66*	2.7*
Thermal Power Generation	2 486	104.1	518*	21.9*	449*	18.8*
Gross Inland Consumption	10 029	419.9	1 688	70.7	1 486	62.2

* extrapolated

World Oil Demand [IEA 2004a]

2001 average	2004 average	Estimated 2005
75.7 million barrel/day	82 million barrel/day	84 million barrel/day
12 029 million litre	13 038 million litre	13 356 million litre
10.2 Mtoe/day	~ 11 Mtoe/day	~ 11.4 Mtoe/day

Electricity Generation in 2001 [EUR 2003c]

	EU 25 [TWh]	EU 15 [TWh]
Total electricity production	2 851.3	2 543.1
Conventional thermal power plants	1 526.1	1 304.8
Nuclear power plants	904.4	846.7
Hydro and Renewables	410.8	391.6
Absorbed by pumping	39.1	35.1

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 2001 [IEA 2003d, EUR 2004]

	EU 25 [Mt]	EU 15 [Mt]
Total GHG emissions in CO_2 equivalent	4 861.7	4 116.1

	World [Mt]	EU 25 [Mt]	EU 15 [Mt]
Total CO_2 emissions	23 683	4 021.6	3 430.2
Emissions by sectors			
Electricity and Heat		1 342.8	1 054.9
Energy branch		164.7	142.8
Industry		667.9	573.0
Transport		979.5	910.2
Other		866.7	749.3

TABLES

Table A.1 Bioelectricity support mechanism in the EU-25 ([EC 2004a, Rei 2003 & 2004, Vri 2003, WWF 2004, App 2004] and other national RES-E law documents, personal communications). [ct = € cent]

Country	Dominating support mechanism for bioelectricity	other instruments available
Austria	**feed-in tariff:** for solid biomass and waste with large biogenic fraction: 10.2–16.0 ct/kWh (10–2 MW), 6.5 ct/kWh (hybrid plants); fuels incl. biogenic wastes: 6.6 - 12.8 ct/kWh (10 - 2 MW), 4.0 - 5.0 ct/kWh (hybrid plants); liquid biomass < 200 kW 13.0 ct/kWh, > 200 kW 10.0 ct/kWh; biogas 10.3 - 16.5 ct/kWh; sewage and landfill gas 3.0 - 6.0 ct/kWh	investment subsidy of about 30% on project basis
Belgium	**green certificate/quota obligation system or minimum feed-in tariff** (TGCs replacing the Green Franc system)**:** minimum prices are for biomass 2 ct/kWh [EC 2004]/ 2.5 ct/kWh [Vri 2003]; projects implemented before 2003 receive support for 10 years	fiscal measures and investment support schemes
Denmark	**feed-in tariff:** a settlement price for solid biomass is 4 ct/kWh and it is guaranteed for a period of 10 years, additionally as a guarantee these plants receive 1 ct/kWh in compensation for an RE certificate; for biogas the settlement price is 4 ct/kWh and for waste 1 ct/kWh	investment subsidies, political obligations have been imposed on electric power utilities to use certain amounts of biomass
Finland	**energy tax refund** for biomass 4.2 €/MWh (0.42 ct/kWh)	investment subsidy of 30% for new investments
France	**feed-in tariff** guaranteed for 15 or 20 years: installations <12 MW for biomass: standard rate of 4.9 ct/kWh, premium up to 6 ct/kWh; sewage and landfill gas: standard rate of 5.5 ct/kWh, premium up to 6 ct/kWh; MSW standard rate of 3.5 ct/kWh, premium up to 4 ct/kWh; installations >12 MW tender system & feed-in tariff	also investment compensation schemes in place
Germany	**feed-in tariff** for biomass: 1) up to 150 kW 11.5 ct/kWh, 2) 150 – 500 kW 9.9 ct/kWh, 3) 500 kW – 5 MW 8.9 ct/kWh, 4) 5 – 20 MW 8.4 ct/kWh; Additional payments between 2 and 6 ct/kWh are possible under certain conditions, e.g. that only unprocessed biomass, liquid manure etc. are used. If the biomass is used in CHP plants an additional payment of 2 ct/kWh is paid. Landfill and sewage gas: up to 500 kW 7.67 ct/kWh, 501 kW - 5 MW 6.65 ct/kWh For new plants the quoted minimum tariffs are reduced each year by 1.5% starting 1 January 2005.	investment subsidy
Greece	**feed-in tariff:** 7.8 ct/kWh on the islands and 7 ct/kWh on the mainland	investment subsidies of about 30 (-50) %

Ireland	**tendering/bidding scheme:** current biomass support level (bid price) is ranging 6.4 -7 ct/kWh (biomass 6.412 ct/kWh up to 8 MW, biomass-CHP 7.0 ct/kWh up to 28 MW and biomass-AD 7.0 ct/kWh up to 2 MW)	
Italy	**tradable green certificate/quota system** with obligated targets: relatively favourable certificate prices up to 8.4 ct/kWh (certificates are only issued for plants with production of more than 50 MWh/year)	investment subsidies ranging within 30-40%
Luxembourg	**feed-in tariff:** for biomass and biogas 2.5 ct/kWh up to 3 MW for a period of 10 years	investment subsidy up to 40 % of investments possible
Netherlands	**feed-in tariff:** tariffs for 2004 (from 1st of July onwards) for mixed biomass and waste 2.9 ct/kWh (in 2005 2.9 ct/kWh), pure biomass large scale 5.5 ct/kWh (2005 7.0 ct/kWh), small-scale biomass <50 MWe 8.2 ct/kWh (2005 9.7 ct/kWh)	tax incentives (eco-tax exemption being phased out)
Portugal	**feed-in tariff:** for biomass in 2003 were 6.2 ct/kWh	investment subsidies (subsidies generally 40% of the investment) and tax deductions/credits available
Spain	**feed-in tariff:** generally specified for plants up to 50 MW, installations built after 28.3.04 must choose either to sell electricity to distribution company (regulated tariff up to 6.7 ct/kWh) or to sell it freely in the market (full market option up to 7.1 ct/kWh); existing plants before 28.3.2004 may choose the transitory regime (with certain premiums, prices up to 7.2 ct/kWh) or be fully covered by the new regime set out by the Royal Decree 436/2004	investment subsidies and fiscal instruments
Sweden	**green certificate/quota system:** expected prices are in the range 1.3 - 1.6 ct/kWh for certificates traded (there is minimum price starting 0.66 ct/kWh and a penalty level of 150% of the average price in a year (set at 2.63 ct/kWh in 2004), price is guaranteed for producers up to 2007	investment subsidy to CHP plants based on biomass (of about 330 €/kW_e or a max. of 25% of the total capital cost of the project) + energy tax exemption for small-scale RES-E producers
United Kingdom	**green certificates/quota obligation:** non-compliance penalty/'buy-out' price for 2003-3004 is set at approx. 4.5 - 4.8 € ct/kWh (GBP 30.51) + Climate Change Levy: RES-E is exempted from the CCL on electricity of appr. 0.63 ct/kWh (0.43 pc/kWh)	investment subsidies (grant schemes) : funds for energy crop/biomass power generation investments and planting grants for energy crops
Cyprus	**feed-in tariff:** for biomass, landfill and sewage: 6.3 ct/kWh (3.7 cyp. cent/kWh) (a fixed purchase price for RES is 6.3 ct/kWh (3.7 cyp. cent/kWh). In addition to that there is a special premium depending on the technology used from a Special Fund, financed by a levy on electricity consumption.	financial incentives in the form of governmental grants (30-40% of the investment) for investments in biomass, landfill and sewage waste systems

Czech Republic	**feed-in tariffs:** for RES-E and cogeneration (annually adjusted minimum tariffs), minimum prices for 2004: for biomass and biogas plants commissioned before 1.1.2004 7.69 ct/kWh; biomass co-firing (with coal) 6.15 ct/kWh; biogas after 1.1.2004 7.38 ct/kWh + tax exemption up to 5 years for RE investments (quota obligation/green certificate system might be introduced earliest from the beginning of 2005) (exchange rate 1€ = 32.5 CZK)	bonus for decentralised production: 0.06 ct/kWh on 110 kV, 0.08 ct/kWh on high voltage, 0.02 ct/kWh on low voltage; investment subsidies from different funds (e.g. for RES CHP)
Estonia	**feed-in tariff:** 5,2 ct/kWh (electricity price for all renewable energy is 1.8 times the residential price), price is paid for 7 years for biomass [WWF 2004]: 4.86 ct/kWh	0% VAT for renewable energies
Hungary	**feed-in tariff:** in 2004 18.25 HUF/kWh = 7.3 eurocents/kWh (exchange rate 1 € = 248.4 HUF), it is guaranteed untill 2010 and without differentiation between technologies (peak and off-peak price are different)	investment subsidies, VAT on energy is 25 %
Latvia	**feed-in tariff:** currently for power plants using waste or biogas equals to the average electricity sales tariff for 8 years period (up to 7 MW, operation started by 1.1.2008) = 5.23 ct/kWh + support scheme for biomass CHP (using peat or wood, other biomass or biogas): remuneration <0.5 MW_e 5.86 ct/kWh, 0.5 - 4 MW_e 4.97ct/kWh	quota system for RES-E (annual capacity limits for the installation of RES-E generation) + long-term loans on favourable conditions for projects in private and public sectors
Lithuania	**feed-in tariffs:** prices for electricity produced from renewable energy sources are set by Resolution No. 7 of 11 February 2002, for power plants using biofuel 20 LTLc/kWh = 5.7 - 5.8 ct/kWh (calculated with a rate 1€ = 3.45 LTL; waste collection included), for other power plants using RE or waste energy sources the price is set by separate decision	
Malta	no support scheme	
Poland	**quota system:** electricity utilities are required to maintain a renewable energy portfolio (of at least 2.65 % in 2003, and 7.5% in 2010 and in the following years) (not currently supported by a scheme of green certificates trading)	environmental funds (with grants and loans) supporting RES as well as low interest credits; tax relief in agricultural production related using RES
Slovak Republic	**feed-in tariffs:** tariff level for all RES recently at the level of 3 ct/kWh (3.03 - 3.51 ct/kWh [WWF 2004]) (no differentiation between technologies)	investment subsidies for RES projects + VAT reduction (proposed from 14% to 10% on all RES equipment)
Slovenia	**feed-in tarif:** for biomass up to 1 MW 6.98 ct/kWh; biomass above 1 MW: 6.76 ct/kWh (valid from April 2002); the qualified producer can choose instead market price + bonus (for biomass 3.50 - 3.28 ct/kWh OR they can choose a time-of-delivery tariff (or bonus))	CO_2 -tax introduced in 1996 amounts to 15 €/t CO_2 [Rei 2003]: 13.5 ct/kWh (3 SIT/kg CO_2))

Table A.2 Energy and electricity production potentials from biomass in EU Member States [Bau 2004]

	Energy potential from residues (PJ) [1]	**Energy potential from energy plantations [PJ)**[1]	**Potential electricity production from biomass (PJ) in 2020**	***Potential electricity production from biomass (GWh_e) in 2020*** [2]
Austria	246	40	101	9 825
Belgium-Luxembourg	104	12	38	3 684
Denmark	115	23	52	5 046
Finland	670	192	360	34 976
France	1 113	257	536	52 075
Germany	1 107	170	438	42 607
Greece	118	73	102	9 937
Ireland	63	10	26	2 536
Italy	415	151	255	24 814
Netherlands	92	9	32	3 149
Portugal	172	43	86	8 363
Spain	460	234	349	33 957
Sweden	739	231	416	40 431
United Kingdom	411	69	172	16 702
EU-15	**5 825**	**1 514**	**2 963**	**288 102**
Czech Republic	243	45	92	8 945
Hungary	229	52	109	10 609
Poland	611	176	329	31 959
Slovakia	128	27	73	7 066
EU-4	**1 211**	**300**	**603**	**58 579**

1) See more detailed conditions for energy potential calculations in [Bau 2004]
2) Energy production: 25 % residues + 5 % of crop, forest and woodland at 150 GJ/ha (10 t/ha year) (assumes electrical efficiency of 35 %). Note that this does not take into consideration any biomass resource use for production of transport fuels.

Table A.3 Support mechanisms for Wind Energy [ct = € cent]

Austria	7.8 ct/kWh for new plants
Belgium	Feed in tariff: Wind offshore**:** 9 ct/kWh; Wind onshore**:** 5 ct/kWh
Cyprus	Feed in tariff: first five years: 9.2 ct/kWh (5.4 cyp. cent), for the next 10 years: 4.8 ct/kWh to 9.2 ct/kWh (2,8 to 5.4 cyp. cent/kWh) according to the mean annual wind speed.
Czech Republic	Feed in tariff: 9.6 ct/kWh Tax incentives: Tax relief up to five years (concerning income and property) for investment in renewable energy. The import duty on renewable-energy-equipment is reduced. Low VAT rate (5% instead of 22%) for small facilities (wind: 0.075 MW).
Denmark	**Onshore:** New installations receive spot price plus (on a monthly basis) an environmental premium (maximum of 1.3 ct/kWh) plus a compensation for offsetting costs (0.3 ct/kWh), in total limited to 4.8 ct/kWh. Turbine owners are responsible for selling and balancing the power. The tariff can be well below the 4.8 ct/kWh in times of a low spot price. The tariff is insufficient to attract new investments. **Offshore:** New installations receive spot price plus (on a monthly basis) an environmental premium (maximum of 1.3 ct/kWh) plus a compensation for offsetting costs (0.3 ct/kWh), in total limited to 4.8 ct/kWh. Turbine owners are responsible for selling and balancing the power. The tariff can be well below the 4.8 ct/kWh in times of a low spot price. Tendering procedure planed but conditions are currently under discussion.
Estonia	Electricity Market Act (EMA): electricity price for renewable energy 1.8 times the residential price, so the price for renewable energy is: 5.2 ct/kWh. This price is paid for 12 years. The EMA has come into force on July 2003. Sales Tax Act: 0% VAT for renewable energies.
Finland	Exemption from energy tax for renewable electricity. Unlike electricity from fossil or nuclear sources renewable electricity is exempted from the Finnish energy tax paid by end-users. This brings the following benefits for wind: 6.9 ct/kWh Investment subsidies of 40% are available for new investments in wind.
France	8.5 ct/kWh for the first 5 years, then 6.5 ct/kWh up to 10 years after installation and 3€ ct/kWh for a further 5 years. A tendering system is in place for renewable energy installations > 12 MW. Tenders follow an open bidding procedure, where the winner is awarded a guaranteed-price contract. The tariff contracted depends on the bid. Calls for projects have published for biogas, wind onshore and wind offshore with a total power capacity of 250 MW.
Germany	Feed in tariff: **Onshore:** min. 5.5 ct/kWh if the plant produces at least 60% of the reference output. If the plant produces more than 150% of the reference output an additional 3.2 ct/kWh are paid for 5 years. This tariff is reduced by 2% each year starting 01/01/2005. **Offshore**: min. 6.19 ct/kWh; all plants which go into operation before 31/12/2010 receive an additional 2.91 ct/kWh for 12 years after commission-

	ing. This period of time is extended for those plants constructed in a distance of more than 12 sea miles and more than 20 m water depth. Each additional sea mile extends the period by 0.5 months and each additional meter water depth by 1.7 months. The minimum tariff for offshore plants is reduced by 2% each year starting 01/01/2008.
Greece	Law 2244/94 (feed-in tariff) and Law 2773/1999 (liberalisation) (Feed-in tariff of a bout 7,8 ct/kWh on the islands and 7 ct/kWh on the mainland). Development Law 2601/98. The Law supports investment activities (including energy investments) of private companies (investment subsidy of about 30%). The Operational Programme 'Competitiveness' of the Hellenic Ministry of Development is part of the 3rd Community Support Framework (State aid for RES investments, ranging from 30 to 50%). Law 2364/95 introduces a reduction of the taxable income of final users installating renewable energy systems in private buildings (75% of costs for purchase and installation is tax-deductible).
Hungary	Ministerial Decree 56/2002: Guaranteed feed in tariff (on indefinite term), beginning in January 2003, all energy generated from renewable energy resources must be purchased between 6 and 6.8 ct/kWh, not technology specific.
Ireland	Alternative Energy Requirement tender scheme. Targets and purchase prices: Large-scale wind: 5.216 ct/kWh up to 400 MW Small-scale wind: 5.742 ct/kWh up to 85 MW Offshore wind: 8.4 ct/kWh up to 50 MW; indicative price cap only
Italy	So far investment subsidy and certificate scheme, but a feed-in law was passed in February 2004. Regulations and tariffs are not defined yet, but are expected for 2005.
Latvia	Law on Energy: With the amendment adopted in 2001 that phased out the so-called double tariff by 1st January 2003, regulations fixing the total capacity for installation and specific volumes for next year are annually published. The annual purchase tariff for wind power plants are approved on a case-by-case basis by the regulator.
Lithuania	Feed-in tariff: 0.075€/kWh. Resolution No. 1474 of 5 December 2001: Procedure for promotion of purchasing of electricity generated from renewable and waste energy sources.
Luxembourg	Feed-in with quota (1% of total energy consumption). 1 kW – 3 MW 2.5 ct/kWh for 10 years.
Malta	At present Malta is formulating a strategy for renewable energy for the Maltese Islands.
Netherlands	The policy programme MEP to support renewable energy investments is in operation since 1 July 2003. The 2005 subsidies are higher because of the phasing out of the eco-tax). Wind on-shore 6.3 ct/kWh (2004) 7.7 ct/kWh (2005) Wind off-shore 8.2 ct/kWh (2004) 9.7 ct/kWh (2005)
Poland	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). Green Power Purchase Obligation.

Portugal	Feed-in tariff: First 2000 hours 8.3 ct/kWh From 2000 to 2200 hours 7.0 ct/kWh From 2200 to 2400 hours 6.0 ct/kWh From 2400 to 2600 hours 5.1 ct/kWh Above 2600 hours 4.3 ct/kWh
Slovakia	No specific wind energy programme. Tax deduction on income earned.
Slovenia	Feed-in tariff: up to 1 MW: 6.33 c/kWh; above 1 MW: 6.11 c/kWh CO_2 tax introduced in 1996 amounts to 15 €/t CO_2.
Spain	Feed-in tariff with cap of 13,000 MW: Royal Decree 436/2004, 12/03/2004 The regulation offers two tariff options: 1) fixed tariff in percent of the electricity sector's average tariff (TMR) TMR = 8.52 ct/kWh in 2004 ≤ 5 MW 90% TMR for first 15 years, than 80% > 5 MW 90% TMR for first 5 years, 85 for next 10 years and 80% after 2) trading production on pool market plus incentive in % of TMR - variable pool price + 50% TMR premium
Sweden	Electricity certificates for wind, solar, biomass, geothermal and small hydro were introduced in May 2003. The system has created an obligation for end-users to buy a certain amount of renewable certificates as part of their total electricity consumption (increasing to 17% in 2010). Non-compliance leads to a penalty which is fixed at 150% of a year's average price. To secure a smooth transition, price guarantees are available for producers up to 2007. Within the system prices will be settled by supply and demand. Forecasts show expected prices in the range of 1.3 – 1.6 ct/kWh for certificates traded. For wind energy investment grants which offer 15% reduction of costs are available. As transition measure, an environmental bonus for wind is also available. This bonus has a value of 1.9 ct/kWh in 2004 and will gradually decline to 0 in 2007. Furthermore exemptions for renewables on environmental taxes are applicable, which provide a benefit of around 1.79 € /toe for renewables used for transport or heat supply.
United Kingdom	Obligatory targets with tradable green certificate system. The non-compliance 'buy-out' price for 2003-2004 is set at £30.51/MWh (approx. 4.5 ct/kWh). This buy-out price will be annually adjusted in line with the retail price index. Climate Change Levy: renewable electricity is exempted from the climate change levy on electricity of 0.43 p/kWh (approx. 0.63 ct/kWh)..

Table A.4 Support mechanisms for Photovoltaic [ct = € cent]

Austria	Feed-in tariff paid for 20 years with cap of 15 MWp, but only for systems installed in 2003 and 2004 (cap was reached after already four weeks); 0.6 €/kWh < 20 kWp, 0.47 €/kWh > 20 kWp
Belgium	Feed-in tariff: 0.15 €/kWh
Cyprus	Feed-in tariff: 0.12 – 0.26 €/kWh and investment subsidies up to 55% for private investors and up to 40% for companies.
Czech Republic	Feed-in tariff: 6 CZK/kWh (0.2 €/kWh). Reduced VAT (5% instead of 22%) and subsidies (up to 2 kWp for private and 20 kWp for legal entity investors).
Denmark	No specific PV programme, but settlement price for green electricity.
Estonia	No specific PV programme but Renewable Portfolio Standard. Sales Tax Act: 0% VAT for renewable energies.
Finland	Investment subsidy up to 40%.
France	Feed-in tariff: 0.15 €/kWh < 12 MW for 20 years; lower VAT on investments
Germany	Feed-in tariff for 20 years with build-in annual decrease of 5% from 2005 onward. For plants, neither on buildings nor sound barriers, the decrease will rise to 6.5% from 2006 onward. 0.457 €/kWh minimum; on buildings and sound barriers 0.574 €/kWh < 30 kWp, 0.546 €/kWh > 30 kWp and 0.54 €/kWh > 100 kWp, for façade integration there is an additional bonus of 0.05 €/kWh.
Greece	Feed-in tariff: 0.078 €/kWh on islands and 0.07 €/kWh on the mainland. Grants for 40-50% of total cost. Holds only for commercial applications >5 kW, no grants for domestic applications. Law 2364/95 introduces a reduction of the taxable income of final users installing renewable energy systems in private buildings (75% of costs for purchase and installation is tax-deductible).
Hungary	Ministerial Decree 56/2002: Guaranteed feed in tariff (on indefinite term), beginning in January 2003, all energy generated from renewable energy resources must be purchased between 6 and 6.8 ct/kWh, not technology specific. Subsidies for renewable energy projects.
Ireland	Alternative Energy Requirement tender scheme (no targets for PV).
Italy	So far investment subsidy, but a feed-in law was passed in February 2004. Regulations and tariffs are not defined yet, but are expected for 2005.
Latvia	Feed-in tariff: double the average sales price (currently 0.146 €/kWh) for eight years, then reduction to normal sales price. A national investment programme for RES runs since 2002.
Lithuania	Feed-in tariff: 0.056€/kWh
Luxembourg	Feed-in with quota (1% of total energy consumption). < 50 kWp: municipalities 0.25 €/kWh and private investors: 0.45 €/kWh (after the revision of the law in January 2004); in addition investment subsidies up to 40% possible (this was also reduced for systems > 10 kWp).
Malta	No specific PV programme yet, but reduced VAT 5% instead of 15%.
Netherlands	Feed-in tariff: 0.068 €/kWh

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	Feed-in tariff: 0.41 €/kWh < 5 kWp and 0.224 > 5 kWp. In addition investment subsidies and tax deductions are available
Slovakia	No specific PV programme. Tax deduction on income earned.
Slovenia	Feed-in tariff: 0.37 €/kWh < 36 kWp and 0.065 €/kWh > 36 kWp.
Spain	Feed-in tariff with cap of 150 MW: 0.396 €/kWh < 100 kWp (previously limited to 5 kWp systems), with payment on 80 percent of rated power output beyond that; > 100 kWp 0.216 €/kWh. Duration of payment 20 years.
Sweden	No specific PV programme. Electricity certificates for wind solar, biomass, geothermal and small hydro. Energy tax exemption.
United Kingdom	Investment subsidies in the framework of a PV demonstration programme. Reduced VAT.

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