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bericht

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Case Study Paper

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Renewable energies – environmental benefits, economic growth and job creation

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Inhalt

1. Introduction

It is generally agreed that the enhanced deployment of renewable energies sources (RES) is a crucial measure for the improvement of environmental protection and the enhanced security of energy supply. In this context, the European Union has set defined objectives within the Green Paper "Towards a European strategy for the security of energy supply" from 1997 to increase the share of renewable energy of total energy consumption from 6 % in 1997 to 12 % in 2010 (EU15).

The potential contribution to innovation, economic growth and creation of new jobs is another aspect, which has gained importance in the debate on renewable energies. More than 100.000 new jobs that have been created in the German renewable energy industry during the last 10 years raise hope that the renewable energy industry could be a job motor for many countries in the EU.

Thus, it seems at first sight that renewable energies can guarantee both – protection of the environment and economic growth and job creation. Therefore, the deployment of renewable energies seems to be the ideal solution to achieve the goals set in the Lisbon Agenda - i.e. environment, economic growth and job creation.

To identify those policy measures which can contribute to the attainment of these goals by the promotion of renewable energies, a close and critical look on the assumptions concerning the advantages of RES is inevitable. First of all, this requires a good understanding of the influence of RES on the environment and the macroeconomic effects of the promotion of RES. Chapter 2 and 3 are dedicated to these two aspects whereas the policy instruments for the promotion of RES are presented and assessed with regard to specific criteria of success in chapter 4. This chapter also includes a paragraph where the dispute on quotas versus feed-in tariffs is illuminated due to the current discussion. This chapter is completed by the presentation of the development of the promotion of wind energy in Denmark during the last two decades is presented as a case study.

The results enter into the final recommendations for the design of policy concepts for the promotion of RES that enables policymakers to establish successful strategies and minimize possible negative effects.

2. Environmental effects of renewable energy utilisation

The deployment of renewable energy is very often pointed out as one of the most important steps on the way to a more sustainable future for Europe. Wind power, solar and geothermal power and heat, biofuels and other forms of renewable energy are often called “green”, for they are believed to have no adverse effects to the environment. Even though this is only partially true, generation of power and heat from renewable sources per se has indeed very little impact on the environment in terms of emissions of polluting substances, unlike the conventional fossil fuel-based technologies.

It is important to understand, however, that in order to produce the conversion technologies, install them, operate, maintain and dismantle them, a broad spectrum of activities and industries needs to be involved. Thus, in order to assess the environmental impact of renewable energy utilisation, one needs to take into account several points:

- Impact needs to be measured in **comparison** to the source of energy substituted
- A **life cycle assessment** is necessary to reflect the actual impact of renewable energy technologies (RET). This implies following all environmental effects (emissions, acidification, eutrophication, etc.) of the energy chains from the manufacturing of the technology through the generation to the delivery of the respective energy service to the customer. Some older studies include data only for the generation of electricity or heat through the use of the respective technology (for example, IEE, 1994). Such a methodology tends to underestimate negative effects of RET and presents them as neutral to the environment.
- A life cycle assessment needs to include also the emissions and other effects inflicted by power generation from other, usually conventional fossil fuel sources, due to the **intermittent** character of some RES. For example, gas turbines or coal-based thermal power stations are usually used to complement power generation from wind.

This does not mean to say that renewable energy utilisation is not an ‘environmentally friendly’ option for the power, heat and transport sectors, in comparison to conventional fossil fuel technologies. On the contrary, emissions and other negative impacts to the environment are certainly lower for renewable energy technologies. Due to the generally higher costs of these technologies, however, it is important to be able to compare the costs and benefits of the introduction of these sources in the European energy mix. Therefore, it is necessary for decision makers to understand the extent of the possible environmental benefits of different RE deployment strategies.

This chapter aims at providing an overview of the latest research in the field. The first part is concerned with general environmental and nature conservation issues related to RE. The second part focuses in more detail on the currently most important environmental issue, reduction of CO_2 emissions due to the substitution of fossil fuel technologies with RET. It compares on the one hand the results of different methodologies and assumptions and on the other the estimated effects of different policy options.

2.1 Comparison of the environmental effects of renewable and conventional energy utilisation

It is certainly difficult to compare renewable with conventional energy technologies in general. The comparison depends on a large number of context dependent parameters, (BMU 2004, 13) e.g.:

- the technology configuration examined (e.g. polycrystalline, monocrystalline or amorphous silicon or thin-film solar cells, steam turbine or combustion engine CHP units, etc.);
- the type of energy source used, especially in the case of biomass, and its specific properties (fuel inventory, transport distances, etc.);
- the geographical location, topographical situation and local conditions of the plant (crucial for solar radiation, full-load hours, expenditure on barrages for hydro power, etc.) and
- integration in the local infrastructure (e.g. integration of photovoltaic in the building).

Nevertheless, some general trends can be noticed, even if through a qualitative, rather than a quantitative comparison. Table 2-1 provides a gross survey of the scale of impacts from different RET in comparison with the effect from conventional technologies. The methodology is adopted from a table in a report by the Watt Committee on Energy (1991, cited in IEE 2004, p.), and somewhat changed as to include the whole lifecycle of energy production, rather than just the power generation component. This is a more comprehensive approach, taking into account the so-called energy chains or fuel chains, as used for example by Nitsch for Germany and by E4Tech for the United Kingdom. (Nitsch et. al., 2005; E4Tech, 2003; IEA 2002, p.5). It includes the technical properties of the renewable energy systems as well as of the “background systems”[1]. It takes into account fuel cultivation, harvesting, collection, transportation and processing, as well as power plant construction, operation and decommissioning.

[1] Systems that do not form a direct part of the system investigated, but are necessary for its creation, use or disposal, for example the power stations for the provision of production energy (BMU 2004, p.12)

	Source	Wind		Solar		Hydro		Geothermal		Biomass		Conventional		
Effect	Technology	Onshore	Offshore	PV	Thermal	Large	Small	Hot dry rock	Aquifers	Gasification	Combustion	Coal	Gas	Nuclear
Air	Emissions	0	0	S	0	0	0	0	0	S	S	L	L	S
	Aesthetics and noise	M	S	0	0	0	0	S	S	0	0	L	L	L
Soil	Sterilisation	S	0	0	0	M	0	S	S	L	L	M	M	M
	Erosion	0	0	0	0	M	0	0	0	+	+	M	M	M
Water	Flow	0	0	0	0	L	S	0	0	0	0	M	S	L
	Pollution	0	0	S	0	0	0	S	S	S	S	L	L	L
Other	Climate change	0	0	S	0	0	0	0	0	S	S	L	L	S
	Biodiversity	S	S	0	0	M	S	0	0	S	S	S	S	L
	Materials	M	M	S	S	M	0	0	0	0	0	M	M	M
	Catastrophes	0	0	0	0	L*	0	0	0	0	0	M	S	L**
	Finite ES	S	S	0	0	0	0	0	0	0	0	L	L	L
	Wastes	0	0	0	0	0	0	0	0	S	S	L	S	L

Table 2-1: Qualitative analysis of the environmental effects of some renewable and conventional energy chains

+ - positive effect
0 – no effect
S – small-scale negative effect
M – medium-scale negative effect
L – large-scale negative effect

2.1.1 Effects of renewable energy utilisation on air quality

The first type of environmental effect, emissions of polluting substances, is the main reason for critique of fossil fuel-based energy production. Impacts on air quality from the utilisation of renewable energy sources and all supporting activities are generally lower than from conventional energy chains. An exception is the possible higher contribution to summer smog of waste wood-based power and straw-based heat generation.

Figure 2-1, Figure 2-2 and Figure 2-3 provide a comparison between the emissions of three GHG gases from renewable and conventional sources for electricity production based on a life cycle analysis (without co-generation (CHP)).

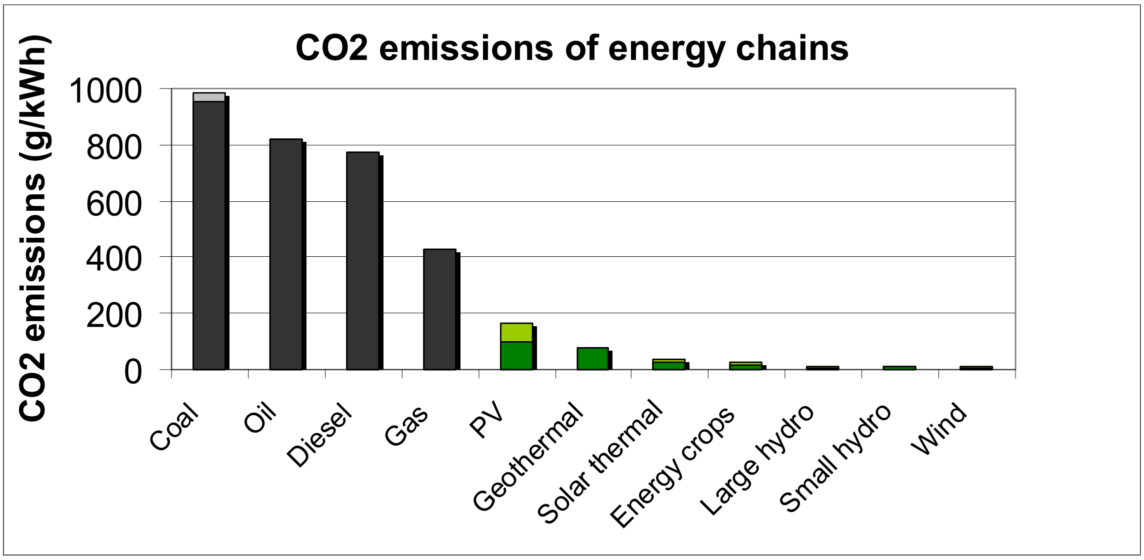
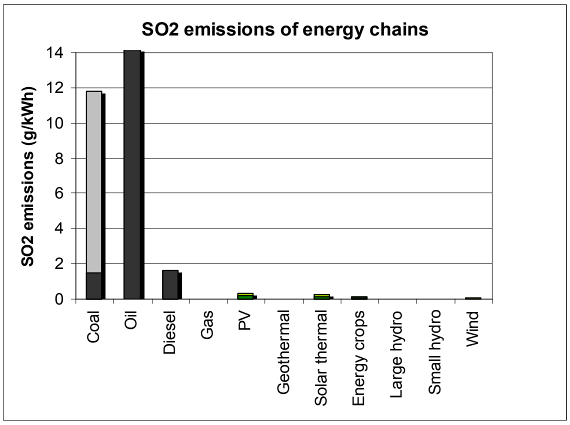


Figure 2-1 [2]



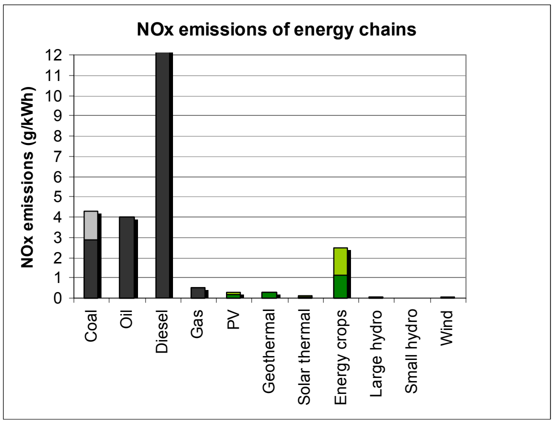


Figure 2-2 [2]

Figure 2-3 [2]

The only instance when emissions from renewable energy (RE) may in some cases be higher than from fossil fuels is in the case of NO_x from energy crops in comparison to combined cycle gas turbines. Even so, the CO_2 and SO_2 emissions of energy crops are more than ten times lower than those of natural gas and by far offset the difference in NO_x quantities. Emissions from biomass utilisation are usually due to the agricultural support system and the transportation of the biomass from the source to the processing plant. These characteristics do not apply for any other renewable energy sources (RES).

The main sources of pollution from the wind and photovoltaic energy chains come mainly from the demand for raw materials and from the steel industry. It is impossible to give a generalised account of the emissions per kWh from wind, if one considers also the impact of the sources used to fill in the generating capacity whenever winds are not strong e-nough. Such emission levels depend strongly on the specific wind potential dynamics of

[2] Sources[2]: IEA 1998, ETSU, Cited in IEA 2002, p.6

the area, as well as on the back-up energy source used. Coal and diesel, though currently cheaper than gas, would necessarily increase the emissions of the generation cycle much more.

In the case of geothermal energy, in comparison, possible pollution levels are endogenous to the source itself. Hot water heated up deep in the Earth's crust carries dissolved chemicals, such as CO_2, hydrogen sulphide, traces of ammonia, hydrogen, nitrogen, methane, radon, boron, arsenic, and mercury. (IEA 2002, p.7)

All in all, for the renewable energy chains analyzed by Nitsch et. Al., 2005[3], the inputs of finite energy sources and emissions of greenhouse gases are very low, compared to a conventional energy system:

- in the power sector, the environmental effects of renewables are only 20% of the respective effects of a conventional system in 2010;
- for heat this is a maximum of 15%, and
- using biofuels saves up to 45% of the environmental effects of a future diesel car.

Substitution of fossil fuels with renewables can also help solve the problem of summer smog in cities, both in the power and the transport sector. Only waste wood and straw used for in the heating industry could induce smog at a higher rate than conventional sources.

As far as aesthetic and acoustic disturbances are concerned, there is a hot public debate on the effect of wind farms, for example. Wind turbines are believed to disturb the landscape and decrease the value of land nearby. This category, however, is very hard to assess, as it has a very subjective character. Nevertheless, it can be said that wind farms and large-scale hydropower plants are the examples of RET with negative aesthetic and acoustic effects. Looking at the entire lifecycle, however, one should also mention similar problems with high-tension transmission networks and their impact on the landscape.

Renewable energy technology must be located close to the RES, for example wind power stations close to the coast. This often results in the installation of electricity production sites in significant distance from the existing grid. Thus, the deployment of RES can demand the extension of the grid. Grid extensions are also necessary for the compensation of fluctuations of electricity from RES.

Whether the aesthetic and acoustic effects from RET are stronger than from coal, gas, or nuclear plants, is largely disputable.

2.1.2 Effects of renewable energy utilisation on soil quality and land availability

Land sterilisation, or the prevention of its use for any other purpose, could be mentioned as somewhat problematic around wind turbines and geothermal plants, and very problematic as far as large-scale hydropower is concerned. For conventional power plants it is true that this is also an issue. Thus, these technologies require a careful selection of the site and consultation with all potential stakeholders, as to minimize low acceptance problems. What is more interesting from the point of view of the expansion of the renewables

[3] **Hydro**: small run-of-river; **PV**: 3 kW with polycrystalline solar silicon; **Wind**: onshore; **Solar thermal**: parabolic; **Geothermal**: HDR; **Biomass**: steam turbine with forest wood; **Solar collector**: local heat with long-term heat storage; **Straw**: straw-fired heating plant; **Wood**: central heating with forest wood.

sector is the competition for land between the energy, agriculture and forestry sector as well as nature conservation areas, infrastructure, etc. Figure 2-4 illustrates this point.

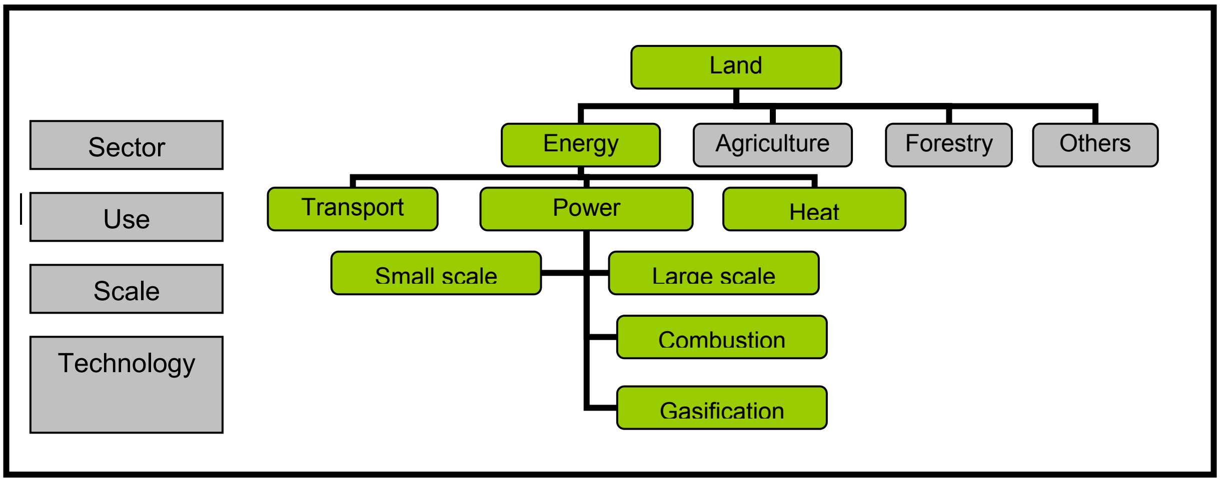


Figure 2-4: Competition for land among different economic sectors

In Europe this may present a serious problem with the potential for the expansion of biomass production for energy uses. It is necessary in this case to make effective policies that solve the problem. For example, nature conservation restriction to the use of land can be used to actually increase the potential biomass resources, by providing access to residues from forest margin maintenance, compensation areas and biotopes, as well as from coppice and composite forests. In the case of Germany, for example, nature conservation regulation would most probably decrease the potential area for production of biomass from 2,500,000 hectares to about 200,000 hectares in 2010. Within the following four decades, however, this area could steadily grow to as much as 4,150,000 hectares, given the abovementioned harmonisation of the two sectors. (BMU 2004)

Another way to combine the growing of energy crops and nature conservation measures is to plant perennial plants suitable for energy generation on sites with high erosion risk. Perennial plants stabilise the soil and prevent erosion and flooding. Similarly, larger hydropower projects may affect the transportation of sediments. In many cases, the regulation of the water flow of rivers through dams prevents floods, which wash away the upper and most fertile soil layer. The construction of hydropower plants, however, leads to irreversible ecosystem changes, including of the soil layer, for the flooded areas.

2.1.3 Effects of renewable energy utilisation on water quality

There are several effects that can be connected to energy systems that concern hydro resources. The first type of effects is physical, and involves changes in the flow rates and temperature of rivers, as well as changes in the water table. It is important to mention large-scale hydropower projects, which distort the natural flow of rivers and with this the hydrological characteristics of the areas around. This problem can be somewhat tackled by the introduction of minimum flow rates for dams. It should not be forgotten, however, that coal and nuclear power plants also affect rivers, as they use large amounts of water for cooling purposes. Thus, the water that leaves the plants has a temperature much higher than the natural level.

The second type of effects concerns changes in the chemical content of rivers and lakes.

Acidification is a problem usually connected to mining activities, especially of coal. In many coal producing areas in Europe, such as the region around Cottbus in East Germany there is still no real solution to the heavy environmental pollution. The use of renewable energies can thus be of help in avoiding acidification. There exists only one exception, i.e. utilisation of biogas for electricity and straw in the heat sector which imply higher acidification levels. This effect, however, in the case of biogas is connected to ammonia emissions from the agricultural system providing the biomass. In case organic farming is used, these effects can be overcome. In the case of straw, there are emissions of gases with chlorine and sulphur content and NOx.

The agriculture sector leads also to the feeding of large amounts of nitrates and other nutrients in the water, leading to eutrophication. This is the development of algae, bacteria and plants that feed on these nutrients on the water surface, and thus do not allow sunlight to penetrate the lower layers, thus disturbing the natural balance. Conventional energy chains, especially from fossil fuels, however, lead to much higher levels of eutrophication, than all other renewable energy chains.

2.1.4 Other effects of renewable energy utilisation

The effects of fossil fuel extraction and utilisation on **biodiversity** range widely in scale, but in general it can be said that mining, as well as oil and gas extraction, lead to severe pollution problems from heavy metals and other substances. Such long-term disturbances of ecosystems affect the biodiversity not only in their immediate vicinity, but also in entire watershed areas. Oil spills and other accidents have also lead to extremely rapid and severe changes in the natural balance of entire areas and lead to heavy losses of flora and fauna. In comparison, the risks of the utilisation of renewable energy are minute, with the exception of large-scale hydropower. There exists a certain risk of endangering birds through installation of wind turbines along routes of migratory birds and near nesting areas, but this problem can be avoided by careful planning (see BMU 2004, pp. 17-19). Hydropower projects also need to incorporate alternative routes for fish in their planning and construction, in order to minimize the effect throughout the lifetime of the plants. There is still, however, the problem of converting large areas into aqueous environment and thus changing the whole ecosystem through the construction of dams in large-scale hydropower plants.

An important consideration in the expansion of the renewable energy sector is the growing demand for **materials**. The demand for iron ore for solar and wind technologies in both power and heat generation exceeds that for conventional technologies. Moreover, PV cells make use of other more rare materials, and a large-scale expansion could bring a shortage of material and may necessitate recycling.

The risk of **catastrophic events** is usually brought up in connection to large-scale hydropower (the risk of floods due to breaking dams) and nuclear power plants (accidents such as Chernobyl, as well as the fact that there is no long-term solution to the issue of nuclear waste). There is, however, a certain risk of severe air pollution in cases of malfunctions in coal and gas thermal power plants, oil and gas storage facilities and tankers, etc.. Due mainly to the much smaller scale of the technologies and the lower levels of polluting and hazardous substances involved, all other renewable energy chains could help avoid such disasters.

Finite energy sources may be used in certain quantities in each energy chain. For renewable energies, that concerns the support systems and the quantities are negligible. The only exception could be fossil fuels used for power generation to fill in for wind capacity. Naturally, these quantities are much lower than if the filling in technology would operate at 100% capacity instead.

Power and heat generation from RES is generally not associated with **waste.** The only sources of residues could be the supporting systems. Quantities, however, are minute in comparison to those of conventional energy chains. Radioactive nuclear waste is particularly problematic and is the main reason why renewable energy is preferred by many over nuclear power even in the context of CO_2 emission reduction targets.

Climate change is a topic of particular relevance to the energy sector. Accumulation of greenhouse gases (CO_2, CH_4, SO_2, and NO_x, among others) due to anthropogenic activity can enhance the natural greenhouse effect. A wide spectrum of research on the topic shows that this may lead to severe consequences, such as a several degree rise in average temperatures, and the extremisation of the climate, leading to much higher frequency and impact of natural disasters, ranging from severe draughts to inundations of vast populated and agricultural areas. Also expected are general deterioration of health, increased risk of famine, wars for water supplies, or even a sudden transition to a new glacial period[4]. The main factors increasing drastically the natural greenhouse effect are transportation, industry, electricity generation.[5] This makes energy policies a crucial factor for the mitigation of greenhouse gas emissions. As was shown in Figure 2-1 to 2-3, greenhouse emissions from renewable energy chins are in most cases negligible in comparison to those of fossil fuel chains. In this sense, renewable energies are seen as an important instrument for the mitigation of climate change. The actual extent to which expansion of the use of renewable energies can decrease the adverse effects of the energy sector on the global climatic system will be discussed in more depth in the following section. It should be mentioned that nuclear energy is also proposed as an alternative to fossil fuels, as far as climate change is concerned. Given the very low emissions of greenhouse gases (GHG) from the nuclear energy chain, the comparison between renewable and nuclear energies needs to be made on basis of other environmental impacts or social and economic costs.

2.2 CO_2 emission reduction

By far the most discussed feature of renewable energy is the low amount of CO_2 emissions associated with its utilisation, compared to fossil fuels. The propagation of renewable energies in Europe's energy mix is seen as one of the most important steps towards keeping up with demanding national and international targets related to climate change. There exists a variety of research on the topic, aiming at assisting policy makers assess the effectiveness and efficiency of different policy options. The following section is meant to provide an overview of the most recent research and look for traces of consensus among researchers on the ability of Europe to reduce emissions by adopting renewable energy promotion strategies.

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[4] The word "sudden" in this context is used in geological terms and refers to periods of two to five decades.

[5] For more information on climate change, turn, for example, to the United Nations Framework Convention on Climate Change's *Climate Change Information Kit* (2002)

2.2.1 Methodology

Different research projects have used different methodology in order to assess the effects of renewable energy utilisation on CO_2 emission levels. The first option is to assume different policy options, such as a certain level and duration of subsidy or a tax, and extrapolate their effect in future scenarios. Such studies then use factors to calculate the respective emission (reduction) levels for each scenario and compare them. Examples are the FORRES 2020 project (Ragwitz et.Al. 2005), and the study on ecologically optimized expansion of the renewable energy sector in Germany (BMU 2004)

Another option is to assume certain targets and compare different strategies that could achieve the objective. This approach is used, for example, in cluster of models (POLES, MARKAL, PRIMES are the ones relevant to the present study) in the CASCADE MINTS project (ECN 2005). Another approach is to develop general socio-economic visions of the future (including specific emissions and RE targets) and backcast developments in the energy sector that may have lead to such conditions. Examples of this type can be found in IPCC, 2000 as well as in the COOL project for the Netherlands (Treffers, 2004).

2.2.2 Variables and assumptions

Independent from the methodology used, studies are also based on different assumptions and utilise different variables. Thus, results of different projects can very rarely be compared. Given the long timeframes of the execution of such research projects, however, this is actually an advantage. Even though results cannot be checked against each-other easily, this approach provides a larger spectrum of cases and policies analyzed. Variables of highest relevance to the deployment of renewable energy are the countries and regions included, the economic sectors to which the policy applies, the time frame of the policy, the accounting of factors such as the openness of the system and technological learning, the characteristics of the energy sector and the overall aim of the policy.

Due to the different technical potential, learning factor for each specific technology, possible political, administrative and social barriers, etc., the same policy would produce very different results in different countries. As much as studies on the effect of policies in the US have little relevance for Europe, studies concerning Western Europe can not inform policymakers on an EU-level. Different sectors (industry, households, transport, energy, agriculture, etc) need different strategies in order to achieve the same result. Thus, it also makes a difference whether a study considers emission reduction or any other goal in the power or in the transport sector.

The Green-x model, used in the FORRES 2020 project, presents the possibility to compare Western Europe with Eastern Europe and most European countries to one another. It provides interesting insights on the contribution of different sources and sectors to the emission reductions due to renewable energies in different European countries for both BAU and ‘policy’ scenarios. For Germany most impact have on- and off-shore wind and biomass in the power sector. If aggressive policies are applied, solar thermal and biomass for heat could significantly contribute to emission reductions. Altogether, Germany contributes with 60% to the European emission reductions until 2010, and about 40% by 2020 under the current policy mix in Europe. Spain would account for about 12% of the EU-25 emission reductions by 2020 from on-shore wind and solid biomass for the power sector. Biofuels in the transport sector would grow substantially between 2010 and 2020. The electricity sector is most important in the UK, where nearly all reductions come from wind and biomass expansion. In case of strong policies, tidal and wave energy could be utilised after 2010, leading to substantial CO_2 cuts. In Italy wind and biomass have strongest environmental effects as well.

An important variable with regard to renewable energy in Europe and its environmental effects is also the "**openness**" of the system in terms of international trade. In many cases, technical potential within specific European countries or Europe itself may be limited. Thus, costs of reducing emissions through renewable energies may be much higher within the countries themselves, than if international trade is allowed.

> A clear example is the availability of land for growing energy crops. In Europe there is a fierce competition for land between agriculture, forestry, nature conservation and the energy sector. This could be avoided if countries could import biomass from developing countries, where there may be more territory available for growing energy crops. Another alternative would be to invest in the power generation from biomass in countries with abundant and cheap resources and account for that in the investor country's own emissions budget. (see for example Treffers et. al 2005)

One of the most important variables in any research project is the actual **overall aim**. There are different options:

- Concerning RES penetration:
    - A set of policies can aim at the **maximisation of the use** of renewables within some cost constraints and time frame.
    - Another aim can be to achieve a certain **targeted level of penetration** of renewable energies in general or for each source, each sector, etc.
- Concerning CO_2 emissions
    - A certain level of CO_2 emission reduction target can be achieved in many ways, depending on the RES mix, the substituted source, and the total cost. It is therefore important to model different strategies and find out the **least-cost** ones. Usually least-cost scenarios for emission reduction do not rely only on introduction of renewable energies.
    - Another option is to set as initial conditions a time frame and a cost limit and model the **maximisation of the emission reduction** level.

The possible reduction of CO_2 emissions according to the reviewed studies is substantial. However, it varies very much according to the policy used and the aim of the policy. While the utilisation of renewable sources per se involves less CO_2 emissions than that of fossil fuels, this effect may be lost or outweighed by ineffective policies. Moreover, the level of penetration of renewables in the energy mix is certainly not in a linear dependency with the amount of emission reductions. This is due to the interference of various factors, such as electricity and fuel prices, learning rates of RET, the level and type of subsidy/quota/cap, etc.

A variable used according to the overall aim is for example the conventional source of energy substituted by the RES. The following example illustrates this point. The MARKAL model (ECN, 2005) assumes a policy framework aiming at a certain share of renewable energies in the primary energy mix (as proposed by the European Commission in Berlin, 2004), rather than at the reduction of CO_2 emissions. The substitution that occurs in the power sector is of the more expensive natural gas thermal power plants, rather than of more carbon-intensive coal power plants. This leads to an actual increase in the share of coal in the energy mix and thus to high emissions levels. Thus, the model does not predict any substantial emission reduction due to the introduction of more renewable energies in the energy mix. If the aim would be shifted to CO_2 emission reduction, more carbon-intensive coal plants would be excluded from the energy system and gas power plants would be kept. The difference between the two scenarios would be substantial. This conclusion is supported also by, Palmer and Burtraw (2005) who show clearly that in case it becomes too expensive to produce electricity from natural gas, the reliance on coal may actually outweigh the CO_2 savings from the introduction of renewable energies.

2.2.3 Examples of study results

Figure 2-5 and Figure 2-6 illustrate the possible emission reduction levels resulting from the increase of the share of renewable energy in the total mix. Even though this section offers some numerical representation of possible emission reduction levels, it is not meant to show the effect of specific policies or technologies. As already mentioned, all projects reviewed in this paper use specific methodologies and assumptions that cannot be reasonably compared. The section below is rather meant to show the possible range of emission reductions caused by different RES deployment strategies – from rather pessimistic ones, such as the PRIMES model, to overoptimistic ones, such as FORRES 2020.

The first graph is a summary of the CASCADE-MINTS project (ECN 2005). The three models used analyze two targets each: a high target of 20% renewable energy in the gross inland primary energy consumption in the year 2020; and a low target of 12% share for the same year. Consequently, they create different scenarios, depending on the region assessed, additional targets (e.g. on electricity consumption), subsidy levels, etc[6].

The resulting range of emission reduction levels can be seen on Figure 2-5. The levels of emission reduction vary substantially, for 2020 between 10% and 22% compared to a business-as-usual (BAU) scenario. The cost for the subsidies for the POLES model high

6 PRIMES assumes a growing feed-in tariff, the cost of which is passed to the consumers through higher electricity prices. For the Low target the tariff reaches € 18 / MWh, while for the high target, it is € 40 / MWh in 2020. The model encompasses the EU25 member states.

POLES uses additional subsidies, uniform for 7 specific RES. The subsidies are constant throughout the study period. The coverage of the subsidy is EU, plus Romania, Bulgaria, former Yugoslavia, Norway and Switzerland (EU30)

MARKAL has different sectoral policies: lower bound on the share of RES in the total share of electricity generation; an indirect carbon tax equal to € 0.25 / l gasoline; an emissions trading system for the industry sector, with a cap increasing from 125 Mton to 200 Mton. The model comprises EU15 and Norway (except in the power sector) Iceland and Switzerland.

target scenario, for example, are about 0.48% of GDP each year, an amount that no government is likely to approve of.

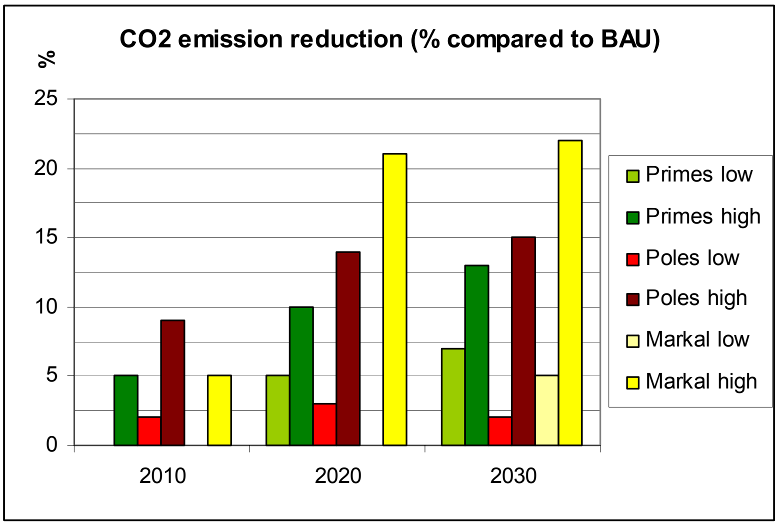

Figure 2-5: Model results from the CASCADE MINTS project, presented in ECN 2004

In contrast, the FORRES 2020 project aims simply at the maximisation of renewable energy penetration in the energy mix. For this reason, the ”best” policies, specific for each technology, are selected and applied in all countries. The result is an overoptimistic scenario, showing the possible effect of very strong European directive, enforcing the explicit support for renewable energies in each of the 27 countries considered.[7] The result is a stunning average of about 100% less emissions than under BAU for EU 25. For EU 10 these levels reach over 300% for the years 2010 and 2015. The costs of such a substantial CO_2 reduction grow from 0.14% of GDP for 2005 to about half a percent of the GDP in 2020 for EU 25. This scenario, however, assumes no socio-economical, political, or technological barriers to the deployment of RES. Even though it is highly improbable, it is still a good illustration of the upper boundaries of societal effort towards the deployment of renewable energies.

Despite the differences between the studies, most research agrees that as far as CO_2 emission reductions are concerned, RET deployment may not be the cheapest strategy. The social welfare costs of renewable energy policies are usually very high[8]. There are other measures that could lead to significant emission reductions and possibly at a lower cost. Such options are energy efficiency, emission caps, and carbon taxes. It is important to note, however, that these policy options are not competing, but rather complementary. The relative importance of RES for the reduction of CO_2 emission levels thus varies from country to country.

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[7] EU-15, the 10 new Member states and Bulgaria and Romania

[8] For various estimation methodologies, see for example Palmer and Burtraw (2005) (including a comparison with EIA studies) or ECN (2005)

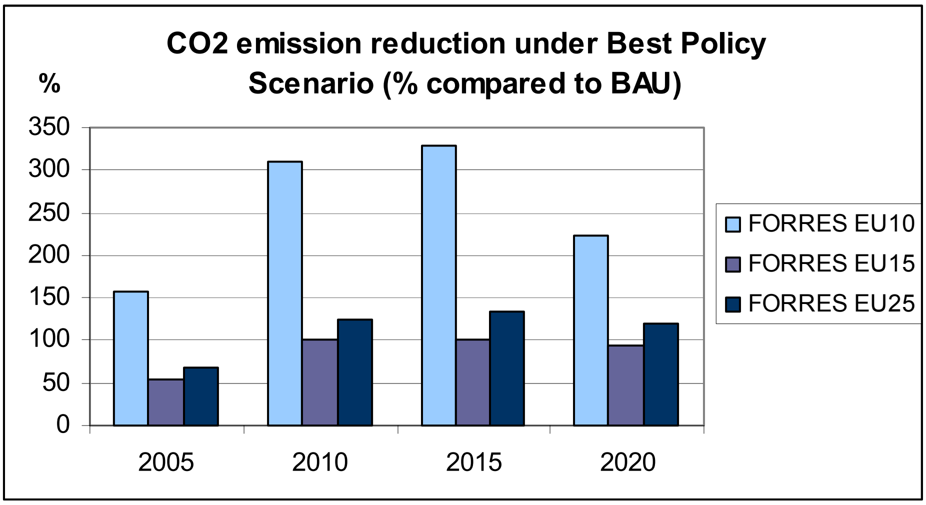

Figure 2-6: Model results from the FORRES 2020 project, presented in Ragwitz et. Al. 2004

2.3 Conclusion

In conclusion, most renewable energy chains are "cleaner" than conventional ones in terms of pollutants causing acidification, eutrophication, summer smog or enhance the greenhouse effect, as well as in terms of wastes and impact on biodiversity. An exception is biomass, which (depending mainly on the use of fertilizers and pesticides in the agricultural processes) may have higher emissions of ammonia, pollutants with chlorine and sulphur content, NOx. Most environmental effects, such as ecosystem disturbance, particulate matter emissions, catastrophes, etc. could be avoided. Possible solutions are specific filters and processes, avoidance of areas of high ecological importance, creation of passage ways for fish and other river fauna. Such measures however would lead to increased generating costs of power, heat, and fuels. Thus, a cost-benefit analysis is needed to find a compromising solution for the environment at acceptable prices.

As far as reduction of GHG emissions is concerned, renewable energy sources could become very important. It should be clear, however, that the deployment of renewable energies in the energy sector per se will not necessarily bring about the entire potential of emission savings. It is important to build up an effective strategy that is tailored for the energy potential, needs and capacity of each country and sector and has clearly defined aims in terms of environmental effects.

3. Macroeconomic aspects of RES

Besides their positive impact on environment, RES are supposed to contribute to job creation. In this context, mostly the number of jobs created in the RES industry due to investment in RES and operation of the RES installations is cited as evidence. (ERECa (2004), UBA (2004). Recent studies state that the present investment in RES amounts to more than € 10 billion and that over 200.000 jobs have been created in the renewable energy industry in the EU (EREC a 2004), among them more than 100.000 in Germany. (Mitre (2004), UBA (2004)). This raises hope, that RES industry could be a driving force for economic growth and employment in many countries in the EU.

To gain a realistic estimation of the influence of RES on economic growth and employment, we will deal with this problem in two steps:

- some general remarks on the methodology
- and an examination of the macroeconomic effects in detail.

3.1 General remarks on growth prospects

Economic growth depends on a number of driving forces. The most important are:

- development of population including age distribution, availabilities of skills etc.
- availability of natural resources and their production cost
- technology and capital
- age distribution of existing capital stock and the technology embedded in this capital stock
- ability to produce innovations
- institutions and regulations. Existing institutions and regulations referring to all parts of economic life have important implications for economic growth and development (e. g. taxation, labour market regulation, distribution and policies etc.)
- cultural aspects. A lot of soft factors maybe mentioned here like development of social values, education, motivation, achievement orientation etc.

What are the implications of the transition to a more renewable energy economy for economic growth?

1. The share of energy in current GDP is relatively small. The importance of increasing energy efficiency which is clearly one of the most important instruments to reduce greenhouse gas emissions will also reduce this share potentially. It therefore does not seem to be a very meaningful exercise to try to find out the implication of higher or lower share of renewable energy for economic growth in general. A very small change in the exchange rate between the Euro and the Dollar as an example or a very small change in the wage settlements negotiated between employers and trade unions have far more important consequences for economic growth and development.
2. If we want to study the implications of different energy strategies for economic growth and development and employ modelling exercises for this purpose we implicitly have to consider a lot of the driving forces of economic growth to be con-

stant. So even if general equilibrium models [9]are being employed the results are in many aspects “partial”. This important restriction is often forgotten when looking at the results of such modelling exercises.

3. Modelling exercises trying to analyse the impact of changes in the energy system on the overall performance of the economy crucially depend on many parameters. The empirical basis for parameters like elasticities is often weak, particularly as they are derived from the past and thus reflect the overall conditions of the economy of the past. Some of the driving forces of economic growth mentioned above can be modelled, others not. This is why such models tend to be “pessimistic” about the results of transitory measures.

We know from many exercises where future projections had been later compared to actual development, that projections were wrong. Therefore there is no absolute truth in such modelling exercises. The truth is always relative to the assumptions and the assumptions are relative to reality that however, we can only partial incorporate.

From an economist’s point of view therefore to judge on general economic effects of the transformation of the energy system we should therefore, rather than looking at quantitative results of modelling exercises concentrate on the general framework of the economy and ask the following questions:

- Is there wide acceptance for renewable energy policies?
- Are the markets open and are there proper incentives to promote efficient changes in the energy system?
- Does the market framework support international division of labour in the production of renewable energy?

To avoid misunderstandings:

- The transformation towards more renewable energies above a certain level is a difficult task. Many renewables are more costly than conventional energy which puts a strain on the economy.
- In the longer term relatively rich societies can use their GDP in any way they want. The important economic question therefore is that there is a sufficient willingness to pay for renewable energy and their quality aspects. This may not be the case due to the public good dilemma connected with the environmental quality aspects of renewables. Therefore policy decisions discussed in chapter 4 of this paper are so important.
- Another problem arises from relative international competitiveness within the European Union. Strangely enough after the opening the internal European market and the removal of many barriers to international exchange between European countries promotion of renewable energy although being a European target is established by using national policies that differ in many ways between countries. Thus, efficiency gains from international cooperation and using the natural advantages of different locations in Europe with their different conditions for renewable energies are not available. This is certainly an important obstacle to realizing economic gains from an increase of the share of renewable energies. Even if there is a sufficient willingness to pay on the side of the domestic consumers (which can

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9 An excellent survey of recent modeling studies can be found in the paper by Herman R.J. Vollebergh: Increasing the Role of Renewables in the EU: Gloomy Prospect or Pitfall

be doubted), different cost of renewable energy in different countries caused by different schemes of promotion and different natural conditions change the relative competitive situation of all economic factors for which energy is an important cost factor. My conclusion therefore is that to avoid harmful effects from expending the renewable energy sector we need to have a harmonisation within the Union and we have to make sure that we are as efficient as possible in order to avoid economic losses. This however, requires a strong role of markets.

3.2 Macroeconomic effects of the deployment of RES

To go somewhat into details: The introduction of renewables causes a typical structural change. New products replace partly old products or at least reduce the increase in old products if demand is rising. Such a structural change produces winners and losers (e.g. if wind energy replaces coal in the electricity industry). To get an idea of the implications of such changes we have to balance the winning and losing sectors. In addition indirect effects have to be considered caused by price and demand effects.

This includes the consideration of creation and losses of workplaces, the investment which is redirected to RES, the influences on external trade by the increase in use of domestic energy resources, etc.. Direct influences results from investment in renewable energy technology (RET), services for operation and maintenance. Indirect effects come for example from the redirecting of capital and the substitution in the fossil energy sector.

The results of this approach show, that

- the overall effect of RES on economical growth is of minor importance under current conditions and
- job creation in the RES sector is thwarted by reduction of jobs in other sectors due to displacement of financial resources

Part of the motivation to promote renewable energy is to substitute imported energies by local production and in this way to promote economic activity locally and increase employment. Basically we have to distinguish between economic effects of the investment phase of renewable energies and the economic effects of operating the newly created plants and their impact on the economy and employment. It is also important whether renewable energies produced replace domestic energy production or imported energies and whether renewable energies produced add to the growth of energy consumption and thereby replace potential domestic or imported energies. Table 3-1 shows these four cases that in reality of course cannot be separated as clearly, but are useful to understand the different mechanisms in the influence of economic development and employment.

Table 3-1: Cases of substitution

Energy consumption	Renewable energy substitutes	
stable	(1) Domestic energy	(2) Imported energy
growing	(3) Additional domestic	(4) Additional imported

Figure 3-1 shows the value effects that have to be considered. It is typical for renewable energies that a relatively high investment is necessary to start production, but afterwards the cost may be relatively small because the energies processed are free in some cases (hydro power, wind, solar).

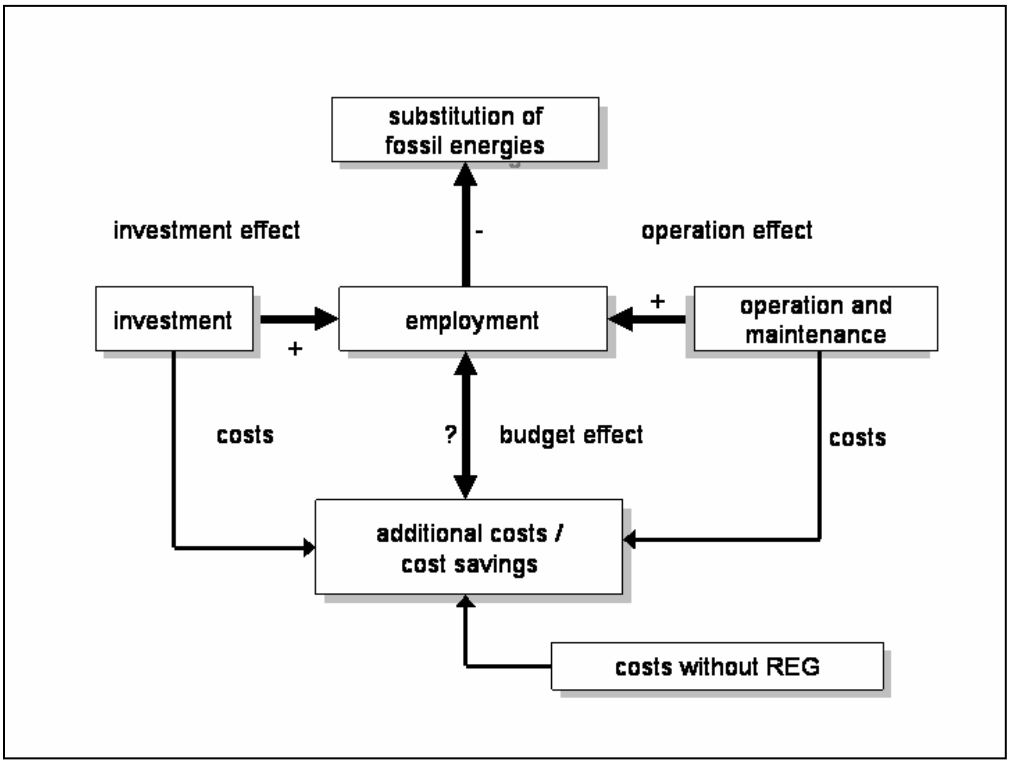

Figure 3-1: Employment effects

If we start with the first case (replacement of domestic energy by renewable energy in case of stable energy consumption) we have to balance the replacement effect in the traditional energy sector (like production of coal or natural gas etc.) against the employment effects of the new renewable source that to a large extend exists on the basis of the initial investment. So here we can expect a strong economic effect of the investment in the renewable source and then afterwards a remarkable negative effect because existing energy production is being replaced by a renewable source. If the renewable source is a free good it does not have any economic effects associated with it except that the renewable energy plant needs to be serviced and operated. The only renewable energy remarkably different is biomass where production, collection and transport cause considerable cost and therefore also would add to the employment balance during the phase of operation.

So in short if we substitute domestic energy resources by renewable resources where the resources are free, the overall balance depends on the relation of the investment effect versus the operation and employment effect in the traditional energy system. Replacement of employees in the traditional energy sector is likely and it is very likely that the overall balance will be negative for the renewable source.

The overall balance however, also depends on the relative cost of renewable energy system versus the traditional energy system if consumers have to pay more for the renewable energy than they had to pay for the traditional energy that additional value created by the renewable energy sector corresponds to a replacement of consumer purchasing power that went into other products outside of the energy sector. Then the balance of the energy sector may be positive but at the cost of a negative balance in other industries.

So in the first case (stable demand, domestic energy) a negative effect can be expected because of replacement of other former energies and an additional possible negative effect depending on the relative cost of renewable energies from the so-called budget effect (replacement of purchasing power due to higher price of renewable energy).

In the second case (stable demand, imported energy) the balance may look better because in this case a domestic renewable energy replaces an imported traditional energy. This imported energy creates value and employment in the country of origin but only very low value and employment in the country of destination (due to transport mainly). In this case you would expect a positive balance for the renewable energy as a source of import substitution but the overall balance again would depend on the relative cost-price-situation of traditional and renewable energy. The argument in this respect is the same like in case one.

In the third case renewable energy does not replace existing energy but replaces potential growth of traditional energy sources. In this case no replacement occurs, the traditional energy sector remains stable and the value and employment balance depends solely on the relative cost-price-situation between renewable energy and potential other energies used for the same purpose. So in this case it is mainly the budget effect that is decisive.

Case four is not different in this respect and the same arguments hold as in case three.

As was mentioned before the four cases are helpful for analytical reasons but in reality we can expect a mixture of these different cases. If renewable energy grows faster than energy demand we will have a combination of cases one/two or cases three/four.

In the longer run additional effects may be important:

1. Growing export capabilities: an industry that is able to produce investment goods for the renewable energy industry (wind energy converters, photovoltaic cells etc.) can add value by exporting these goods. There may be positive effects on the economy as far as the exported goods contain values created domestically. This is of course, relative to a lot of macroeconomic factors determining the comparative advantage of one country against other countries in the same industry. This comparative advantage may be higher in industries with a high technological specificness than in other areas.

2. The economic benefits from using renewable energies depend on the environmental policy regime. The present scheme of greenhouse gas reduction puts a considerable fine on all prices of energies with carbon content. It puts renewable energies in a relatively better position.

3. In the longer term the effect of a growing renewable energy industry depends on the relative effects of the investment versus the operation and budget effects as it is shown in Figure 3-1. A layer of investment carried out in a specific year leads to operation and budget effects for a sequence of years corresponding to the lifetime of this equipment (Investment one and operation and budget effect one in the diagram).

   Assuming that the operation and budget effects are negative, which is very likely for many renewable energies, this negative effect can be compensated if additional investment is carried out in the next period etc. However, a problem arises when investment stops. In the time after investment three in the diagram strong negative operation and budget effects will have negative influences in the economy in the time period after the investment boom of renewable energy has come to an end. In other words building up renewable energies can add positive economic effects in the phase of investment but when investment slows down or stops the effects associated with higher price of the energy will be dominant and will have negative impacts.

This can be summarised in a very simple and distinctive conclusion: the more economic renewable energy is from the beginning, the better will be the effect on employment and economic development.

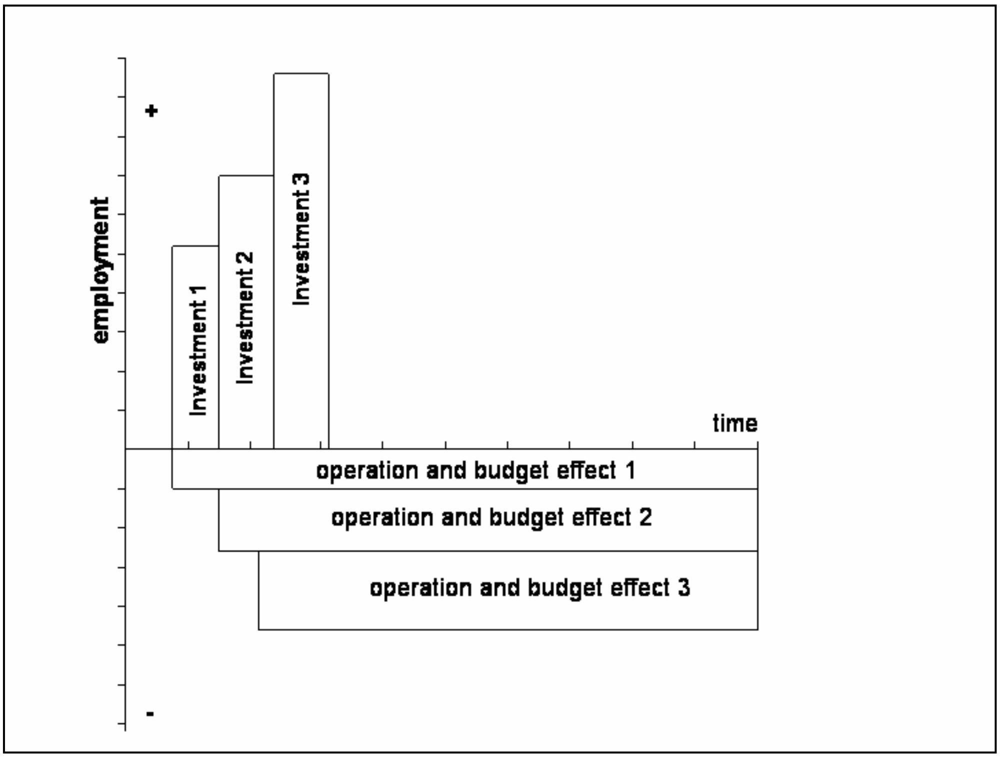

Figure 3-1: Dynamics of effects

3.3 Effects of promotion of RES for selected sectors

As mentioned above, the discussion about RES and job creation is mostly limited to the direct effects – i.e. the creation of jobs within the sectors which benefit from the investment in RES installations and the subsequent operation.

Looking at theses sectors, one can distinguish between two kinds of effects of the promotion of RES: those which were already registered during the past and those which are predicted by simulation models.[10] Both will be presented in this paper, whereas the results of simulation are more useful for the valuation of the future effects than the historical data.

[10] There exists a broad range of simulation models, which are classified and described in detail in Kempfert (2002).

3.3.1 Recent development of employment in the RES sector

During the last two decades, a remarkable number of jobs was created by the enhanced deployment of RES. Exemplary data for selected countries are listed in Table 3-2. The numbers from different sources show, that renewable energy industry is a noteworthy sector with about 200.000 jobs in the EU in 2003 (EREC b 2004), between half and one third of them in Germany.[11] Wind energy contributes approximately one third of those in the EU and 50% in Germany. Regarding these numbers one can state– despite the different figures in the studies -, that RES industry is growing and upcoming industry sector.

Table 3-2: Gross Employment in RES-related sectors
[1]: numbers approximated to hundreds

Source	Region	Sector	No. of Jobs in 1998[1]	No. of Jobs in 2002[1]	Comment
EREC b 2004	EU-15	all RES		200.000 (in 2003)	
EWEA 2004	EU-15	Wind	28.100	72.300	calculation based on EUROSTAT data
ECOTEC	EU-15	all RES	39.000 (in 1995)	145.000 (2005)	data for 2005 from simulations
UBA 2004	Germany	all RES	66.600	118.700	
UBA 2004	Germany	Wind	15.600	53.200	
Staiß 2003	Germany	All RES		58.000	
Pfaffenberger 2003	Germany	all RES		61.000 (in 2003)	Own calculations, based on an inquiry of RES industry associations

[11] The numbers vary according to different source due to different approaches for the calculation of numbers of jobs, especially for the indirect effects.

For the assessment of the future contribution of RES to economic growth and the increase of employment, the projected contribution of RES industry is of higher significance than the recent status. Therefore, some studies were evaluated regarding the development of employment due to RES (Table 3-3).[12] Due to the fact, that presently a great part of the jobs in the RES sector in the EU is located in Germany, studies were selected, which refer either to the EU or to Germany. The studies differ in many aspects – time range, the presumed development of deployment of RES, incorporation of different indirect effects.

Although one can state an impressive increase of employment in RES-related sectors, RES are not a job machine in the macroeconomic context when indirect effects as the budget effect are taken into account. With rising prices for fossil fuels due to price increase or the price of CO_2 certificates, the positive impact of RES on employment could increase.

3.4 Conclusion

Looking more closely at the results of the studies, one can state that the results depend very much on the underlying assumptions, the time scale and the treatment of substitution and budget effects.

Nonetheless one can conclude that:

- All studies predict increase of the gross employment of RES.
- The lion´s share of this increase is attributed to the biomass/agricultural sector. Most of these jobs require only low qualification.(MITRE 2004) [13]
- Budget effects are negative in all cases, as currently the production of electricity from renewable sources is much more expensive than from conventional sources and has to be subsidized
- Those studies, which consider budget effects of the increased deployment of RES predict low or even negative net employment effects from RES deployment.
- The low impact of increased deployment of RES on employment is due to the fact that RES technologies are not yet competitive with fossil fuels.
- None of the studies has already taken into account the recent increase of energy prices, which will tend to increase the positive effect of RES on employment.
- The effects of emission trading are not yet included in these studies.

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[12] The underlying models will not be described in detail, only the main features will be mentioned.

[13] Mitre 2004 In 2010, in the CP-scenario 324 of 450 workers will be unskilled. In the ARS-scenario 610 of 838. In 2020, in the CP-scenario 577 of 813 workers will be unskilled; in the ARS-scenario 1037 of 1439.

Study	Model(s)	Region	Time range	Investment in RES (billion €)	Net employment effect (1.000 jobs)		Comments
MITRE (2003/2004?)	Safire / RIOT	EU-15	2010 / 2020:	---	2010: CP: ARS: 2020: CP: ARS:	 450 813 1.439	2 scenarios: current policies (CP), Advanced Rernewable Strategie (ARS) base line: 2000 Without export and job security effects in agriculture
EREC a 2004	??	EU-15	2010 2020	2010: 140 2020: 443	2010: with Bimass/Biofuel: 2020: with Biomass/Biofuel:	305 1.067 881 2.023	Substation effect included, budget effects not regarded Assumptions for investment are very low
ECOTEC 1999	Safire / RIOT	EU-15	1995 – 2005 1995 – 2020		gross effect: with biomass: gross effect: with biomass:	106 414 346 861	only gross effects, budet and substitution effects not regarded
MITRE (2003/2004?)	Safire / RIOT	Germany	2010 / 2020	---	2010: CP: ARS: 2020: CP: ARS:	8 38 77 141	2 scenarios: current policies (CP), Advananced Rernewable Strategy (ARS) Without export and job security effects in agriculture
Hillebrand et al 2005	RWI-Model	Germany	2004 - 2010	ca. 12,6	net effect gross effect	-6,10 19,37	Reference scenario: 2003, doubling of RES deployment until 2010, CO_2-permit: 10€/to
Pfaffenberger et. al. 2003	MIS	Germany	2002 - 2022	ca. 100	Net effect gross effect	-4,0 84,5	Constant increase in RES capacity, Basis: 2002, Export effects not included constant energy prices (2002)
Ragnitz 2005	Own model ?	Germany	2001 - 2010		Net effect gross effect	7,3 51,0	
Ziegelmann, 1999	Markal-IKADAT / MARES	Germany	2000 – 2015	---	Scenario I: gross effect: Scenario II: gross effect	36,8 44,5 90,25 113,35	2 scenarios with enforced introduction of RES, **Energy saving measures included!**

Table 3-3: The development of employment due to RES from selected studies

Another observation that could be drawn from a dynamic representation of the macroeconomic effects concerns the accumulation and balancing-out of positive and negative effects. Those studies, which take into account budget and substation effect, show that new capacity boosts demand and employment only in the year(s) when investment is made. The combined effect of operation, maintenance, and financing, in contrast, lasts for the whole technical lifetime of the installation, and it is normally negative. Thus an accumulation of the negative effects can be observed, which balances out the positive investment effect and can even lead to losses.

It is important to note that the budget effect will change if prices of conventional fuels such as coal and natural gas change. The current trend of rising prices for fossil fuels, combined with carbon taxes and other policy instruments may have beneficial effect on the standing of renewable energy.

4. Policy instruments and measures

The previous remarks point out, that a significant development of RES in the EU took place during the last decade. Nonetheless, further efforts are necessary to carry forward this development as intended by the EU. Against that background, experts discuss intensively about the appropriate instruments for further promotion of RES.

There are various policy instruments which intend to influence the behaviour of actors in the energy market in way that leads to enhanced deployment of RES. In the following we will try to answer the following questions:

- Which policy instruments are available?
- Which instruments fit to different market sectors (electricity production, heat, transport)?
- Which instruments are appropriate for different RES?
- How can the instrument (measures) be financed / financial resources?

This paper will follow the structure of a study of Espey (2004), where RES Policies of the EU and eight selected countries were evaluated and systematically analyzed. In the first chapter, the policy instruments will be characterised and evaluated according to their suitability for different RES and market sectors. Chapter 4.2 is dedicated to the assessment of the instruments. The instruments are assessed in chapter 4.2.1 with respect to their applicability for different stages of readiness for marketing. In chapter 4.2.2.1, the criteria of success for the assessment of policy instruments are presented and elucidated. Chapter 4.2.2.2 contains the assessment of the policy instruments for the promotion of RES regarding the criteria mentioned before. The last chapter 4.3 summarizes the recent discussion “Quotas versus feed in tariffs”.

4.1 Characterisation of policy instruments for RES

Depending on the respective point of view, there exists a large variety of classification schemes for policy instruments for RES. In this context, a top-down-perspective was chosen due to the fact that policy instruments are regarded from a governmental viewpoint. According to that approach, one can distinguish five categories of instruments for the promotion of RES: institutional instruments, regulation of prices, regulation of quantities (quota), promotion schemes and voluntary measures. In the following, the different instruments will be characterised and their advantages and disadvantages will be presented.

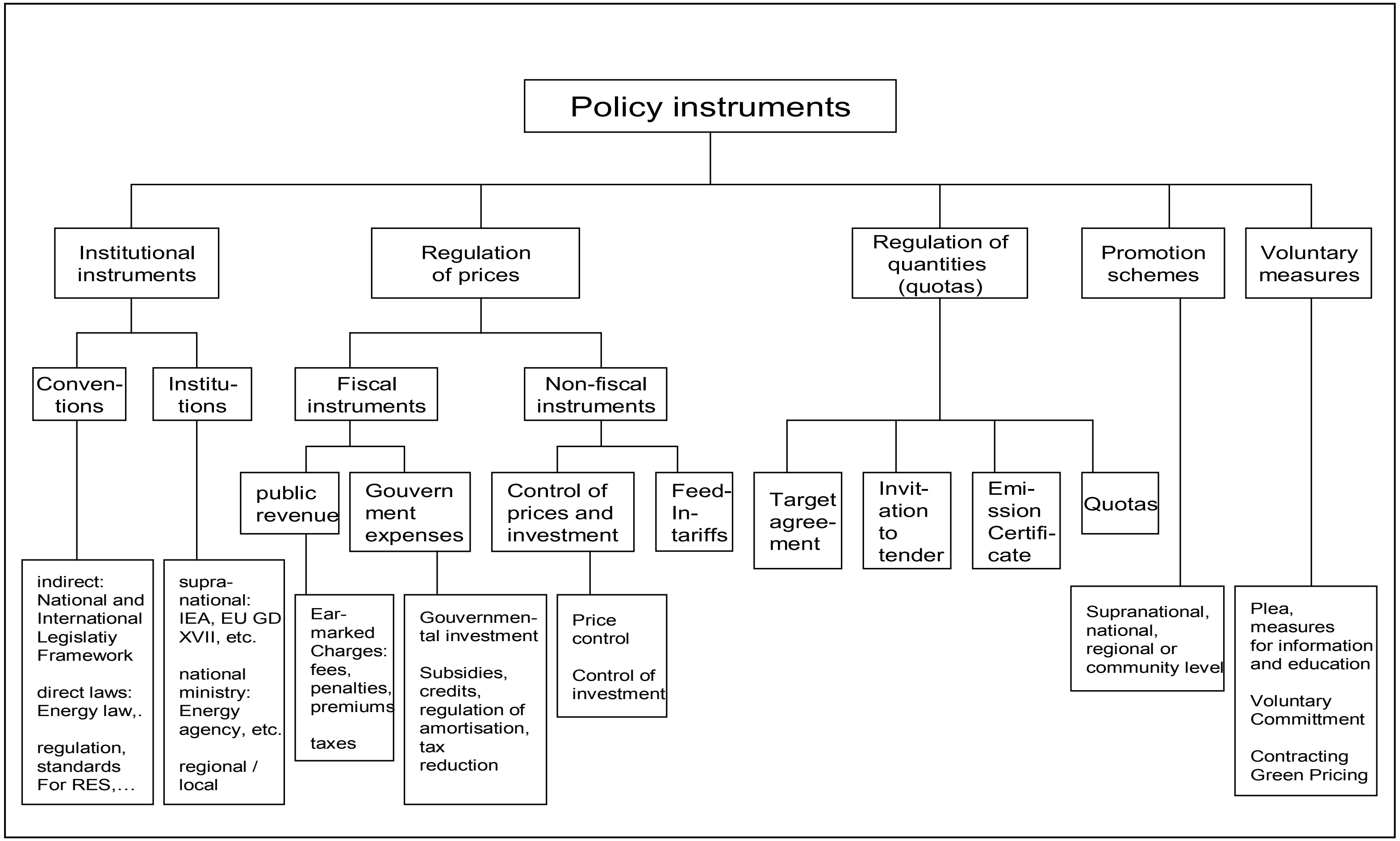

Figure 4-1: Classification of Policy instruments for the promotion of RES (according to Espey 2001)

4.1.1 Institutional instruments

To achieve the aims concerning RES, the state has to establish appropriate institutions. In this context, the term "institutions" includes conventions, i.e. laws, policy programs, framework plan, as well as organisations, like the ministry of energy, national, regional and local administrations and energy agencies, etc..

Conventions define the framework for the actors on the energy markets. This can be a matter of indirect regulation like building laws, which contain for example regulations of energy standard for heating systems, the environmental law that limits the impact of emissions pollutants in the atmosphere or the approval process for new power generation plants. These indirect regulations will not be the subject of this paper. In this paper only direct regulations will be regarded, i.e. regulations which refer explicitly to RES.

Regulations have some serious advantages:

- They are due not cause fiscal expenses for the national budget.
- Sometimes the announcement of regulations is sufficient to achieve the desired reaction of the relevant actor.
- Obligations for the deployment of RES can induce a market development for technologies which would otherwise not take place.
- Laws and regulations are mandatory for all affected actors
- Market conditions are calculable, transparent, and controllable, which leads to higher planning reliability.
- The chances to achieve the desired behaviour of the actors are high if sanctions are imposed.

There exist also some disadvantages:

- Financial resources are necessary for the administration and control of the compliance with the regulations.
- Interest groups will always try to influence the definition process of the regulations as well as the interpretation after their coming into force.
- As the decision process is often time-consuming, there is a risk that the regulations do not consider the recent technical development.
- The regulations are often static and cannot be easily adapted to fast dynamic developments.

Despite the disadvantages, regulations are indispensable for the implementation of more detailed policy instruments and for a general acceptance of the aims concerning RES in the pubic.

Example: Solar building regulations

One regulation that aims directly at the implementation of solar energy systems is the solar bylaw for buildings. First proposed for the city of Berlin, established in 1999 in Barcelona and meanwhile in various Spanish cities, the solar bylaw for buildings makes the installation of solar thermal systems mandatory (mainly) in newly constructed building. Within one year after the entry into force, the total amount of square meters of solar thermal applications quadrupled in Barcelona. Additionally, the houses equipped with solar thermal appliances became relatively more valuable.

4.1.2 Regulation of prices

Regulation of prices can be achieved by fiscal and non-fiscal measures. Fiscal measures can either concern the public revenue or the public expenditure.

4.1.2.1 Fiscal instruments

Public revenues

The best known fiscal measure in connection with RES is the ecological tax. Here, energy and CO_2-taxes can be distinguished.

CO_2-taxes are chosen when the reduction of CO_2 as most important green house gas is the aim. CO_2-taxes are not incurred for nuclear energy and RES, thus privileging these sectors. However, CO_2-taxes can also induce the substitution of CO_2-rich energy sources like coal by energy sources with lower CO_2-content like gas.

With energy taxes, also other green house gases than CO_2 can be affected. In any case, energy taxes can also support energy saving measures. Energy taxes can refer to primary energy as well as to useful or end energy. Taxation of primary energy incorporates conversion losses, whereas taxation of secondary or end energy has the advantage that energy imports can be taken into account.

Most energy and CO_2-taxes are defined as surcharges on the price or a fixed amount per unit. The taxation rate must be chosen sufficiently high to achieve the intended control function. The validity period of the taxation must be sufficiently long to ensure a reliable basis for the planning of future investments. On the other hand, the regulations have to comprise a certain flexibility to allow an adaptation to changes in the general economic framework.

The tax income from ecological taxes can be used to raise the income of the state, to finance promotion schemes for RES or to reduce tax loads in other field, for example the non-wage labour costs. Thus it is claimed that ecological taxes have a multiple dividend: reduction of emissions, promotion of RES and rise of public revenues.

Disadvantages of these taxes, which often lead to special regulations, could be:

- Creation of financial problems for people with low income.
- Deterioration of the conditions for public transport leading to an increase in individual transport which is accompanied by an increase in CO_2-emissions.
- In case of a national ecological tax: deterioration of conditions in the international competition for industry sectors with high energy consumption.

Concerning the effect on RES it must be stated, that ecological taxes are of minor importance for RES as long as other possibilities of substitution of energy are more cost-effective.

Public expenditure

Governmental financial support for RES can be delivered in form of public investment or subsidies for RES.

Subsides

Due to the high cost, public investment in RES-projects can only be limited. Public investment is not suitable as an impulse for mass production or cost reduction. It is, however, money well spent for research and demonstration projects which helps to achieve technical improvement, to display a role model and raise of awareness of RES.

Despite the direct governmental investment, subsidies can be classified in the following categories:

- Promotion schemes
- Grants for investment or operation
- Credits
- Tax or amortisation relieves
- Bonus

One type of subsidies, the promotion schemes, will be presented in more detail in chapter 4.1.2.2. In general, subsidies are an important incentive for the deployment of RES. They are indispensable for research, as companies often would not engage in research if they had to bear all the costs on their own.

A second, very important function of subsidies is the support of the rollout of RES. Well designed subsidy programmes can strongly stimulate investment in RES. For a the design of a successful programme, the following point should be regarded:

- The sector which receives subsidies is well defined.
- The duration of the program is clearly established and is not too short.
- Stop and go situations must be avoided because they can create serious problems for the RES industry due to high fluctuations in demand.
- The program and the formalities for application are transparent and easy to handle to reduce the barriers.

The appropriate type of subsidies depends on the special situation of the respective target group(s): Often a project that is of economic interest for an investor is not implemented due to a lack of credit rating. This problem can be overcome by the provision of favourable state loans. On the other hand credits are of no use, if the investor expects an encouraging signal from an official institution. In that case, grants for investment should be chosen.

Despite the fact, that subsidies are a useful instrument to support market introduction (rollout), they also have considerable problems:

- Information and transaction costs are high, both for the state and for the beneficiary.
- Long lasting subvention programs are hardly to abolish, therefore the duration of the programme should be well defined from the beginning on.
- Windfall gains can not be excluded.
- The contribution of subsidies to the development of RES can hardly be quantified.

Nevertheless, subsidies remain an indispensable instrument for market introduction.

4.1.2.2 Promotion schemes

Promotion schemes are one kind of subsidies. They are applied for the promotion of selected RES. Promotion schemes can be designed for different phases of the development of a RES technology – research and development activities as well as demonstration and pilot projects or the rollout of RES products. They can aim at different target groups from research institutes to producers and end-consumers of RES technology.

Two characteristics that distinguish promotion schemes from quotas or feed-in tariffs are the limited duration and a maximum limit of the budget. Promotion schemes can be either grants for investment or operation, credits at a reduced rate, tax or amortisation relieves or bonus. The specific design depends always on the specific RES and the target groups.

Often promotion schemes are accompanied by an evaluation to identify the result of the programme, the barriers that exist for the application of the RES as well as for a proper performance of the program and the resulting amelioration potential.

Problems that arise often with promotion schemes are:

- The provision of money from the public budget depends strongly on political decisions.
- The effects that can be achieved are restricted due to limited budget and duration.
- There often arise bottle-neck situations when the budget is too small to accomplish a high number of applications.
- In many programs the application and approval procedures are intransparent and time consuming.
- There often exist different promotion schemes on different levels (national, regional, local), and it is difficult to find the corresponding information and to identify the optimum combination of promotion instruments.

Despite all the problems mentioned above, promotion schemes are an important instrument for all RES which are still far from marketability.

4.1.2.3 Non-fiscal instruments

With this type of measure, the government can influence the prices of RES without touching national budgets. The costs are shifted to the producers or the consumers of the respective energy. Non-fiscal instruments can be classified into two types: control of price (or investment) and feed-in tariffs.

Control of investment

In this context, the keywords are least-cost-planning (LCP) and integrated resource planning (ICP). These mechanisms oblige the utilities to verify whether investment in RES (or reduction of consumption) is possible (or even favourable) when they intend to substitute or extend their existing production capacities. This type instrument provides a certain support for energy saving techniques, but is not appropriate for RES which are often not competitive with fossil fuels.

Feed-in tariffs

The state obliges the network operators to feed electricity from RES into the network and to pay a fixed price for it. Normally, the conditions for the feed-in and the feed-in-tariffs are specified by law. The price can be either determined by avoided costs of substituted electricity from fossil fuels or a fixed amount that depends on the respective kind of RES. The latter gives the possibility to stimulate investments in technologies which are not yet competitive with fossil energy sources, for example photovoltaics.

Feed-in tariffs with a long- or medium-term scale provide

- provide a high planning reliability for investors and
- support strongly the market introduction,

- induce price reductions due to mass production.

Therefore, feed-in tariffs are an important non-fiscal instrument to support market introduction.

Nevertheless, feed-in tariffs retrieve some problems:

- They are feasible only for network-fed energies like electricity.
- Windfall gains can not be excluded.
- The burden charging for the network operators and their clients can be asymmetric due to regional differences in the deployment of RES. Thus, feed-in tariffs can turn out to be a competitive disadvantage.
- Long-term feed-in tariffs can inhibit innovation processes. Therefore, tariffs should decrease gradually with time.

The discussion about advantages and disadvantages of feed-in tariffs will be deepend in chapter where feed-in tariffs, quotas and emission certificates are discussed in detail.

4.1.3 Regulation of quantities

These instruments aim at the energy quantities, delivered from different energy sources, and not at the prices. The definition of quantities can either refer to produced energy quantities, production capacity or emission quantities.

In the following, four different instruments are presented: target agreement, invitation to tender, emission certificates and quotas.

Quantitative target agreements

Targets for the deployment of RES are fixed on a medium-term or long-term scale. They can refer to a certain percentage of energy supply (gross or net) from RES or to the production capacity. A target on its own is not an instrument for the promotion of RES. But it can give strong signals in context with future investment. Target agreements must be support by other efficient instruments like subsidies or tax reduction or they should be combined with penalties.

Invitation to tender

For this instrument, a fund is established for investment in new production capacities based on RES. Potential investors are identified by an invitation of tender. The price is the dominant selection criterion. Either all tenderers who submit offers below a price fixed in advance are chosen, or those with the most favourable terms receive an acceptance of bid until the maximum limit of the stock budget or the intended amount of production capacity is reached. Concerning the payment of the produced energy, the tender price or an average price can be fixed. The network operators are obliged to feed in the electricity from the selected projects and pay an average tariff comparable to the reimbursement for electricity from fossil fuels. Thus, the price of the renewable energy has two components, the reimbursement from the network operator plus the premium form the fund.

The concept intends to create a market for electricity from RES with predictable quantities at a certain price or range of prices. The main objectives of the concept are to generate competition between the producers of electricity from RES during the tender procedure and to keep the prices of electricity from RES as low a possible.

Characteristic features of this concept are:

- Competition takes place amongst the producers of electricity from RES

- The risk of the cost recovery remains with the investor.
- Reduction of costs after the acceptance of the offer leads to higher earnings for the producer. This mechanism can favour technical innovation.
- A mix of electricity from different RES can be achieved by fixing certain target figures for different RES.
- The difference between actual cost of electricity from RES and from fossil fuels is covered by the fund. From the feed-in of electricity from RES there do not arise additional cost for the network operators.
- The instrument can be easily adapted to changed framework conditions.
- Financing of the fund can be organized without impact on the national budget, for example by a surcharge on the electricity prices for consumers.

Despite a number of advantages, the invitation to tender exhibits also some problems:

- There doesn´t exist a guarantee that the production capacities will be really built.
- A reliable planning basis is given only for those investors, who have gained a contract.
- Larger companies, who have a good access to planning and financing capacities, are clearly privileged in the tender process because they can overcome long planning and decision periods.
- There are no stimuli to build RES capacities additionally to those which are constructed due to the tender process as long as electricity from RES is more expensive than from fossil fuels.
- There doesn´t necessarily exist a long-term perspective, because the tender conditions can change in short terms, for example every year. This can turn out to be a barrier for innovations and for a continuous planning for the manufacturers of RES energy systems.
- The expenses for the organisation of the tender process are high, for the administration as well as for the tenders.

Emission certificates

The objective of this concept is to limit and reduce the greenhouse gas emissions. For that purpose, a cap for emissions is fixed by law. In the beginning, the total start emission volume is allocated in the different economic sector in form of emission certificates. Companies have the possibility to sell or buy emission certificates. Depending on the price of the certificates, this instrument can stimulate energy saving and RES technologies. Due to the fact that most of the energy saving measures and substitution of CO_2-rich fuels are still more cost-efficient than RES, RES will benefit only little from this concept (Reinaud, 2003) This situation can improve, when the prices of emission certificates rise make investment in RES economically more interesting than purchase of emission certificates.

The advantages of the concept of emission certificates are the following:

- Emission trading complies with free-market economy mechanisms.
- There arise no (or only little) cost which must be covered by the national budget.
- Market mechanisms result in cost-efficient solutions for the reduction of greenhouse gases.

Concerning the RES, there are some critical disadvantages:

- Emission trade is an instrument that supports only those RES which are already nearly competitive with energy saving technologies.
- As the prices of the emission certificates are subject to fluctuations and as the trend is unknown, they do not permit a reliable planning basis for long-term decisions on investment in RES capacities.

Quotas

Regulation of quantities by quotas requires a state controlled specification and fixation of a minimum level for RES production capacities or fraction respectively absolute amount of electricity from RES. When the quota system is coupled with trade of certificates of RES capacities, respectively RES electricity, this will provide a market instrument to create competition and to achieve cost efficient solutions. The costs for the additional RES capacities will be transferred to the consumers.

The certificate has a double function: First, It provides a verification of the fulfilment of the quota which is required. Second it can be traded on a market for RES certificates. The second function permits the owners of certificates to gain additional income by trade of certificates.

Quotas can be fixed for all kinds of RES, not only for grid-connected ones. Thus not electricity from RES but also heating energy can be included in the concept of quotas.

The proper design of a quota system requires a proper conceptual design. Important aspects are.

- In the beginning quotas must be fixed which regard the already existing RES capacities, and the available RES technologies.
- The initial quotas should be sufficiently high that an extension of RES capacities is necessary. But they should induce a moderate increase to limit the costs of these additionally capacities and – consequently – the prices of the certificates.
- The RES which shall be applied for the fulfilling of the quotas must be defined.
- The development should be outlined on a long-term scale to deliver a reliable basis for investment.
- It is necessary to define who has to fulfil the quotas – consumers, those who sell energy to the end-consumers, the producers, etc. pp.. To limit the expenses of certification, one tends to limit the numbers of actor. On the other hand, cartelisation should be avoided, to guarantee the proper function of market mechanisms. This mostly leads to the selection of the vendors as the one in charge for the compliance with the quotas.
- The time within which the quotas have to be fulfilled must be adequate to enable the investors to perform a proper planning and construction.
- Penalties must be defined in case the quotas are not accomplished in time.
- A certification system for RES capacities / Energy from RES must be installed.
- A trading system for RES certificates has to be established.

The effects of a quota system depend strongly on the design of this instrument.

In principle quotas show the following advantages:

- It complies with free-market economy mechanisms.
- Market mechanisms result in cost-efficient solutions for the construction of RES energy production capacities.
- The influence of the state is limited. State is only involved in the definition of the quota system, the installation of the certification and the respective trading system, the supervision of the compliance with the quotas and the imposition of penalties.
- When the system is once established, there arise no (or only little) cost which must be covered by the national budget.
- Thus it is an instrument that can be applied until RES has achieved competitiveness with fossil fuels. It is an instrument that can induce a broad effect.
- The involvement of energy utilities has the advantage, that their financial resources and planning capacities can be activated. Thus RES are not longer restricted to a niche market, but can be broadly integrated in the energy market.
- For those who must fulfil the quotas, there exist different options to act: investment in RES, buying certificates or paying the penalties.
- The influence on competition processes is little, because the conditions are predictable and the same for all market participants.
- Quotas are an instrument that can be easily transferred on an international level.

Despite the positive aspects of quotas as an instrument for the implementation of RES, there do exist some disadvantages, which are often claimed:

- Quotas can act as a cap, if they are not designed dynamically.
- It does not deliver a sufficiently reliable basis for decision on investments.

The first problem can be dealt with by a quota that is chosen sufficiently high on a long-term scale and which is divided into sub-quotas that have to be reached after well defined periods.

The second critical point can be avoided, when the quota system is accompanied by subsidies for those RES which are far from competitiveness.

4.1.4 Voluntary measures

There exist several instruments to support voluntary efforts of end-consumers and industry for the application of RES: information and education. All theses instruments are “soft” instruments because they haven ´t necessarily the strength to change the behaviour of the target groups: Voluntary measures are not connected with legal regulations, penalties or financial support. They try to influence behaviour by information, education, appeal, voluntary obligations or recommendation of RES-products like green electricity. All these measures do not interfere with market mechanisms, i.e. they comply with market economy.

The following instruments which belong to this type of measures will be regarded more closely: offering of information and education, voluntary obligations and green electricity.

Information and education

Often the deployment of RES technology fails due to a lack of correct information on the possibilities, the prerequisites, the costs and the limitation of these technologies. Information and education programs tend to transfer the specific knowledge and to increase the awareness of end-consumers as well as of experts like planners, craftsmen and architects. For the information, all modern communication marketing methods are applied, for example emissions in radio, tv, the press and the internet, publications like handbooks, flyers and leaflets and event marketing. Conferences and training courses are often chosen for further training of experts. In the field of information and education, non-governmental actors are of high importance because they are supposed to deliver neutral information free from individual economical interest.

Depending on the chosen tool, information and education measures can be connected with high expenses. Unfortunately, their efficiency is hardly to verify. Nonetheless, they are indispensable for the stimulation of the interest of target groups of several other instruments, for example promotion schemes.

Labelling

One kind of information source that has proven its suitability in context with white goods is labelling. Labelling can refer to energetic quality of buildings as well as on solar thermal systems, photovoltaic systems or green electricity. Recently labelling in Germany has been extended to low-energy buildings, solar thermal and photovoltaic systems.

This instruments aims at two aspects: It signalises the energy efficiency of the product and it indicates it´s environmental benefit. In this way it can act a decision criterion for people with high environmental awareness.

That fact, that the efficiency of the measure can not be determined, applies also for labelling. On the other hand, it is an instrument that can be organised without state interference, it needs no financing by the national budget, it complies with competition and it can act as a marketing instrument for producers.

Voluntary obligations

Voluntary obligations are mostly contracts between national or regional governments with industry which gain at the achievement of a RES-related objective or the compliance with emission limits. Normally, the measures which are taken to reach the aim, can be chosen freely by the industry partner.

The conclusion of voluntary obligation is undertaken with the hope that official regulations with high administration expenses and high financing cost can be avoided and that cost effective solutions for the achievement of the aim can be realised easier.

Unfortunately, the experiences with voluntary obligations are so far not encouraging. They often didn´t deliver the results desired, but delayed the implementation of the intended measures.

Green electricity

In the course of the liberalisation of the electricity market in Germany, many new suppliers appeared with offered of green electricity. Meanwhile, there are only a few actors left who operate on a national level. Most of the green electricity products are offered by local power suppliers and are limited regionally or locally. In the mature of the cases, they include electricity from RES that are already nearly competitive with electricity from fossil fuels.

Due to the fact, that electricity from RES is strongly supported by the feed-in law in Germany, and because of the comparably high prices, green electricity products do not play a significant role.

In general one can state that green electricity is appropriate to skim the willingness to pay higher prices for energy from RES, but it is not an instrument for a broad market penetration of RES.

4.2 Assessment of instruments

There a two approaches for the assessment of instruments for the promotion of energy from RES:

- the appropriateness of the instruments for different stages of readiness for marketing and
- the valuation of the instruments concerning criteria of success, i.e. the achievement of objectives (effectiveness), the efficiency of the deployment of financial resources and the social, regional and economic equity.

4.2.1 Instrument for different stages of readiness for marketing

In the following, the instruments presented in chapter 0 will be valuated regarding the aspect of readiness for marketing. For this purpose, Figure 4-2 gives a survey of the different instruments. The upper part of the diagram displays the different phases of RES technologies, the lower part the corresponding promotion instruments.

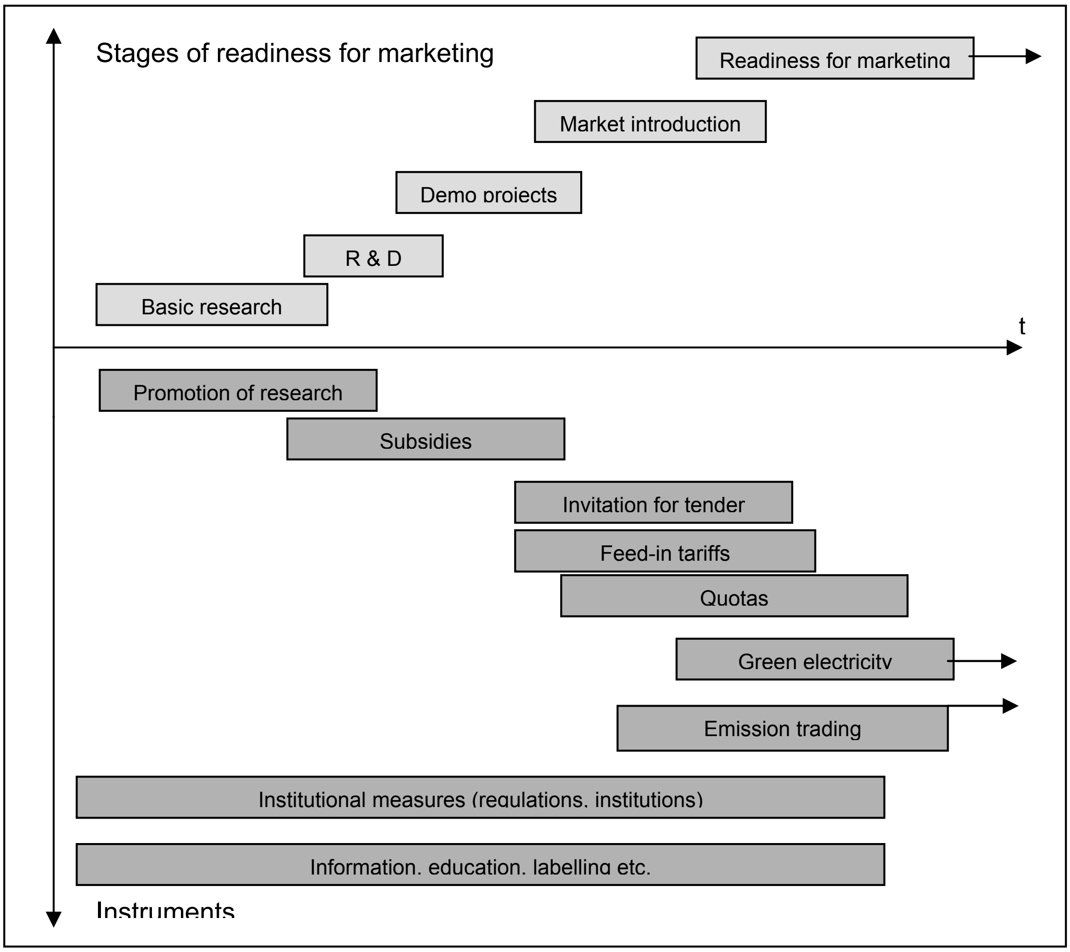

Figure 4-2:: Instruments for the promotion of RES and readiness for marketing (according to Espey (2001))

4.2.2 Evaluation according to criteria of success

An instrument for the promotion of RES can be called successful, if

- the intended objectives are achieved with
- a minimum of financial and administrative expenses and – simultaneously –
- it achieves high acceptance of the instrument by different interest groups in the country but also on an international level.

Or in other words:

The instrument must be **effective** concerning the objectives, **efficient** regarding the expenses and in compliance with **equity**, i.e. with social an economical requirements on an national and international level.

According to Espey (2001), this results in five domains of requirements, which are illustrated in Figure 4-3:

- conformity with objectives
- conformity with environmental policy principles
- conformity with the system
- institutional controllability
- economic efficiency

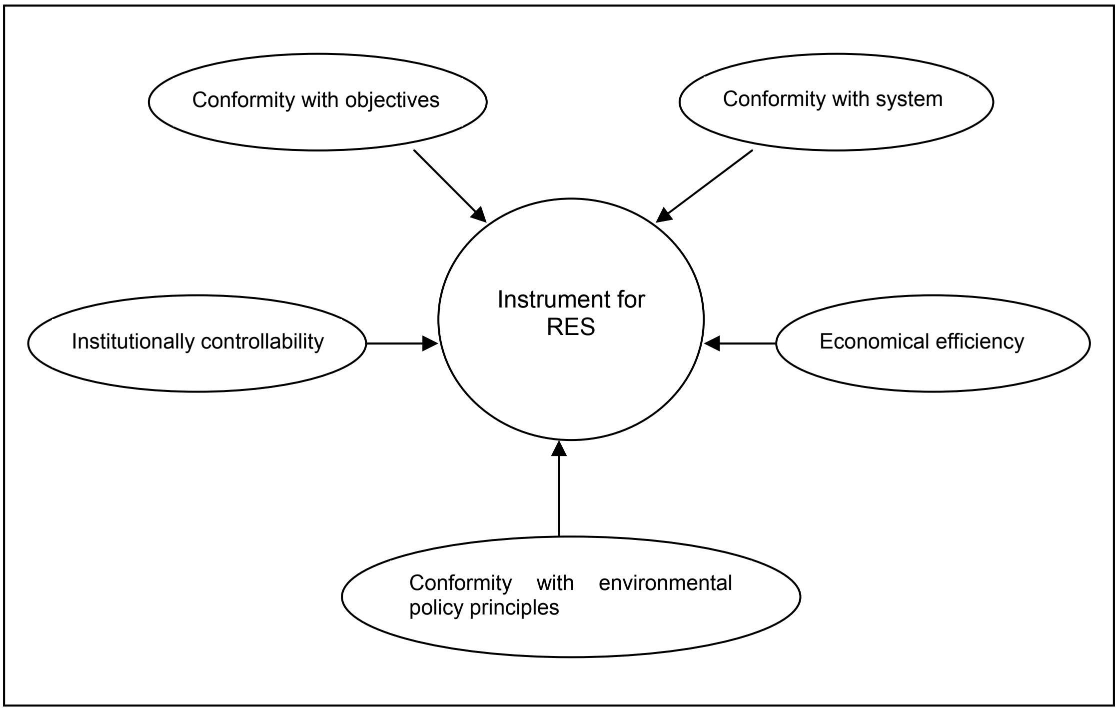

Figure 4-3: : Requirements for RES instruments (according to Espey (2001)

It is obvious that not all the requirements can be fulfilled completely: An instrument that is accepted by all interest groups – national and international – does not exist. And if everybody would be content with a measure, it is for sure that the expenses would be excessively.

So, the purpose of this valuation will be to find out the most appropriate instruments for different tasks. The first step is the careful consideration of the criteria of success.

4.2.2.1 Criteria of success

The criteria mentioned above shall be regarded more closely in the following.

Conformity with objectives

The most important criterion is the conformity with the objectives. If an instrument is not adapted to reach the intended objectives it will fail, even if it fulfils the other criteria. Possible objective could be an absolute or relative increase in energy production from RES, a reduction in prices for energy from RES or acceleration of the implementation of RES.

As already indicated in chapter 4.2.1, the various instrument are designed for different market situations. Furthermore, not all instruments are appropriate for all the different kinds of energy: Electricity, heat and transport require specific measures. One also has to differentiate between the dimensions of the RES technology: Solar thermal systems for individual houses can be promoted by other instruments than wind power plants. And last but not least, the instruments, respectively the mix of instruments will vary with the overall strategy. If a broad mix of RES is to be achieved one has to select other set of instruments than for a strategy that focuses only on one RES.

Conformity with environmental policy principles

The superior objective of RES promotion is a sustainable energy supply. Therefore, the four principles of environmental policy should be considered when selecting instruments. These principles are:

Polluter pays principle:	Those who are responsible for the pollution have to bear the cost of the disposal of the pollution
Principle of cooperation:	Measures should be taken in reconciliation with the relevant actors to achieve a high acceptance
Principle of main focus:	Measures should be taken in the field where large improvements can be achieved with limited expenses and not in sector where small effects are gained with much efforts.
Precautionary principle:	governmental decisions and measures must be taken in such a way that negative impact on environment is avoided, but a development towards a sustainable development is induced.

Conformity with the system

The instruments should take care of the general framework: competition, national and international legislation and liberalisation of the market. In any case they should have no or little influence on competition on the market and the influence should be restricted in time. This means that the instruments should comply with the free market thus leaving the freedom of action to the actors on the market to ensure efficient competition and unrestricted formation of prices.

Additionally further economic and social objectives as the prevention of windfall gains and a uniform distribution of the costs of deployment of RES (regionally and socially), should be regarded in the conceptual design of policy instruments for RES. Last but not least, the impacts of changes of the political conditions on the instruments, as for example the election of a new government, should be minor.

Economic efficiency

The cost of a measure should be as small as possible compared to the benefit obtained, thus ensuring an efficient allocation of financial resources. A measure should be designed in such a way that it encourages innovation dynamics and provides at the same time a reliable basis for planning. This means, that for example subsidy programmes should have a sufficiently long duration and that they should include a sunset clause reflecting the limitation of the programme as well as a decrease of the height of subsidies.

A crucial point is the guarantee of the financing of the chosen instruments of the complete duration. This includes that the instrument should be affected by the usual economical fluctuations as little as possible. This means for example that problems with the national budget should not result in an abrupt termination of a measure.

Institutional controllability

One aspect of institutional controllability is the political decision process for the introduction of RES instruments. High transparency of the instrument and an early involvement of relevant interest groups in the decision process facilitate the achievement of a consensus and later on the enforceability of the instrument.

To ensure a smooth implementation of the instrument, the administrative procedures should be as simple as possible and the rights and obligations of the involved persons or institutions should be well defined. All institutions which are responsible for the implementation and administration of the instrument must be equipped with the appropriate competences

The concept of the instrument should have a compulsory character and should include penalties which are sufficiently high to favour the implementation of RES to the omission of the intended measure.

4.2.2.2 Evaluation of RES instruments

The instruments regarded in chapter 0 will be valuated on the basis of the criteria described in the previous chapter. This assessment can only be quantitative whereas

- the conditions in different countries vary substantially,
- the explicit design of an instrument influences its quality with regard to effectiveness, efficiency and equity,
- general conditions may change and modify the assessment.

Regarding the requirements of effectiveness, efficiency and equity, those instruments were pre-selected for further analysis, that have - according to the characterisation in chapter 4.1 - the potential to promote RES significantly:

- regulations – in particular solar bylaws,
- subventions (promotion schemes),
- feed-in tariffs,
- taxes,
- invitation for tender,
- emission certificates and

- quotas.

The following instruments were not regarded in detail:

- control of investment - main impact on energy saving, little influence on RES,
- target agreement - due to poor results in the past,
- voluntary measures - important as accompanying instrument, but measurement of effectiveness and results difficult

The assessment of the measures includes also the aspect of the suitability of the instruments for different applications, i.e. electricity, heat and transport.

Table 4-1 displays a summary of the assessment. The scale of rating was chosen as follows

Rating	Correspondence with criterion
O	no effect / impact
S	Small effect / impact
M	Medium scale effect / impact
L	Large effect / impact

The results shown in Table 4-1 correspond well with the main findings of the EU funded study GREEN-X from Ceijne et. al. (2004), where a range of policy instruments and their combinations were assessed applying an elaborated dynamic model. In the following, the main results for the different models will be elucidated in detail.

Subsidies

Subsidies in form of promotion programmes are an instrument mainly applied during the pre-market stage for research and development and demonstration projects and in the early phase of market introduction. They can be tailored corresponding to the intended aims thus ensuring an achievement of objectives, if the instrument is accepted by the target groups as predicted. During the early phase of market introduction, the financial aides help to diminish the cost difference between energy from RES and fossil fuels. Promotion programmes mostly provoke a fast reaction of those members of the target groups who show interest in this instrument. This instrument leaves a high freedom of action to the target groups, which results also in a high institutional controllability.

The duration is normally limited and they are mostly financed by the national budget. Therefore they accord to the precautionary principle, but depend – for the same reason - on the political framework. The administration expenses are limited, because normally the institutions which are responsible for the implementation have much experience with promotion schemes.

The economic efficiency as well as the effects on CO_2-reduction and the achieved increase of the deployment of RES is difficult to predict, due to the voluntariness of the use of promotion programmes. Promotion programmes often support research and development, thus inducing innovation.

Table 4-1: Valuation of the instruments for RES regarding the criteria of success (according to Espey, 2001)
[2] : if the tariff / quota / budget is sufficiently high

Instrument / Criteron	Subsidies	Regulation	Feed-in tariff	Invitation for tender	Quota with certificates	Tax	Emission certificate
Applicability for stages of marketing	R & D, demo projects, introduction	Introduction, readiness	Introduction, readiness	Introduction, readiness	Introduction, readiness	Readiness	Readiness
conformity with objectives							
increase of RES energy production	S – M	L	L [2]	L [2]	L [2]	S	S
reduction in RES prices	M	S	S	M	M - L	O - S	S
Reduction of CO_2	S – M	S – M	S – M	S – M	S – M	L	L
acceleration of the implementation of RES	L	M	L	M	M - L	O - S	O - S
conformity with environment policy principles							
Polluter pays principle	O	S – M	S – M	S - M	L	L	L
Principle of cooperation	L	S	S	M	L	L	L
Principle of main focus	S – M	S – M	S - M	L	L	L	L
Precautionary principle	L	L	L	S	L	L	L
conformity with system							
Intensity of impact on markets[1]	O - S	L	L	S	L	S	S
Reduction of freedom of action	O	L	L	O – S	O	O	O
Promotion of competition	O – S	O	O	M - L	L	L	L
Market integration	S – M	S – M	S – M	L	L	L	L
Negative side effects	O – S	O	O – S	O – S	O	O	S – O
Stability versus political changing	M	M	M	M	L	L	L
Durability	M	M	M	M	L	L	L
Institutional controllability							
Enforceability	L	M	M	M	M	M	M
Administrative expenses [1]	M	S	M	L	M	S	M
economical efficiency							
Cost-efficiency ratio	M	M	M	L	L	L	L
Promotion of innovation	M - L	M	M	M	L	S – M	S - M

Regulations

Regulations can be applied during the phase of market introduction of RES-technologies or to products which are ready for marketing. They can be tailored corresponding to the intended aims thus ensuring an achievement of objectives. In contrast to subsidies, the obligor has little freedom of action.

The effect of regulations on the reduction of CO_2, the increase of the energy production from RES and the degree of acceleration of the implementation of RES depend on the specific configuration of this instrument. One example of a successful regulation is the solar bylaw hat was introduced in Barcelona for the first time. Within the first three years it resulted in an increase of the number of installed solar thermal systems by a factor of four. The administrative expenses of regulations are low and – after the implementation of the regulation – they were restricted to the control of compliance.

Regulations can support cost-efficiency and can induce price reductions for RES

Feed-in tariffs

Feed-in tariffs are an effective instrument for the increase of network-related electricity production from RES. They have been established in many countries and have proven to be a success in Denmark, Germany and Spain inducing remarkable increases in electricity from wind power.

Nonetheless, their ability to acceleration the implementation of RES and increase energy production from RES depends on the detailed design, for example the height of tariff and the continuity of the instrument. The influence of feed-in tariffs on CO_2-reduction and as a consequence – on the compliance with the precautionary principle - depends on the type of production capacity which is substituted by wind energy.

In most cases, the polluter pays principle is considered only partially, because the financing costs of this instrument are allocated only on (?) the standard consumers. Also cooperation takes place only during the design of feed-in tariffs. Once feed-in tariffs are established, the parties who have to finance this instrument are no longer free to choose cooperation or refusal.

Concerning the conformity with market mechanisms, one has to state that feed-in tariffs do not induce competition, that they permit windfall gains and can comprise negative side effects like financial disadvantages for regions with high rates of RES electricity if compensation mechanisms are not provided.

From the viewpoint of the state, feed-in tariffs exhibit high economic efficiency because the expenses for the implementation of this instrument are low. Ragwitz, Held (2005). Regarding national economy, this instrument is not necessarily efficient because it does not favour the cost efficient solutions.

The enforcebility of feed-in tariffs has degraded during the last years due to the transition from monopolistic markets to liberalised electricity markets which was accompanied by an increase of resistance to feed-in tariffs by the power utilities.

Invitation for tender

The effect of this instrument on the acceleration of the implementation of RES and the increase of energy production from RES depends strongly on the available budget and the kind of financial support. If the allocation of the fund is carried out regarding the resulting price of RES energy, this instrument is suited to create competition and to induce price reductions. One disadvantage of invitations is the fact, that it is not guaranteed that the selected projects are implemented.

As in the case of feed-in tariffs, the influence on CO_2-reduction and the compliance with the precautionary principle depend on the type of production capacity which is substituted by the RES. Due to the fact that invitations for tenders aim at techniques which have achieved readiness for marketing, this instrument complies with the principle of main focus. The polluter pays principle is only applied when financing by energy taxes or surcharges on the electricity price are chosen. As the participation in invitations is voluntary, the cooperation principle is valid and the energy producers have full freedom of action.

The efficiency of invitations for tenders depends strongly on the volume of the available budget. This instrument is capable to induce high extension rates if an appropriate financing is guaranteed. But it does not necessarily ensure a continuous growth. (Ragwitz, Held, 2005) Therefore, this instrument can only be durable if the budget is guaranteed over a long period. Thus, it depends strongly on political conditions.

Invitations create a niche market and the transfer to a free market situation is not assured. The administrative expenses for the handling if tendering processes are comparably high and wind fall gains can not be excluded.

Quota with certificates

A model including quotas and trade of certificates can be designed specifically to achieve increase of RES energy production. The height and the rise of the quota determine the development of the RES. Additionally, the development of the price of the certificates has an influence on the promotion of RES.

As already marked out for feed-in tariffs and invitation for tenders, the influence on CO_2-reduction and the compliance with the precautionary principle depend on the type of production capacity which is substituted by the RES.

The instrument complies with all the environmental principles quotad above and gives a high degree of freedom of action to the market partners. Quotas also comply with market mechanisms and show conformity with other system aspects: They support competition, help to reduce the prices of RES and comprise little or no risk of wind fall gains.

Consequently, the cost efficiency of quotas is high as well as their promotion of innovations. On the other hand, the expenses of the installation of a quota system with certificates and the control of compliance are not negligible. In chapter 4.3, the quotas and feed-in tariffs will be compared in detail.

Taxes

CO_2-taxes, eventually also energy taxes increase the prices of energy from fossil fuels. These taxes support substitution potentials and offer an effective tool for the reduction of CO_2-emissions. (Palmer, Burtraw 2005) CO_2- and energy taxes comply with market mechanisms and leave a high degree of freedom of action to the market partners. These taxes can be easily integrated in the tax system and the administration expenses are low. The effect of taxes on the increase and the acceleration of the implementation of RES is judged to be of minor importance. Taxes can be an additional stimulus – together with other instruments – for the implementation of RES.

4.3 Quotas versus feed-in tariffs

During the last decade, two of the above presented instruments emerged to be the favourable ones for the promotion of RES electricity:

- Feed-in tariffs - in 8 countries of the EU-15 and Cyprus, Czech Republic, Estonia, Hungary, Latvia and Lithuania and

- quota with certificate - in 6 countries.Experts

Currently discuss the advantages and disadvantages of these two instruments very intensively. One group of experts outlines the progress in RES deployment induced by feed-in tariffs in Germany, Denmark and Spain, while the other party focuses on the for higher degree of compliance of the quotas with market mechanisms, which is advantageous for a broader market implementation of RES.

Table 4-2: Main instruments for the promotion of electricity from RES

Country	Feed-in tariffs	Quota with certificate	Taxes	Invitation for tender
Austria	●			
Belgium		●		
Cyprus	●			
Czech republic	●			
Denmark		●		
Estonia	●			
Finland			●	
France	●			
Germany	●			
Greece	●			
Hungary	●			
Ireland				●
Italy		●		
Latvia	●			
Lithuania	●			
Luxembourg	●			
Netherlands	●			
Poland		●		
Portugal	●			
Sweden		●		
Spain	●			
UK		●		

In a recent publication (Häder, 2005) the results of several studies are analysed and evaluated regarding the criteria effectiveness, efficiency and compliance with the EU market (Häder (2005)).[14]

Häder points out, that the direct comparison of results of both instruments is difficult due to the fact that there exists a lot of experience with feed-in tariffs, whereas quotas are a relatively "young" instrument for the promotion or RES. He analyses the evaluation of feed-in schemes and quotas and argues from economical theory for promotion schemes.

The main conclusions are as follows:

- Feed-in tariffs and quotas are two instruments with high effectiveness for RES promotion.
- Feed-in tariffs are a reliable and attractive promotion scheme for investments in RES electricity capacities lowering the risk of investments and providing long-term stability, if an appropriate feed-in tariffs is chosen.
- Uncomplicated and fast approval procedures, appropriate network structures and well adapted regulations for the network access are basic requirements for the successful implementation of both instruments.
- Feed-in tariffs support the development of technology and the creation of new RES industry sectors in an early market phase.
- Feed-in tariffs do not sufficiently encourage innovations and the exploitation of cost reduction potentials. Thus, they are not very efficient instruments.
- Feed-in tariffs do not promote the integration of RES in the electricity market.
- With increasing expansion and rising readiness for marketing of RES, feed-in tariffs have structural disadvantages with respect to competition, market integration and innovation.
- Quota mechanisms contain price, volume and balancing risks for the renewable energy generation. Therefore quotas are a mechanism that favours large, integrated companies which can overcome these risks. This is not possible for small companies. (Mitchell et. al. (2006))
- Existing quota systems result in higher prices of RES electricity due to the higher risks compared to feed-in tariffs. (Mitchell et. al. (2006))
- Quotas support the development versus competitiveness of RES on the market activating cost reduction potentials and innovations.
- Quotas promote the integration of RES in the electricity market.
- Quota systems can be easily transferred to the EU-level without the creation of complex systems for the equitable cost distribution.

These results match well with the valuation of the instruments for RES summarised in Table 4-1 and the results of Sawin, Flavin (2004).

An evaluation of Ragwitz and Held regards the aspects effectiveness and efficiency of feed-in tariffs, quotas and invitation of tender. (Ragwitz, Held 2005) They emphasize that the analysis of instruments applied in the EU for renewable electricity shows that at pre-

[14] The last criterion is not absolutely identical with the above mentioned "Equity" but is related to the aspect "conformity with the system.

sent, feed-in tariffs are more efficient than quota systems. But for both instruments a framework with long-term stability that allows sufficient time for project planning, realisation and operation under reliable conditions is an inevitable basis for investments in RES. (OPTRES, 2005)

Additionally to the aspects mentioned above, one argument against feed-in tariffs is that they do not encourage innovation. This problem could be overcome by regular adjustment of the tariffs to the technical development. For this purpose, experts would be required who can determine the appropriate height of tariffs.

On the other hand, quotas are said to have the disadvantage, that technologies which are far from readiness for marketing will no longer be developed. (Ragwitz, Held 2005) To ensure the desired mix of technologies, a general quota can be divided in sub-quotas for different technologies. This would correspond to existing regulations for feed-in tariffs which vary for different RES technologies.

Although the feed-in tariffs resulted in high rate of growth of RES electricity, it is not necessarily a success. In fact, the individual design of the promotion instrument is an important factor for success– in connection with the above mentioned conditions, a coherent mix of different instruments and a conclusive political conception. Only when the relevant investors, i.e. the industry, are convinced that the conditions for investments in RES are favourable and stable in the long run, they will install new production capacities and create new jobs.

Another aspect not yet regarded is the applicability of the two instruments to other sectors than electricity, .i.e. heat and transport. As recent evaluation of the status of RES in the EU show, the activities in these sectors must be enforced to meet the goals set for 2010 in the EU (Ragwitz et. al. 2005).

One can conclude state, that both instruments - feed-in tariffs as well as quotas - have the potential to be introduced easily into the transport sector – in a modified form - due to the limited number of actors in the mineral oil distribution sector.

For Germany, Nast et. al. (2000) developed a concept based on quotas, which was improved later on (Nast 2004). In the quota model, the operators of RES production capacities would receive certificates and the distributors of fuels would be obliged to buy a certain amount of certificates depending on the quantity of sold energy (percentage of sold energy) to fulfil the quotas. The quotas would rise in pre-determined periods and would be divided into sub-quotas for different technologies.

A concept for feed-in tariffs would encounter the problem that prices for the produced energy must be fixed sufficiently high to encourage investment in RES heating technology but sufficiently low to limit wind fall gains and to induce innovations. This requires advisory boards who can fix prices at appropriate levels. Another problem is the equitable distribution of the of the cost of the instrument: In contrast to electricity, where a small number of network operators can allocate the resulting cost on the network tariffs which are finally paid by the consumers, a comparable mechanism does not exist for heat, because heat is not fed into a form of network.

With respect to the discussion "quotas versus feed in tariffs" one can conclude:

- Feed-in tariffs are an effective tool for the initiation of the market introduction of RES and the creation of new RES industry sectors as they provide low risks of investments and long-term stability.
- With increasing expansion and rising readiness for marketing of RES, quotas are an appropriate instrument for the creation of competition, the activation of cost reduction potentials and the market integration of RES on a national and EU-level.
- Both instruments can be transferred to the transport and heating sector, whereas the adaptation of the quota concept is easier.
- Uncomplicated and fast approval procedures, appropriate access to energy transport structures (i.e. mostly network) and well adapted regulations for this access are basic requirements for the successful implementation of both instruments.

4.4 Case study Denmark

The development of wind energy in Denmark since the early 80s[h] can be taken as successful model for promotion concept for the introduction of RES. Along the time scale from the decision to promote RES until the establishment of wind energy on the energy market (compare **Fehler! Verweisquelle konnte nicht gefunden werden.**), the Danish strategy combined the following main instruments (Meyer, 2004):

Danish government energy planning and targets on a long-term scale

- Information campaigns and the establishment of national and local energy offices for the promotion of RES
- Long-term government support for research, development and demonstration for the development of appropriate technologies
- National test and certification procedures which guarantee quality assurance to acquire a credible market reputation
- Government-sponsored analysis and documentation of energy potentials of RES (wind atlases) to facilitate the selection of appropriate installation sites for wind turbines
- Local ownership and careful selection of sites to ensure high acceptance of wind farm installations
- Feed-in tariffs and regulations and (decreasing) investment subsidies to ensure a reliable basis with low risks for investments in wind turbines.[15]

[15] Investments subsidies decreased from 30% of the turbines pruchase in 1979 to 10% during the 80s and were eliminated in 1989.

As a result of this continuous strategy, Denmark became a leader in wind turbine installations and wind turbine production, covering 50% of the world market in 2002.

Since 2000, the situation has changed due to the liberalisation of energy market and a redirection of the Danish energy policy. The new Danish Energy Act, approved by the EU-Commission in September 2000, introduced a shift from the feed-in model to a quota system with trade of green certificates. This transition proved to rise problems for the further development of wind energy:

First, the introduction of the trading of green certificates was delayed drastically due to operational complications of the system including high transaction costs at a small national market.

Second, the installation of land-based wind capacity dropped from 600 MW in 2000 to 100 MW in 2001 because of the uncertainty of the conditions in this new system and the higher risks of investment especially for private wind power investors.

Future has to show, whether these are only transition problems or serious barriers for the further development of RES.

5. Conclusions and forecast

One of the current challenges of European energy policy is not to find the one and only instrument but to create a reliable framework for the investment for the increased deployment of RES. As shown above, there does not exist one policy that is appropriate for all countries in the EU. In fact, the optimum strategy

- depends always on the objective that is chosen: The appropriate strategy for "Enforced development of RES" differs from that one for "CO_2-reduction" or "Short/Medium term creation of jobs".
- is always a combination of well co-ordinated instruments.
- depends on the specific national condition concerning availability of RES, economy, infrastructure, legislation, social aspects and key actors.

If the focus is on "Enforced development of RES", the instruments should be chosen according to the readiness of marketing of the specific technology. For those RES which are close to competitiveness with fossil fuels feed-in tariffs and quotas are possible instruments. Feed-in tariffs have proven to ensure a reliable basis for investment and to induce impressive developments of RES. Quotas haven been introduced recently in some EU countries. They imply higher risks for investment but tend to match better with market mechanisms and competition. Future will show which of these aspects dominates and whether quotas are capable to promote RES.

Future policy should not only provide sufficient incentives for the development of a market of renewable energy, but also promote technological research and development and public acceptance. Moreover, the policy framework for the renewable energy sector needs to be harmonized with many other sectors and issues, such as agriculture and forestry, nature conservation, transport, energy efficiency, construction industry, economic policy, etc. One common trend that can be followed through all studies is the rating of the relative importance of different renewable energy sources for Europe in the next decades. The literature review clearly shows that the most utilised RES would be wind and biomass, especially for power and heat generation, at least until 2020. The further increase in the deployment rate of photovoltaics is necessary in order to keep up with ever more stringent direct and indirect national and international targets. Geothermal energy is also meant to have a certain smaller role in the future, especially as hydropower potential is almost exhausted. This brings up several conclusions for the “green” development of the European energy sector:

- There will be an ever-growing competition for land for energy crops, which needs to be regulated.
- The limited wind and hydropotential would make it necessary to invest in repowering (upgrading) of existing generation capacity.
- The future energy system will increasingly rely on intermittent energy sources (wind and solar). Therefore, technological research and development are needed in order to optimize the use and storage of renewable energy through hydrogen, seasonal storage heat pumps, etc.

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