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The Political Economy of the Green Technology Sector

by

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The Political Economy of the Green Technology Sector

A study about institutions, diffusion and efficiency

JEL: D72, H21, L52, Q28 and Q48.

Key Words: Regulation, Renewable Energies, Green Technologies, EEG, SEG.

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Abstract

This paper discusses aspects related to the green technology sector in Germany. In a first step institutional reforms enabling diffusion of green technologies are analysed. Cost arguments are also taken into account. In a second step a theoretical model developed by Tanguay et al. (2004) is modified in order to evaluate the efficiency of the institutional setting in a political economy framework. The model is able to show that command and control policies (CCPs) are accompanied by cost-inefficiencies depending on the political weight of the green technology sector. Because actual costs related to the support of green technologies are relatively low, the theoretical predictions of the model are moderated. Nevertheless, as additional money will be transferred to the green technology sector during the next decades, interest groups will gain additional political power and the problem of cost inefficiency can therefore become more relevant. The paper gives important hints whether the CCP system installed in Germany is the right instrument in order to *increase* the share of energy produced with green technologies from 12.5% (in 2010) up to a level of 30% (in 2020).

1 Introduction

The topic discussed in this paper is the political economy of the green technology sector in Germany. As the diffusion of green technologies (GTs) is highly

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dependent on the institutional setting, it is important to know which political targets policymakers attempt to reach with respect to the support of GTs. As stated in Article 1 (1) of the "Erneuerbare Energieengesetz" (EEG), the EEG is an act aimed to

"facilitate a sustainable development of energy supply, particularly for the sake of protecting our climate and the environment, to reduce the costs of energy supply to the national economy, also by incorporating external long-term effects, to conserve fossil fuels and to promote the further development of technologies for the generation of electricity from renewable energy sources".

(EEG 2009)

This shows that different targets play a role concerning the support of renewable energies. The overall political target is *sustainable development*. Sustainable development includes topics like (1) *climate protection* as well as the (2) *incorporation of external long-term effects* with respect to energy supply. Additionally the EEG aims to (3) *conserve fossil fuels* and is aimed to (4) *promote future development of technologies*. It becomes clear, that it is difficult to discuss the EEG and the diffusion of GTs separately from these political targets.

(1) implies that all topics related to climate change, like international political agreements (e. g. the Protocol of Kyoto) have an impact on the future of GTs. Studies like the so called *Stern Review* (Stern 2007) therefore have a direct or indirect impact on the future development of the GTs sector. The aim to allow for sustainable development by incorporating long lasting external effects can be considered as an implicit target to substitute conventional energy in the long run.¹ This conclusion can be drawn because conventional energy bears the risk of costly externalities from a long term perspective. Substitution of existing technologies (2) is necessary if the aim to become independent from fossil energy sources is taken serious. Increasing energy prices have direct and indirect effects on the future development of the GT sector (3). The fourth aim worth to mention in this context is the promotion of future technologies (4). This target seems to be the political target outweighing the others, because goal (2) and (3) cannot be reached without success with goal (4). To achieve this goal, it seems that policymakers are willing to ignore goal (1), as many investments were directed into coal power plants as an answer to the nuclear phaseout decided in 1998.² The discussion shows that the targets aimed to be achieved with the EEG are very ambitious. Nevertheless, so far the EEG is evaluated as a successful policy measure not only by policymakers.

From a political point of view it seems to be clear that the share of energy produced with GTs will increase. Regarding the diffusion of GTs over time, it is important to mention that the initiative often comes from the EU. For instance the EU has set the political target that in 2010 the share of renewable energy production in the internal electricity market shall increase up to a level of 12.5 % (EU 2001) . The proposal for 2020 is to achieve a share of 20 % (COM 2008). However, countries are free to define targets above the targets agreed on the European level. The German government aims to achieve a share of

¹The notion of conventional energy is used for nuclear energy production as well as for energy production using fossil energy sources like coal or gas.

²The nuclear phaseout was decided in 1998 under the red-green-coalition.

30 % of electricity production with GTs in 2020 (EEG 2008).

The aim of this study is to make a contribution to the assessment of the EEG and the diffusion of GTs. As the current system enabling the supply of GTs is mainly based on CCP instruments,³ it is important to ask the question *whether the current system should be used in order to achieve the political target defined under EEG (2008) (30 % of electricity produced with GTs) or whether it might be worth to think about an institutional setting which uses market based instruments.* It will be shown theoretically that even though there might be positive effects related to the EEG according the diffusion of GTs, the support as such turns out to be inefficient.⁴ With respect to the cost argument this seems to play only a minor role in the short run. Problems may occur rather in the long run. Because there is a lot of uncertainty related to the success of GTs and its future development, it is difficult to make a statement about the overall success of the CCPs implemented by the German government. Nevertheless, the main finding of the paper is that for *further* diffusion of GTs it might be better to switch from a command and control system to the application of more market based instruments. Additionally the paper is able to underline the importance of competition in order to keep costs for the achievement of certain political targets on low levels.

The outline is structured as follows: In section 2 research contributions about structural change in the energy sector are presented. Then, a short overview about different studies with the focus on the political economy of environmental policy is given. Section 3 describes the underlying institutions of the EEG and its antecessor the "Stromeinspeisegesetz" (SEG) in more detail. Section 4 takes a closer look at the diffusion of GTs and the related costs. What follows in section 5 is a theoretical model based on Tanguay et al. (2004) and the Economic Theory of Regulation developed by Stigler (1971). The model assesses the EEG from a political economy perspective. In section 6 the different results of the previous chapters are put together to draw a conclusion.

2 Environmental Policy and Renewable Energies

Many studies deal with the evolution of GTs and how it is possible to manage structural change towards the development of GTs. This chapter gives a short overview over the recent literature and discusses some of the results in more detail.

³One definition for CCPs is given as follows: "Under a command-and-control approach, government regulators specify the control technology or the maximum levels of pollution [...]. Other approaches, such as market-based incentives or contractual arrangements, allow sources much more flexibility to take into account variances in costs, production processes, and individual circumstances relevant to environmental protection goals. " (Stewart 1993, p. 2057, fn 79). For further discussion of CCPs compare Ackerman and Stewart (1987).

⁴The term "efficiency" is used in this context in order to underline the fact that the same outcome might be achieved with the investment of less resources.

2.1 Institutional Change

The history of renewable energies is very old. As stated by Sørensen (1991), during a long period of human history, renewable energy was the only energy option available. The emergence of conventional energy production came up mainly due to the cost argument. Nowadays, the increase in prices for fossil energy sources as well as environmental damages are the main reason why policymakers focus on GTs (Sørensen 1991, p. 10). In the context of environmental damages, global warming plays an important role. In 1990, when the Working Group I of the United Nations Intergovernmental Panel on Climate Change (IPCC) published an assessment about the scientific evidence of climate change, more economic research was done to find the adequate policy reaction. There is an ongoing debate about policy instruments which are able to reduce CO₂ emissions (Pearce 1991). The argument of climate change is also used by policymakers in order to support GTs (EEG 2004, BMU 2008, p. 8).⁵ What also plays an important role with respect to structural change in the energy system are theories about resource extraction developed by Hotelling (1931) or Dasgupta and Heal (1974). Nordhaus (1973) developed a framework how to manage structural change with investments into so called “backstop technologies” (technologies able to get independent from non-renewable energy sources). The pioneering work from Nordhaus (1973) has been developed further by Chakravorty et al. (1997). The authors distinguish between the extractions of different resources. The simulation results show that if a shift towards a primary use of solar energy will become possible than the increase of world temperatures turns out to be less than predicted by the IPCC. Even though they have focused on the technology of solar energy in their study, other “backstop technologies” may also play a role.

Many studies evaluating the diffusion of green technologies are related to political science. A review about the demand for green power is given by Bird et al. (2002). The study gives an overview over the demand for contracts on electricity produced with GTs in countries like Australia, Canada, Japan the US and several countries in Europe. In some countries the market share of contracts for green electricity is about 10%. On the global level on average the market share for such contracts was relatively low and did not exceed a level of 1%. Factors that can be considered as driving forces for increasing market share of green electricity contracts are customer education, aggressive marketing, price and transparency (e. g. labelling of the products) (Bird et al. 2002, p. 530).

More common than studies about the demand side are studies focusing on the supply side. Studies using a supply-side approach in most cases give an overview over the policy-induced structural change related to GTs and the driving forces behind it. Jacobsson and Lauber (2008) describe in detail the development and the factors which have been important to allow the GT sector to evolve. Their main argument is that the evolution of the GT sector in Germany was a “battle over institutions” between conventional energy producers and the renewable energy sector. The apparent success of feed-in tar-

⁵This argument is somehow misleading. With the political decision about the nuclear phase-out in Germany, many investments went into energy plants using carbon as main input factor.

iffs (FITs) is summarised by Wüstenhagen and Bilharz (2006).⁶ They study the institutional setting implemented in Germany and develop policy conclusions determining the likelihood of political support of the GT sector. Agnolucci (2003) also analyzes factors that can be considered as the main drivers for institutional change in the energy sector. With respect to the results, financial sustainability is a decisive factor. Furthermore it is found, that different political factors like size and variety of coalitions play a major role. Initiatives on the implementation of green technologies coming from the EU play a similar important role (Agnolucci 2003, pp. 148). Dröge and Schröder (2005) evaluate whether subsidies to the green sector or taxation of the polluting sectors are more efficient instruments to turn an industry green. They use simulation analysis and come to the result that a tax would be the optimal political instrument. If the sector polluting the environment is economically important, a subsidy of the green sector (e.g. the GT sector) is also acceptable.

Most of the studies analyze the success of structural change in the energy sector from a political perspective deliver important insights into the driving forces behind this development. From an economic point of view it can be criticised that efficiency does only play a minor role. The reasons determining the difference between economic efficiency and the outcome of the political process can be explained by the political economic theory.

2.2 Political Economy of Environmental Policy

An early work worth to mention in this context was done by Buchanan and Tullock (1975). The authors compare command and control policies with market based instruments in competitive markets. The question is why market based instruments in most cases are not the first choice of policymakers. The main reason why policymakers support direct control policies more often is due to lobbying activities of the regulated industries. The incentive to lobby against environmental taxes is due to the efficiency related to the penalty tax (Buchanan and Tullock 1975, p. 140). Redistribution of property rights might be significant and firms will lobby in favour of abatement subsidies. If firms compare the penalty tax with results expected from regulation, regulation can be considered beneficial for a single firm because of reduced competition with firms who might enter the market. This result also demonstrates the power of certain interest groups as command and control policies do not increase the political budget and are therefore relatively unattractive for policymakers. Kirchgässner and Schneider (2003) establish their study by discussing the acceptance of CCP measures. They determine the reasons for this observation by looking at the different actors who are shaping and influencing the political outcome. The interests of four groups of actors are described in detail: voters, politicians, public bureaucrats and the owners or decision makers of those industries that shall be regulated. As a result it turns out that beside the industries which are regulated, the members of the public bureaucracy have a high interest in CCP measures. The result is mainly based on the fact that CCP

⁶A feed-in tariff is a "minimum price standard that obliges distribution network operators to connect [green electricity power plants], to purchase [green electricity] and to pay a fixed remuneration (Cent per kWh) to the plant operator" (Langniß et al. 2008, p. 3).

“strengthens [the] [...] personal position [of policymakers] in the environmental policy game” (Kirchgässner and Schneider 2003, p. 380). The constitutional setting of the political process seems to be important for the success of market based instruments (e. g. taxes or certificates). Decentralised systems tend to be more close to individual preferences and seem to be more successful in implementing environmental reforms in favour of the public interest. Elements of direct democracy are instruments that are equally important. What might also help to implement ecological taxes or tradable permits is to compensate citizens with general tax reductions. That taxes not always increase the budget of policymakers is the result of a study of Fredriksson (2001). Taxes may have the surprising effect of a declining political budget. This is mainly due to the fact that industries lobby to get abatement subsidies. It is shown theoretically, that in a dynamic modeling setting, pollution can also increase with a pollution tax reform. Such a counterintuitive result can occur when interest groups successfully influence the political outcome in favour of their particular interests.

How citizens have successfully been winning a political contest against a monopolistic energy supplier in Germany is described by Graichen et al. (2001). The authors use a case study to demonstrate that self-organisation of citizens with respect to energy production can be successful. A theoretical model shows the determinants necessary for the emergence of the results reported in the study. Thalmann (2004) uses an empirical approach in order to find the determinants behind the failure to implement an ecological tax reform in Switzerland. As one of the results it turns out that the awareness of the expected social benefits of ecological tax reforms are important. The failure of the referendum is mainly explained by misunderstanding the expected benefits. The influence of different environmental systems on environmental regulation has been analyzed by Fredriksson and Wollscheid (2007). Contrary to the suggestion of the literature, they did not find support for the hypothesis that democratic systems positively affect environmental stringency. Environmental policies set by democracies therefore are not significantly different from those of autocratic systems. Their findings are based on an empirical cross country analysis including 163 countries. Fredriksson et al. (2007) use an empirical approach to determine whether corruption hinders or facilitates environmental lobbying. The panel they use includes 170 countries. They found out that an increase in environmental lobbying had a significant impact on the probability for the ratification of the Kyoto Protocol. The positive impact they found was additionally positively correlated with the degree of corruption within countries. Tanguay et al. (2004) use an extended theoretical approach of Stigler’s theory about public interest in the context of environmental regulation.⁷ The

⁷The approach proposed by Stigler was criticised by Posner (1974) because of the need for formalization of the model. A first formalization was made by Peltzman (1976). Therefore in the literature the Stigler model is often called *Stigler-Peltzman-Model*.

empirical study supports the view that with respect to environmental regulation interest groups have an influence on the political outcomes and distort optimal results.

The main findings so far can be summarised as follows: First, several studies assess the determinants of structural change towards a more environmental oriented policy and the support for the GT sector. The review of recent public choice literature has shown that beside the “desirability” of environmental policy, the political process has some shortcomings leading to different results as initially intended. The following section introduces the institutional framework enabling energy production by GTs in Germany.

3 Institutional framework

The diffusion of renewable energies in Germany as well as in other countries depends on the institutional setting implemented by the government. Even though the development of GTs already began in the seventies,⁸ the expansion of the technology was restricted. This was mainly due to the political energy strategy. The main focus was on conventional technologies and markets were monopolistic (Toke and Lauber 2007, p. 683). In this section two important institutional changes enabling innovation and diffusion of renewable energies are analyzed. The first important institutional change was the *Stromeinspeisegesetz* (SEG), the second the *Erneuerbare Energiengesetz* (EEG). In the following the two institutional arrangements are discussed in more detail.

3.1 Stromeinspeisegesetz (SEG)

The SEG entered into law in January 1991 (Toke and Lauber 2007, p. 683).⁹ It was a simple feed-in mechanism with a guaranteed price for electricity that was fed into the electricity network based on a certain percentage of the average “market price” for conventional energy. The feed-in tariff lay in between 75 % (for WATER and BIO), and 90 % (for SOLAR and WIND) of the market price. As the market for electricity was monopolistic, the SEG can be considered as a first small step allowing for decentralised energy production and implemented some kind of subtle competition.¹⁰ Due to the still outstanding liberalisation of the market, the electricity prices were relatively high and stable (Mitchell et al. 2006, p. 298). Therefore, the SEG already allowed especially the wind energy sector to enter into the market and to produce a certain percentage of the total electricity supply. The share of renewable energies increased at a relatively constant rate from year to year (this will further be evaluated in section 4). From the point of view that the SEG allowed for some decentralisation of the energy market and implemented some competition, it can be considered as a success. With respect to the monetary transfer, it seems

⁸As a reaction to the oil crises (Wüstenhagen and Bilharz 2006, p. 1682).

⁹This was done by the coalition government of the Christian Democrats and the Liberal Party.

¹⁰Competition has a lot of *desirable* elements. For a more fundamental discussion about competition and economic policy compare Eucken (1965, 1990).

to be clear that the diffusion of GTs was very limited. Especially cost intensive technologies such as photovoltaics were not able to diffuse with high growth rates. For the progression from the SEG to the EEG, the liberalisation of the electricity market in 1998 plays a notable role. Based on the liberalisation (at least in the short run), the prices for electricity decreased and so did the monetary support transferred to GTs.¹¹ It can be argued that this was one of the reasons why the implementation of the EEG – which will be introduced in a next step – became necessary (Mitchell et al. 2006, p. 298).

3.2 Erneuerbare Energieengesetz (EEG)

The argument that the motivation for the EEG was the liberalisation of the energy market cannot be considered as a satisfactory explanation. The main reason for this is given by the fact that political aspects also play an important role. As the green party became part of the federal government in 1998 for the first time, a fundamental reform with regard to energy production was decided.¹² There was political interest to support the expansion of the GT sector.¹³ The EEG has many elements often described as CCPs,¹⁴ and was installed at the first of April 2000. There are notable studies which compare the EEG with the British Renewable Obligation (RO). The RO is more market oriented. It was the political aim in Britain to allow for “maximum competition” in order to make the system as efficient as possible (Toke and Lauber 2007, p. 681). What is quite surprising in this context is the fact that many studies come to the result that the EEG is more efficient than the British RO system (Mitchell et al. 2006, Toke and Lauber 2007, Butler and Neuhoff 2007).¹⁵

The EEG has been criticised by economists because of its CCP elements. Three factors related to CCPs are important and therefore discussed in more detail. First, it can be seen as a problem that policymakers select ex ante certain technologies they consider to be worth getting monetary support for energy production.¹⁶ Second, as it will turn out in section 5.3, the price paid for each

¹¹In the following the word *subsidy* is avoided to describe the monetary transfer to the GT sector. Instead *support* the word *support* is used as a subsidy directly reduces the political budget. Because in the case of GTs the monetary transfer does not have direct impact on the federal budget, the welfare effects can only be simulated by using a general equilibrium approach. Therefore the notation support (shifting rents to the GT sector) seems to fit better in the case of this model.

¹²The decision was to substitute nuclear energy with other sources of energy supply.

¹³This is mainly due to the fact that the green party has its roots in the opposition against conventional energy supply (Wüstenhagen and Bilharz 2006, p. 1682).

¹⁴This means that under the EEG certain technologies are selected ex ante. In order to allow diffusion of different technologies, feed-in tariffs have to be set on different levels and therefore implies discrimination between different technologies.

¹⁵One of the main advantages of the British RO system is related to the fact that it is non-technology specific, meaning that it is not attempting to pick winners (Mitchell et al. 2006, p. 299). Energy suppliers are forced to buy a certain percentage of renewable obligation certificates (ROCs, 1 ROC=1MWh). ROCs are tradable and can be bought directly from the GT supplier or other suppliers. One of the main criticisms of the RO system is the uncertainty about future prices for ROCs and electricity. Therefore a high risk premium increases the price for energy produced by GTs (Toke and Lauber 2007, p. 682).

¹⁶The ex ante decision about the monetary support for a certain technology bears the potential threat that the most efficient technology in economic terms is not supported. This is related to

unit of energy produced by a certain technology will very likely not be optimal. Third, policy can use the support of GTs in order to strategically foster certain technologies.¹⁷ From this perspective, there might be certain strategic reasons why the monetary support a certain technology receives is set on a higher level than optimal in economic terms. The EEG is constructed in a way that requires electricity network operators to:

- connect GTs to the network;
- accept the entire electrical output produced by GTs;
- remunerate the producers of “green” electricity at the pre-determined rate for each KWh electricity produced.¹⁸ The remuneration is foreseen to decrease slightly over time and is *guaranteed for 20 years*.

With respect to growth in the GT sector, it has to be mentioned that the EEG does not put any upper capacity limits for the diffusion of the technology. The following formula summarises the remuneration of electricity under the EEG:

$$FIT_{tvj} = p_{Tj}(1 - d_j)^{v-T} + k_j. \quad (3.1)$$

Specific remuneration per kilowatt-hour is denoted by FIT_j , t represents the actual year of remuneration and T is the base year when the EEG was established. The starting year of operation is characterized by v , the technology sector (SOLAR, WIND, ...) is indicated with j , d is the degression rate and the parameter k indicates additional premiums for innovative technologies (Langniß et al. 2008, p. 4). With respect to k_j , learning curves may be important. The impact of learning curves related to the different feed-in tariffs is further discussed in subsection 3.3. The different feed-in tariffs are summarised in table 1.^{19 20}

As it can be seen in table 1, the EEG supports different technologies with emphasis on different remuneration rates. The range is from 6.5 ct/KWh for electricity produced by using WATER and BIOGAS up to 51.62 ct/KWh for electricity produced by using SOLAR. The comparison of the different technologies with respect to the feed-in tariffs is not as simple as it seems to be at first glance. Because each technology has also different features, it can be argued that different feed-in tariffs are justified.²¹

the relevant critique that CCPs often go in hand with a lot of uncertainty and therefore an ex ante selection of a technology is a pretension of knowledge (Hayek 1945).

¹⁷At first glance it seems that this is an advantage. As it will turn out as a result at the end of this paper, there are also good reasons to criticise such an approach.

¹⁸The remuneration is also given to those plants which do not feed-in to the general network of electricity.

¹⁹For a detailed overview of different feed-in tariffs related to the SEG and EEG compare appendix A, page 31, table 4)

²⁰Note; the EEG has been renewed in 2004 and 2009. The numbers with respect to the feed-in tariffs for GT_j as well as the depreciation rate d have changed. Overall, it can be said that the feed-in tariffs have decreased whereas d has increased slightly by about 1% on average.

²¹Because sun shines only on daytime, SOLAR cannot produce electricity during the night. WIND can also produce electricity during the night, but the amount of energy produced is not very constant.

Table 1: Remuneration (*FIT*) for different GTs

Technology <i>j</i>	Remuneration (2000-2003) (ct/KWh)	Annual Reduction (<i>d</i>)
Wind (WIND)	9.1	1.4 %
Solar (SOLAR)		
Capacity < 100KW	51.62	5.0 %
Plants on building capacity < 5 MW	48,1	5.0 %
Biomass (BIO)		
Capacity < 500KW	10.0	1.0 %
Capacity > 500KW < 5MW	9.0	1.0 %
Capacity > 5MW < 20MW	8.5	1.0 %
Hydro (WATER)		
Capacity < 500KW	7.67	0 %
Capacity > 500KW < 5MW	6.5	0 %
Landfill and sewage gas (BIOGAS)		
Capacity < 500KW	7.67	1.5 %
Capacity > 500KW < 5MW	6.5	1.5 %
Geothermal plants (GEO)		
Capacity < 20MW	8.5	0 %
Capacity > 20MW	7.0	0 %

Own illustration.

3.3 Arguments for different feed-in tariffs

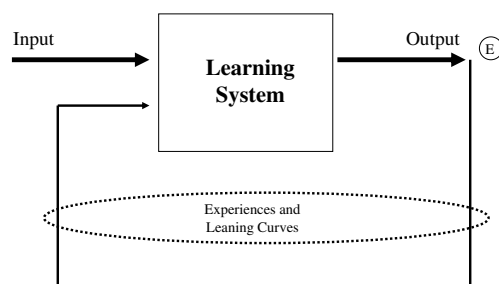
Because GTs were not so much elaborated due to reduced commercial use in the past, learning curves seem to be very important especially regarding the development of technologies like SOLAR or WIND (Isoard and Soria 2001, Wene 2008, pp. 21). Certain technologies like SOLAR might be very promising regarding future energy generation, so that one can argue in favour of higher feed-in tariffs for SOLAR or any other technology due to learning curves and general expectations about future energy supply (compare figure 1).²² The general argument goes as follows: Governments can generate positive welfare effects if they set artificial markets for new energy technologies. Due to learning process, technologies which would otherwise be too costly become cost efficient. As the manufacturing firms that produce a certain technology compete on the market, production costs will decrease and technical performance will increase. Due to uncertainty and market dynamics, the whole process will also be accompanied with positive spillovers (e. g. innovations). Therefore, a successful deployment program can provide, what markets might not provide by themselves, namely the diffusion of certain GTs on high levels combined with certain political targets like the reduction of GHG emissions (Wene 2008, p. 16).

Figure 1 illustrates how learning effects production process regarding input and output e. g. on the company level. The *E* in figure 1 represents an experience parameter. Therefore, as diffusion leads to a higher level of expe-

²²Especially in the case of SOLAR learning curves are very important (van der Zwaan and Rabl 2003, Tributsch 2004, van der Zwaan and Rabl 2004).

rience, output can increase for a given level of input or less input is necessary in order to produce the same level of output. All in all the technology gets cheaper and more cost efficient.

Figure 1: Input Output Model Regarding Learning Curves



Own illustration oriented on Wene (2008), IEA/OECD (2000).

This theoretical reasoning can be used in order to justify different feed-in tariffs for different technologies producing the same outcome theoretically. Additionally, it can be seen in subsection 4.1, that the diffusion of WIND already began with the implementation of the SEG. Because the learning curve model explains marginal production costs as a function negatively affected by time, it can be explained why, even though learning curves play an important role regarding WIND (Isoard and Soria 2001, McDonald and Schratzenholzer 2001), feed-in tariffs are set on a relatively low level compared to SOLAR or other GTs. The rationale behind it would be the already acquired experience regarding the production of the technology WIND under the SEG.

Dynamic effects play an important role regarding development and diffusion of GTs. They are therefore a strong argument in order to explain the discrimination between different technologies. Nevertheless, two arguments have to be looked at separately from each other: Reduction of GHG emissions (IEA/OECD 2000, 2003) and investment into “backstop technologies” (Nordhaus 1973). If the main reason to support a certain GT j is to reduce GHG emissions, one could argue that the investment *should* go to the cheapest technology available in order to achieve a certain target of emission reduction.²³ This would be an argument against discrimination between different technologies. Apart from this, one can also argue that certain technologies have a high potential regarding future energy supply (“backstop technologies”) so that it might be desirable to allow diffusion of these technologies

²³Investors would be able to take the cost reductions due to learning curve effects or economies of scale into account, and the investment would go into the cheapest technology able to achieve the political target.

because they might become important for energy production on large scales in the near future.²⁴ Even though the second argument can be criticised due to the pretension of knowledge (Hayek 1945), it seems to be the main reason why policymakers discriminate between different feed-in tariffs. If one accepts the second argument, the question occurs, up to which level the diffusion of a certain technology might be desirable.

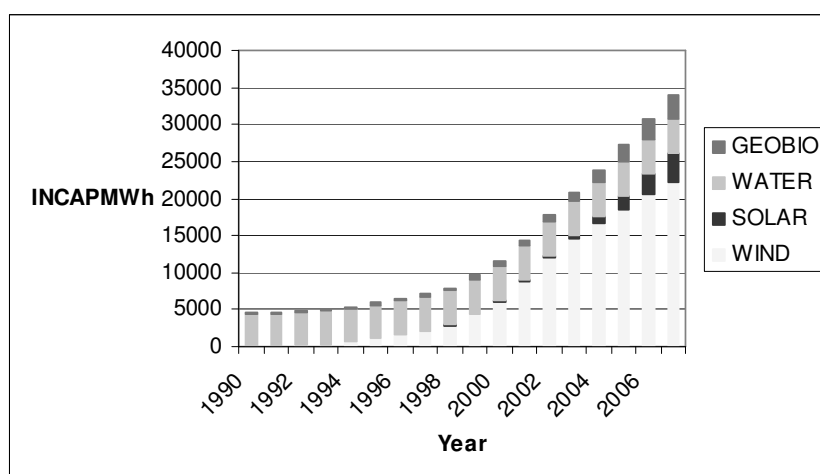
4 Diffusion and Costs of GTs

This section is aimed to give a short overview of the diffusion of green technologies and the related costs.

4.1 Descriptive statistics about the diffusion of GTs

The diffusion of GTs is well documented by the German federal ministry of the environment (BMU). The total share of renewable energies at the gross electricity supply in 2005 was 10.4 % (BMU 2008, p. 13). In figure 2 it can be seen that the installed capacity for WIND increased strongly. The installed capacity for WATER remained at a relatively constant level. SOLAR increased after the implementation of the EEG (after the year 2000) whereas for GEOBIO there was a relatively constant but smooth increase of the total installed capacity.

Figure 2: Diffusion of GTs, measured by installed capacity in MW (INCAPMWh)



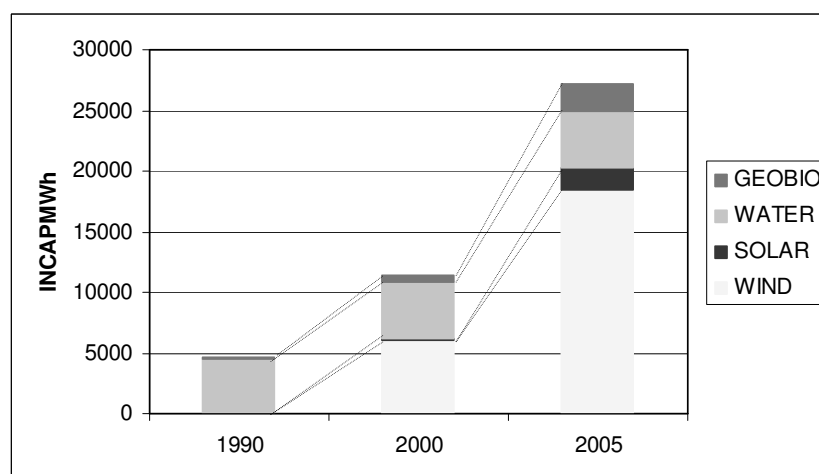
Own illustration, data source BMU (2008).

²⁴A third argument not went into detail in this paper is the expectation of exports of the technologies (Freytag and Wangler 2008).

Figure 3 contains information about the growth of the stock of renewable energies installed (measured by INCAPMWh²⁵). By looking at the stock of installed capacity in 1990, 2000 and 2005, the SEG (1990-2000) and the EEG (2000-2005) can be compared. When the connecting lines between the two blocks remain parallel, the installed capacity did not increase over time. It can be seen that under the SEG the stock of WIND increased and WATER remained more or less constant. GEOBIO increased on a lower rate. In the year 2000, SOLAR represents only a small share of total INCAPMWh. Under the EEG in 2005 the overall share of installed capacity of GTs has more than doubled compared to the year 2000. Within five years it came to a doubling of the installed capacity for GEOBIO. WATER still remained at a relatively constant level. In contrast to this, the stock of SOLAR increased notably. Also the share of WIND grew on large scales. The stock soared by about 200 %.

The German government set the target to produce in 2010 a share of 12.5 % of gross energy consumption by renewable energies. This target was already hit in 2007 (BMU 2008, p. 8). The long term political target is to reach a share of 30 % of electricity produced from GTs in 2020. On the EU level ambitious targets have been installed also. Until 2020 a share of 20 % of total energy consumption shall be provided by GTs.²⁶

Figure 3: Stock of GTs, measured by installed capacity in MW (INCAPMWh)



Own illustration, data source BMU (2008).

²⁵Installed capacity of electricity measured in megawatt hours.

²⁶Note that with respect to this political target the debate is not only about electricity but also about technologies that allow to substitute conventional energy consumption like bio fuels or heating with geothermal energy.

4.2 Costs related to the EEG

As the German network for electricity is separated in four regions and is run by a different operator in each region, a clearing mechanism is needed to make sure that the costs for the network operators related to the feed-in tariffs are fairly allocated (Langniß et al. 2008, pp. 5). The average costs of remuneration are about 10.87 ct/KWh. This is approximately twice as much as the market price for conventional energy. In 2006, the total costs for remuneration were about 5.6 billion Euro (four times the costs from 2001).²⁷ If costs related to the EEG are translated into a price per kWh, they become seemingly low. The EEG "only" accounts for 0.007 Euro/KWh, which is about 3.7 % of the average price for electricity (calculated with a price for private consumers of 0.194 Euro/KWh). At first glance the numbers are not really astonishing and seem to be surprisingly low. Therefore one could highlight all positive impacts related to the EEG and draw the conclusion that the EEG was able to reach its political targets at relatively low costs. Such a conclusion would be far too easy because of the long-lasting cost-effects related to the EEG. It has to be mentioned that according to the forecasts for 2013, annual remuneration will increase to 12.6 billion Euro (Langniß et al. 2008, p. 2). This will be an amount accounting for 4.5 % of the federal budget of 2008. In the reference year 2006 about half of the money collected under the EEG went into WIND. Twenty percent of the money went into SOLAR. Even though the monetary support for photovoltaics is relatively high, SOLAR produces a rather small share of about 4.3 % of all remunerated renewable electricity (Langniß et al. 2008, pp. 2).

From a static perspective costs seem to be rather low. As it turned out in section 3 many studies state that the German feed-in system performs better than the British RO. Nevertheless, it is predicted that the costs increase during the next years and certain technologies will receive guaranteed payments for the next two decades on high levels (compare subsection 3.2). On the one hand this gives necessary stability for investors and has led to relatively low electricity price increases in the last years. On the other hand it might be that some of the investments will turn out to be deallocated resources over several decades so that problems related to the future development of electricity prices should not be underestimated.

This short description of the idea about environmental regulation as well as the overview about diffusion and costs related to the SEG and EEG shall be used as background information for the following theoretical section. The basic assumption of the model is that the GT sector is assumed to generate positive externalities. What seems to be interesting taking arguments of political economy into account is to look whether the feed-in tariffs can be considered to be *optimal* from a *short term perspective* in order to evaluate the efficiency/inefficiency related to the EEG from a *long term perspective*. This question shall be further elaborated by using a theoretical framework.

²⁷Of course from this total number the market value of the output has to be subtracted. The total costs related to remuneration are therefore smaller and are about 3.7 billion Euro.

5 Theoretical framework

The model presented in this section builds on a model developed by Tanguay et al. (2004). A distinction has to be made between the Theory of Public Interest (TPI) and the economic theory of regulation (ETR).

5.1 Theory of Public Interest (TPI)

TPI is based on the microeconomic theory to detect market failure, which is used as an argument to justify political intervention. Market failure, like the problem of externalities, can be corrected with the authority of the state. The aim of political intervention is to reinstall optimal resource allocation. The equilibrium derived under TPI can be considered as the optimal solution for the problem of failed markets.

It is difficult to justify the support of green technologies on the national level with rational economic arguments. It also seems to be the case that green technologies alone are not able to substitute conventional energy production. From a long term perspective it might be that they will only be able to produce a certain percentage of total electricity outcome. Economic rationality might be found by arguing that due to learning curve effects the technology will become cheaper. It also can be that politicians try to generate a kind of first mover advantage with transfer payments to the GT sector (Brandt and Svendsen 2006, Freytag and Wangler 2008, Svendsen 2003). Even though there are many doubts regarding the positive impact of the GT sector, the argument of positive externalities shall be used as a justification why it is rational for politicians to support the GT sector. The market created by politicians by installing a law enabling the diffusion of GTs might generate positive welfare (because of job creation, positive environmental effects or the export of the technology in the near future) so that this can be interpreted as positive externality (if benefits are higher than the related costs).

As already discussed in section 3, the institutional setting of the EEG is constructed in order to shift rents to the GT sector. The monetary support was a necessary condition to enable the sector to evolve. From an industrial policy perspective, monetary support up to a certain amount of money can be considered as "desirable" as long as they are justified with positive externalities. Under the assumptions of complete information and non-existing "state failure" one can calculate the optimal support which should be paid to GTs. This optimal support will allow for an optimal size of the GT sector and will ensure that marginal costs will be equal to the marginal welfare gain.²⁸

5.2 Economic Theory of Regulation (ETR)

Even though economists sometimes seem to ignore that beside market failure there can also be the problem of state failure, it is common knowledge

²⁸The welfare gains will be related to future exports of the technologies. There might also be positive externalities due to job creation in the GT sector or positive environmental effects.

that democratic systems are far from generating an optimal resource allocation. One reason is that governments do not always try to make decisions in order to satisfy the common interests of the whole society. They have high incentives to satisfy the interests of specific interest groups. In this case, the established policy simply reflects the relative electoral weight of different interest groups.²⁹

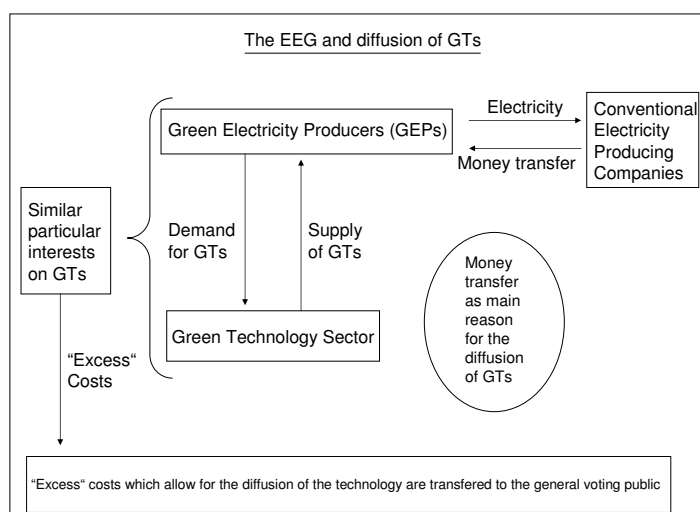
The political weight depends on votes or other factors able to generate political power like monetary and non-monetary contributions. This model seems to fit very well to the evolution of the green technology sector in Germany under the "red green coalition" (1998-2005). This model is closely linked to the theory of the "demand" for industrial regulation developed by Stigler (1971). In his "economic theory of regulation" he developed a model in which demand for regulation (in our case monetary support, e. g. subsidies) comes from interest groups that can be considered being able to benefit from legislation. The supply for the enhanced well-being of interest groups is distributed by the incumbent government which aims to maximise current political support. Therefore politicians in our model can be considered to be political entrepreneurs (Schumpeter 1987b). Politicians try to maximise votes in order to be re-elected.

According to this model, regulation is not only the result of market imperfections. What is declared to be market failure in many cases is also linked to state failure. As a result the welfare effects might be rather low or in some cases they can even be negative. The success of special interest groups depends on their ability to organise their interests and their importance for the incumbent government. The incumbent government places its coercive power in favour of special interest groups aiming to be re-elected. The model developed by Stigler (1971) is also very useful in order to explain the success of the GT sector to tap resources. Nevertheless there is one important difference between the model used in this paper and the approach from Stigler (1971). The Stigler model explains why producer protection might prevail over consumer's interest. In our model GEPs can be both, consumers and producers of electricity. As figure 4 shows the institutional design for the GT sector is constructed in a way that some "privileged" producers of green technology (owner of the GTs) and the GT sector both profit from the support they receive.

At first glance it also seems that the big energy companies have to pay the bill. But this is obviously not the case as long as demand for electricity is very inelastic. The higher costs related to the support for GTs will finally be transferred to the society in forms of higher energy prices. From this perspective the EEG fits very well to what Peltzman (1976) calls the "law of diminishing returns to group size". One can argue that the GT sector as well as those citizens who gain from the EEG simply outweigh the interest of the society as a whole because they are better organised, better informed or simply because they in-

²⁹This fact was mainly highlighted by Olson (1987). He states that in the political process often small interest groups successfully exert more influence than larger groups. One of the reasons is that for larger groups it is more difficult to organise themselves because of higher costs.

Figure 4: Mechanism related to the EEG



Own illustration.

fluence the political outcome more actively.³⁰ It also turned out in section 4, that the price per KWh electricity, the EEG can be blamed for, is relatively low. Consumers may face cost illusion with respect to the EEG.

5.3 The theoretical model

The EEG is constructed in a way that the money enabling the expansion of GTs is paid to the producers of green electricity (GEP) and not to the producers of a certain technology j . This is shown in figure 4. The producers of GTs (GEPs), produce green electricity and the output (electricity) can be fed-in into the electricity network. GEPs can be households, communities, small companies, farmers and others. The remuneration per KWh electricity depends on the GT j (for the different feed-in tariffs compare table 4, page 31). This mechanism generates an "artificial" demand for electricity produced with GTs. Therefore, the possibility to feed-in electricity for a guaranteed remuneration has an indirect impact on the production and diffusion of GTs. Figure 4 also shows, that both, GEPs as well as companies producing GTs have an interest to at least keep the feed-in tariffs on a constant level. It also seems to be clear that both interest groups would not oppose against political decisions in favour of an increase of remuneration. In contrast to this, it can be expected that political decisions towards a reduction of feed-in tariffs should be accompanied by counter-lobbying of GEPs as well as GT producers. The "excess costs" for electricity production are transferred to the general voting public.

³⁰This does not mean that there are no limits for an optimal group size. Two opposite effects can be distinguished. On the one hand one can argue that the larger the group the higher the influence on the government. On the other hand the organisation costs also increase with the group size. As the share of the rents will decrease, the increasing organisation costs put limits on the growth of the group size. Compare also Peltzman (1989).

Therefore two markets are assumed to have the same interests. Namely GEP and GT producing companies. This is incorporated into the model by looking at the GEP market in a first step and the GT sector j in a second step.

Green electricity production level (GEP Market)

In case that the government does not support green technologies, the market share is set to zero. $ENPV_j^{GEP}$ is the “expected net present value” for investment into GT j . Therefore

$$ENPV_j^{GEP} < 0$$

with

$$ENPV_j^{GEP} = -F_j + \frac{E^{t1}}{(1+r)} + \frac{E^{t2}}{(1+r)^2} + \dots + \frac{E^{tn}}{(1+r)^n}. \quad (5.1)$$

The length of the periods is given by n . F_j stands for the price of GT j , r is the opportunity cost of investment and E is the surplus a GEP can make in period t . In each period the individual surplus of GEP i is given by

$$E_{ij}^{tg} = x_{ij}^{tg}(p^{tg} - c_j^{tg} + FIT_j^{tg}). \quad (5.2)$$

x_i^{tg} is the quantity of electricity produced by the particular producer i in period tg ($g \in [1, n]$),³¹ p^{tg} is the market price for electricity, c_j^{tg} are marginal costs and FIT_j^{tg} is the feed-in-tariff for technology j in period tg . Note that it is rational for GEP i to invest into GT j if $ENPV_j^{GEP} \geq 0$. Figure 5 shows the construction of the inverse demand curve. There is a linear relationship between feed-in tariffs and $ENPV$.

Firm level (GT Market)

Consider N_j identical firms operating in different sectors (SOLAR, WIND, WATER, GEO and BIO). Firms are assumed to compete in their particular sector. The market is described by imperfect competition à la Cournot.³² Marginal costs (c_j) are assumed to be constant ($c_j > 0$).³³ If the different GT sectors j are compared, it is plausible to assume different production costs c_j for the technologies. The sector specific demand is assumed to be linear and will be zero without support paid on the demand side (there is no intersection between MR and c_j). Inverse demand without support is given with

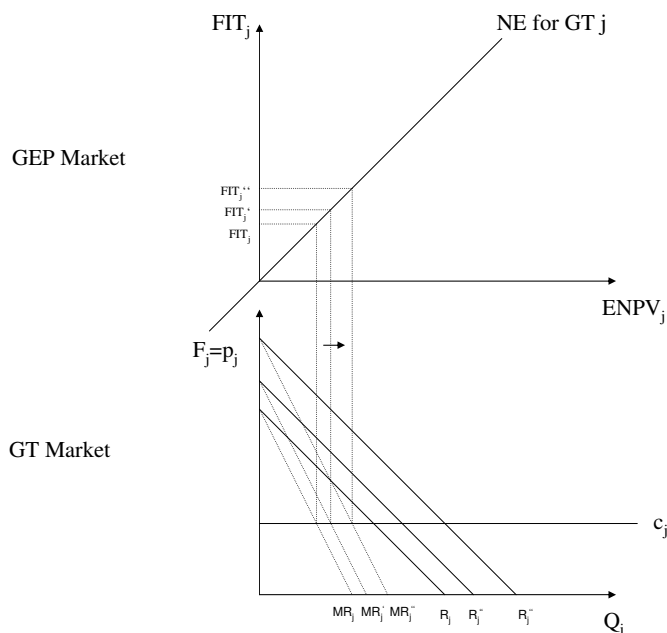
$$p_j = 1 - Q_j, \quad (5.3)$$

³¹Note that x_i^{tg} has to be different between different GEPs because the input factor to produce electricity (e. g. sun, wind or water) is exogenous and differs between regions.

³²It is plausible not to assume complete competition in this case, because the GT sector is depending on monetary transfers (in the following simply called support). If productivity gains lead to lower production costs, firms make higher profits because the feed-in tariffs are relatively constant. It also seems to be clear that high R&D expenditures can only be financed by the companies if enough rents remain within the firm. Dröge and Schröder (2005) among others state that with respect to the GT sector imperfect markets can be assumed.

³³Note, that this assumption only holds for a given point in time t does not take the possibility of economies of scale into account. This does not contradict the assumption of learning curves discussed in subsection 3.3 meaning that over time decreasing marginal costs are assumed to be $c_{t+1} < c_t$. Nevertheless, for every period marginal costs can be taken from the “learning curve” and can be assumed to be constant at the given point in time.

Figure 5: Deviation of the inverse demand curve



Own illustration.

p_j stands for the price of the technology of the GT sector j and Q_j is the total output produced by the N firms in sector j . Because demand is supported by the feed-in tariffs, this can be integrated into the model using s_j . Therefore

$$p_j - s_j = 1 - Q_j, \quad (5.4)$$

$$= 1 + s_j - Q_j. \quad (5.5)$$

Because of the symmetry assumption on firm level, the output is assumed to be the same for each firm so that $Q_j = Nq_j$. Therefore the *residual* demand on the firm level can be written as

$$p_j = 1 + s_j - (N - 1)q_j - q_j. \quad (5.6)$$

Note that $(N - 1)q_j$ is the demand of all other firms. The marginal revenue on the firm level is given by

$$MR_j = [1 + s_j - (N - 1)q_j] - 2q_j. \quad (5.7)$$

The EEG allows the GT sector to diffuse. Firms maximise their profits at $MR = c_j$. Taking (5.7) into account the quantity of output produced by one single firm is given by

$$q_j^* = \frac{1 - c_j + s_j}{(N + 1)}. \quad (5.8)$$

Multiplying q_j with N leads to the total output (Q_j^*) which is

$$Q_j^* = \frac{N(1 - c_j + s_j)}{(N + 1)}. \quad (5.9)$$

Using (5.9) for the market demand gives p^* which is

$$p_j^* = 1 + s_j - \frac{N(1 - c_j + s_j)}{(N + 1)}. \quad (5.10)$$

The results from (5.8) and (5.10) can be used to describe the profit of one single firm. This profit is given by

$$\pi_j^* = (p^* - c_j)q^* = \frac{(1 - c_j + s_j)^2}{(N + 1)^2}. \quad (5.11)$$

Total profits generated by the GT sector j are given by $\pi_{jT}^* = N\pi_j^*$.

5.3.1 Governments

TPI transfers

TPI supports lead to the optimal outcome without any state failure. It is assumed that welfare W (compare equation 5.12) generated by the GT sector j derives from three different sources. The first positive effect is given by the GEP surplus ($GEPS_j = 1/2 * Q_j^* * (1 + s_j - p_j^*)$) generated by those who buy GTs. They receive a state guaranteed positive payoff from their investment. Additionally firms earn a profit which is denoted by π_{jT} . The third term enters with a negative sign into the equation and is given by the support minus the positive effect (b_j) expected from GTs times Q_j^* . The optimal solution can be found by choosing the support s_j able to maximise welfare (compare figure 6).

This leads to an optimal support s_j^* and an optimal welfare level W_j^* . It follows

$$\max_{s_j} W_j(s_j) = GEPS_j + \pi_{jT}^* - (s_j - b_j)Q_j^*. \quad (5.12)$$

The partial derivative from (5.12) with respect to s_j leads to

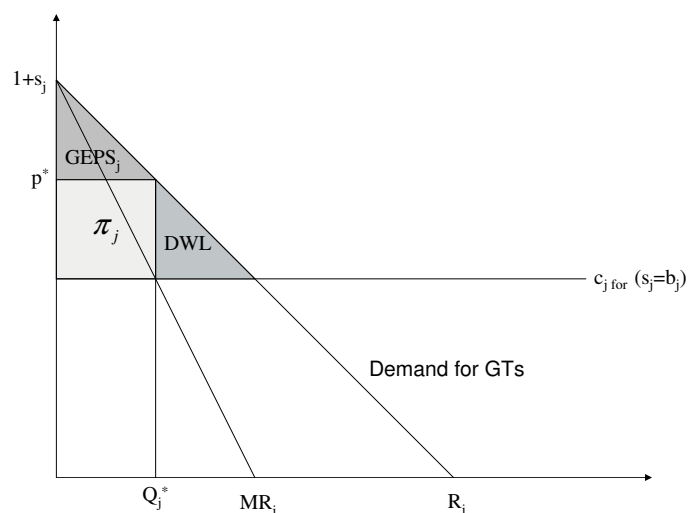
$$\frac{\partial W_j}{\partial s_j} = \frac{N}{(N + 1)^2} [b_j(N + 1) + 1 - c_j - s_j N]. \quad (5.13)$$

Therefore the optimal support s_j^{**} is given by the solution for the first order condition which is

$$s_j^{**} = \frac{b_j(N + 1) + 1 - c_j}{N}. \quad (5.14)$$

The following analysis is restricted to positive welfare effects generated by s_j . As long as $c_j < 1$ equation 5.14 cannot be negative. By substituting s_j^{**} into the

Figure 6: A partial model on national welfare



Own illustration.

equations for price, total output and total profit, the corresponding welfare level can be calculated. This leads to

$$p_j^{**} = \frac{b_j + 1 + c_j(N - 1)}{N} \quad (5.15)$$

$$Q_j^{**} = b_j + 1 - c_j \quad (5.16)$$

$$\pi_{jT}^{**} = \frac{(b_j + 1 - c_j)^2}{N^2} \quad (5.17)$$

$$W_j^{**} = \frac{(b_j + 1 - c_j)^2}{2} \quad (5.18)$$

ETR transfers

ETR supports lead to an outcome which takes the political process into account. In democratic societies it is very likely that policies are not in line with the interests of the general voting public (TPI) because of vested interests.

The policies established in order to fulfill the interests of specific interest groups reflect the relative electoral weight of those interest groups in terms of monetary and non-monetary contributions.

The underlying assumption of the model is that the incumbent government takes the political support expected by the interest groups into account when choosing the support s_j . This can be done following the approach proposed by Tanguay et al. (2004). Welfare (W) and political support can be modelled as a linear function (V).³⁴ Political support for the GT sector j (V_j) is derived from

³⁴ V represents monetary as well as non-monetary political support.

four different sources: First, industries operating in the GT sector make profits.³⁵ Second, as the output of the GT sector increases, jobs are created, which also leads to a higher support for the incumbent government.³⁶ Third, political support is related to environmental factors, as long as the conflict (e. g. with traditional nature protectors) is not too big. Because electricity producing companies have to pay the higher price for the energy produced, consumers might be illusive about the costs related to the support for GTs. Nevertheless, it is plausible to assume that the political support is decreasing with an increase of s_j but is increasing with the positive externalities (b_j) as long as they are communicated well enough.³⁷ Fourth, GEPs who install GTs or buy assets of GTs, receive rents with a guaranteed payoff. The total output produced by firms is given by Q^* . This allows to model the welfare of the incumbent government by G .

$$\begin{aligned} \max_{s_j} G(s_j) &= \alpha W_j(s_j) + (1 - \alpha)V_j(s_j) \\ &= \alpha W_j(s_j) + (1 - \alpha)[\pi_{jT}^* + Q^* - \\ &\quad (s_j - b_j)Q^* + GEPS_j] \end{aligned} \quad (5.19)$$

with $0 < \alpha \leq 1$. Maximizing equation 5.19 relative to s_j leads to

$$s_{jv} = \frac{b_j(N + 1) + (1 - \alpha)(N + 1) + 1 - c_j}{N}. \quad (5.20)$$

It is interesting to see whether $s_j^{**} < s_{jv}$ or whether $s_j^{**} > s_{jv}$. By calculating the difference between the support paid under the TPI and the ETR regime the difference can be looked at. As a result it turns out that

$$s_j^{**} - s_{jv} = \frac{(\alpha - 1)(1 + N)}{N}. \quad (5.21)$$

This allows to state that for all cases in which $\alpha < 1$ the support paid to allow for diffusion of the GT sector j will be too high and is therefore inefficient from an economic perspective.³⁸ To keep things as simple as possible it is convenient to calculate the same model under the assumption of complete competition. The result remains the same (compare appendix B, page 32). By comparing the two models, it turns out that the optimal transfer under complete competition is smaller. It is shown that the same outcome (the optimal support of green technologies) can be achieved at lower prices, what demonstrates the strength of competitive markets to weaken the power of interest groups (compare also Eucken (1965, 1990)).

³⁵This might lead to an increase in monetary contributions for the political parties supporting the expansion of GTs.

³⁶The stock of jobs in the GT sector in 2006 was about 110.000 (Kratz et al. 2007).

³⁷This means that the government has to start campaigns to inform the public of the success of the GTs.

³⁸Note that there are clear boundaries with respect to the difference between the TPI and ETR regime. For the case of monopoly and $\alpha = 0$, the difference would be at maximum $|2|$. For $N \rightarrow \infty$, the maximum difference would be $|1|$. Therefore, a lower concentration of firms in the GT market restricts the government.

5.3.2 Comparative static for s_j^{**} and s_{jv}

For the TPI as well as for the ETR, the support “should” increase, the more positive externalities (b_j) are linked to the GT sector j . Therefore in the model, a government that seeks to maximise a linear combination of the social welfare function, will increase the support paid to the GT sector j if the positive externality increases (e. g. with new knowledge about the impact the GT sector j for social welfare).

Table 2: Comparative static for s_j^{**} and s_{jv}

s_j	TPI	ETR
c_j	-	-
b_j	+	+
N	-	-
α	NA	-

Own illustration.

This result is in line with the argument that under certain circumstances support to a certain sector might enhance welfare. From a political economy perspective it is plausible that governments seek to support industrial sectors if they benefit from an increase in political support. It can also be observed that the support transferred to the the GT sector j decreases with N for both theories. For the ETR regime this is intuitive. Because an increase in firms will lead to lower market concentration, the support a government can gain by shifting rents to this sector will decrease. For the TPI the explanation is given by having an increase in the number of firms producing green technologies the outcome of positive externalities also increases. Because everything else has been kept constant, it is rational to adapt the support to the cost reductions. The result demonstrates the importance of competition. The total share of support necessary to spend to the GT sector j will decline with an increase in N . This is in line with the results derived under complete competition (compare appendix B, page 32).

What is puzzling is the negative sign for the TPI system for an increase of c_j . An increase of c_j goes in hand with a decrease of $GEPS_j$ for green electricity producers j . Profits of firms producing a green technology j (π_j) will also decrease. One possible explanation for the TPR regime is given as follows. Because the positive externality b_j remains constant, marginal costs to produce the positive externality will increase. Therefore the relative increase in costs for b_j are higher than the decrease of $GEPS_j$ and π_j , so that it would be rational to lower s_j . For the ETR c_j enters also negatively into the equation. The explanation can be found in the marginal production costs for GT j , which increase relatively and therefore make support less attractive. Therefore politicians will decrease support. A general pragmatic explanation is given as follows: Due to the increase in marginal costs, the relative price for the positive externality increases. This leads ceteris paribus to a decrease in demand for the positive externality which leads to a decrease in s_j .

The negative sign for α is again very intuitive. By looking at equation 5.19, it is clear that due to an increase in α , more weight is put on the TPI policy. As the inefficiency related to s_j increases, more emphasis is put on the ETR policy (compare equation 5.21); it is obvious that a policy giving more weight to the TPI system will lower s_j . The boundary for this decrease is given by the optimal support under TPI.

All in all, the theoretical model shows that CCPs have to be inefficient. As long as politicians give political weight to job creation and further aspects related to the GT sector, the support always has to be higher than it would be economically optimal. This is also true in the case that information about problems related to climate change increase. The political reaction will be to adjust the feed-in tariffs according to the new information and additionally raise the tariff in order to satisfy the particular interests of the GT sectors. Therefore CCPs are a highly sensitive topic and the problem demonstrated by the use of the theoretical model should be taken very seriously.

6 Conclusion

This study was aimed to assess the institutional setting enabling the diffusion of GTs (SEG and EEG) in Germany from a political economy perspective. The first part of the study intended to set the necessary background to understand the following theoretical model. As a result of the model it turned out that the EEG has to be inefficient. The money transferred to different GT sectors highly depends on the power of the interest groups and other political interest related to technology policy. Therefore feed-in tariffs like those for GEO might be close to its optimum just because GEO as interest group may not be that strong as the interest groups supporting SOLAR and BIO. From the description of the SEG and EEG it also emerged as one of the results that the SEG can be considered as successful because for the first time it allowed for competition in the energy sector. Cost arguments and diffusion of GTs have been evaluated after the theoretical model. By only looking at positive effects like competition and the structural change in the energy market, the EEG can also be considered as success. Its related costs seem still to be on a manageable level. Therefore one could argue that the inefficiency-costs related to the EEG have to be accepted in order to foster structural change. From a dynamic perspective this conclusion is too trivial and there is good reason to criticise such an approach. Because the GT sector is built on lobbying and interest groups are well organised, wrong political decisions today may implement long-lasting cost effects on future generations (because feed-in tariffs are guaranteed over a time horizon of twenty years). This may lead to the result that the aim to "reduce the costs of energy supply to the national economy" formulated in the EEG will not be achieved. If the guarantees for the feed-in tariffs have a too long time horizon, this problem will become even worse. On the other hand, a long term time horizon is needed by investors and therefore should also not fall below a critical threshold. This highlights the importance to adjust the support for different GTs on the actual technological knowledge and increases in productivity related to the production process of GTs. The more competitive

the GT sector gets, the more it is worth thinking about policy reforms enabling further diffusion of GTs. One possibility would be to switch from CCPs to a more market based approach, which does not combine environmental policy with selective GT policy.

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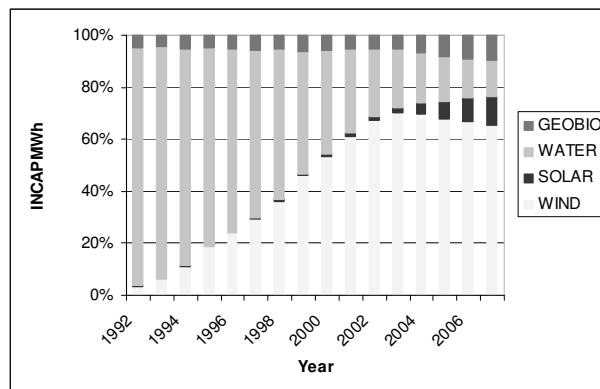
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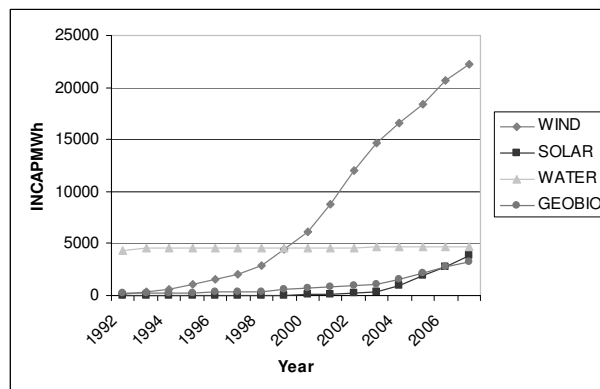
A Diffusion of GTs

Figure 7: Diffusion of GTs as percentage of total capacity of all GTs measured in MW



Source: Own illustration, data source BMU (2008).

Figure 8: Diffusion of GTs given by installed capacity measured in MW



Source: Own illustration, data source BMU (2008).

Table 3: Overview of the Installed Capacity of GTs

Year	WATER MW	WIND MW	SOLAR MW	BIO MW	GEO MW	TOTAL MW
1990	4403	56	2	190	0.0	4651
1991	4403	98	3	190	0.0	4504
1992	4374	167	6	227	0.0	4774
1993	4520	310	9	227	0.0	4839
1994	4529	605	12	276	0.0	5422
1995	4521	1094	16	276	0.0	5631
1996	4563	1547	24	358	0.0	6492
1997	4578	2082	36	400	0.0	7096
1998	4601	2875	45	409	0.0	7930
1999	4547	4444	58	604	0.0	9653
2000	4572	6112	100	664	0.0	11448
2001	4600	8754	178	790	0.0	14322
2002	4620	11965	258	952	0.0	17795
2003	4640	14609	408	1137	0.0	20794
2004	4660	16629	1018	1550	0.2	23857
2005	4680	18428	1881	2192	0.2	27181
2006	4700	20622	2711	2740	0.2	30773
2007	4720	22247	3811	3238	2.4	34018

Source: Own illustration, data source BMU (2008).

Table 4: Feed-in tariffs for the SEG/EEG

GT <i>j</i>	Size	StrEG	EEG			EEG Am.	Annual 2002 ff.	Reduction 2005ff.
		1990-1999 ¹	2000	2002	2003	2004E		
				Cent/KWh				
HYDRO	<500 KW			7.67		9.67	0%	
	500 KW - 5 MW	6.5		6.65		6.65		1%
	5 - 150 MW	0.0		0.0		3.7-7.67 ²	NA	
Landfill Gas, Sewage Gas, Coal Mine Methane	< 500 KW	6.5		7.67		7.67-9.67	0%	
	500 KW - 5- MW			6.65		6.65-8.65		1.5%
	> 5 MW ⁸	0.0		0.0		6.65-8.65	NA	
BIO	<150 KW	7.1	10.23	10.1	10.0	11.5-17.5		
	<500 KW					9.9-15.9	1%	1.5%
	< 5MW		9.21	9.1	9.01	8.9-12.9		
	> 5MW	0.0	8.7	8.6	8.51	8.4		
GEO	< 5 MW					15.0		
	< 10 MW	NA		8.95		14.0	0%	1% ³
	< 20 MW					8.95		
	>20 MW			7.16		7.16		
WIND Onshore	< 5 Years		9.1	9.0	8.87	0.0 or 8.7 ⁴	1.5%	2%
	> 5 Years		6.19	6.1	6.01	0.0 or 5.5-8.7 ⁴		
WIND offshore	< 9 Years	NA	9.1	9.0	8.87	9.1 ⁵	1.5%	2% ⁷
	> 9 Years		6.19	6.1	6.01	6.19 ⁶		
SOLAR	stand-alone building-integr.	8.2	50.62	48.1	45.7	45.7 54.0-62.4	5%	5%

¹ The indicative numbers are based on actual values from 1998.

² Applies to refurbishment of already existing hydropower plants dependent on the size.

³ Degression starts in 2010.

⁴ For projects on poor wind sites (< 60% of average wind resource), no compensation will be payed.

⁵ Will be applied for 12 years on offshore projects commissioned prior 2010.

⁶ Applies on other offshore projects than in ⁵.

⁷ Degression is starting in 2008.

⁸ Is only for coal-bed methane.

Source: Own illustration based on Wüstenhagen and Bilharz (2004).

B Theoretical model under complete competition

There is still the assumption that demand is supported by monetary transfers from the government and therefore total demand for GTs is given for

$$p_j - s_j = 1 - Q_j, \quad (\text{B.1})$$

$$= 1 + s_j - Q_j. \quad (\text{B.2})$$

Residual demand is given for

$$p_j = 1 + s_j - (N - 1)q_j - q_j. \quad (\text{B.3})$$

Firms maximise profits at $p_j = MC_j$ with

$$c_j = [1 + s_j - (N - 1)q_j] - q_j. \quad (\text{B.4})$$

Taking (B.4) into account the quantity of output produced by one single firm is given by

$$q_j^{c*} = \frac{1 - c_j + s_j}{(N)}. \quad (\text{B.5})$$

Multiplying q_j with N leads to the total output (Q_j^*) which is

$$Q_j^{c*} = (1 - c_j + s_j). \quad (\text{B.6})$$

Using (B.6) for the market demand gives p^* which is

$$p_j^{c*} = c_j, \quad (\text{B.7})$$

and profit π_j^* is equal to zero (the notation c* stands for equilibrium under competition).

Governments

TPI transfers

TPI transfers lead to the optimal outcome without any state failure. It is assumed that welfare W (compare equation B.8) generated by the GT sector j comes from the GEP surplus ($GEPS_j = 1/2 * Q_j^{c*} * (1 + s_j - p_j^*)$) minus the support plus the positive effect (b_j) expected from GTs times Q_j^{c*} . The optimal solution can be found by choosing the support s_j able to maximise welfare. This leads to an optimal support s_j^{c*} and an optimal welfare level W_j^{c*} . It follows

$$\max_{s_j} W_j(s_j) = GEPS_j - (s_j - b_j)Q_j^{c*}. \quad (\text{B.8})$$

The partial derivative from (B.8) with respect to s_j leads to

$$\frac{\partial W_j}{\partial s_j} = b_j - s_j. \quad (\text{B.9})$$

Therefore the optimal support $s_j^{c^*}$ is given by the solution for the first order condition which is given by

$$s_j^{c^{**}} = b_j. \quad (\text{B.10})$$

Substituting $s_j^{c^{**}}$ into the equations for price and total output, the corresponding welfare level can be calculated. This leads to

$$p_j^{c^{**}} = c_j \quad (\text{B.11})$$

$$Q_j^{c^{**}} = 1 - c_j + b_j \quad (\text{B.12})$$

$$W_j^{c^{**}} = \frac{1}{2}(1 - c_j + b_j)^2. \quad (\text{B.13})$$

ETR transfers

Political support for the GT sector j (V_j) comes from *three different sources*: First, as the output coming from the GT sector increases, jobs are created which also leads to a higher support for the incumbent government. Second, political support is related to environmental factors, as long as the conflict (e. g. with traditional nature protectors) is not too big. Third, GEPs which install GTs or buy assets on GTs receive rents with a guaranteed payoff. This allows to model the welfare of the incumbent government by G .

$$\begin{aligned} \max_{s_j} G^c(s_j) &= \alpha W_j^c(s_j) + (1 - \alpha)V_j^c(s_j) \\ &= \alpha W_j(s_j) + (1 - \alpha)[Q^* - (s_j - \lambda b_j)Q^* + GEPS_j] \end{aligned} \quad (\text{B.14})$$

with $0 < \alpha \leq 1$. Maximising equation B.14 relative to s_j leads to

$$s_{jv}^c = (1 - \alpha) + b_j. \quad (\text{B.15})$$

It results that

$$s_j^{c^{**}} - s_{jv}^c = (\alpha - 1). \quad (\text{B.16})$$

Compared to the equilibrium which arises in Cournot competition, the number of firms operating in the market does not play a role anymore. Because $(1 + N)/N$ is always bigger than 1, in the equilibrium with pure competition the difference between support will be smaller. This leads to the result that competition increases efficiency with respect to transfers to the GT sector because it weakens the power of interest groups.