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Why Should Support Schemes for Renewable Electricity Complement the EU Emissions Trading Scheme?

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Abstract:

In virtually all EU Member States, the EU Emissions Trading Scheme (EU ETS) is complemented by support schemes for electricity generation from renewable energy sources (RES-E). This policy mix has been subject to strong criticism. It is mainly argued that RES-E schemes contribute nothing to emissions reduction and undermine the cost-effectiveness of the EU ETS. Consequently, many scholars suggest the abolition of RES-E schemes. However, this conclusion rests on quite narrow and unrealistic assumptions about the design and performance of markets and policies. This article provides a systematic and comprehensive review and discussion of possible rationales for combining the EU ETS with RES-E support schemes. The first and most important reason may be restrictions to technology development and adoption. These may be attributed to the failure of markets as well as policies, and more generally to the path dependency in socio-technical systems. Under these conditions, RES-E schemes are required to reach sufficient levels of technology development. In addition, it is highlighted that in contrast to the EU ETS RES-E support schemes may provide benefits beyond mitigating climate change.

Keywords:

EU Emissions Trading System, market failure, path dependency, policy failure, policy mix, renewable energies, subsidies

1 Introduction

To combat climate change, the European Union (EU) has agreed on two ambitious targets for 2020 (European Commission, 2008b). Firstly, greenhouse gas emissions shall be reduced by 20 percent compared to 1990 emissions levels. Secondly, the share of renewable energy sources in total energy consumption shall be increased to 20 percent. The EU strategy to attain these targets rests on a portfolio of policy instruments, out of which two measures are outstanding. The EU Emissions Trading Scheme (EU ETS) sets a cap on CO_2 emissions from the energy sector and certain energy-intensive industry sectors (European Parliament/Council of the European Union, 2003). Additionally, the EU has adopted a framework to promote electricity generation from renewable energy sources (RES-E) (European Parliament/Council of the European Communities, 2001). Within this framework, all EU Member States have now implemented RES-E support schemes, including feed-in tariffs, quotas with tradable green certificates, tender systems or tax incentives (European Commission, 2008a). All of these schemes subsidize the RES-E generation in one way or another. In recent years, however, this policy mix has been subject to growing criticism. This paper aims to clarify whether this criticism disqualifies the use of RES-E support schemes in general – or whether there are conditions under which a policy mix is nevertheless required.

The major criticism raised with respect to RES-E support schemes is that they do not contribute anything to CO_2 emissions reduction in the presence of the EU ETS. Instead, the promotion of RES-E is found to impair the cost-effectiveness of the EU ETS. Critical debates start from the observation of interactions between electricity and allowance markets (see, e.g., Böhringer and Rosendahl, 2010; Frondel et al., 2008; 2010; Jensen and Skytte, 2003; Morthorst, 2001; Pethig and Wittlich, 2009; Sinn, 2011; Unger and Ahlgren, 2005; Weimann, 2008). RES-E support schemes result in renewable energy sources substituting fossil fuels for electricity generation. Consequently, electricity generators emit less CO_2. The electricity sector's demand for allowances declines and brings about a drop in the allowance price. Emitters in other EU ETS sectors take advantage of this price reduction, buy additional allowances and increase their emissions. The overall level of CO_2 emissions is fixed at the EU ETS cap. Thus, RES-E support schemes only result in a shift of emissions across sectors. At the same time, the cost of achieving the emissions cap is increased. The electricity sector abates too much and too costly compared to other EU ETS sectors, which do not employ relatively cheap emission reduction options. Based on these considerations, it is straightforward that some authors recommend that reasonable climate policy should rely primarily on the EU ETS – and that distorting RES-E support schemes should be abolished (see, e.g., Frondel et al., 2008; Sinn, 2011).

However, the conclusion to renounce RES-E support schemes rests on certain assumptions: Firstly, and most importantly, there is efficient competition of different technologies for electricity generation as soon as the EU ETS is established. This implies that (1) markets provide optimal levels of technology development and adoption, (2) existing policy instruments apart from RES-E support schemes do not distort the choice of technologies, and (3) the society can continuously compose an optimal technology mix on the basis of marginal generation costs. Secondly, RES-E support schemes are exclusively meant to combat climate change, just as the EU ETS.

To derive suitable policy recommendations, it has to be revised whether these assumptions actually reflect reality. There are many studies which use a broader and more applied evaluation framework (see, e.g., del Rio, 2007; 2009; Fischer and Preonas, 2010; Kalkuhl et al., 2011; Matthes, 2010; Sijm, 2005; see, e.g., Sorrell and Sijm, 2003). They emphasize that once these assumptions are relaxed, there may be rationales for combining the EU ETS with RES-E support schemes – the criticism raised above notwithstanding. Within these frameworks, the conclusion to abolish RES-E support schemes in the presence of the EU ETS may be less clear-cut – or even wrong.

This paper provides a systematic and comprehensive review and discussion of possible rationales for combining the EU ETS with RES-E support schemes. It focuses on RES-E policies which provide direct subsidies to the generation of electricity from renewable energy sources. It addresses the question under which conditions such policy is a useful complement to the EU ETS. The paper is not meant to discuss the details of designing RES-E policies. Thus, it will not reflect on optimal support mechanisms (feed-in tariffs vs. quotas with tradable green certificates) or the optimal level and differentiation of such subsidies.

The subsequent sections now dismantle the assumptions underlying those studies which are critical of RES-E support schemes step by step. This process helps to understand possible rationales for implementing RES-E support schemes in addition to the EU ETS. Section 2 illustrates possible restrictions to technology development and adoption. It will shed particular light on the implications of market failures, policy failures and path dependencies. Section 3 highlights possible benefits of RES-E support schemes beyond mitigating climate change. Section 4 summarizes and concludes.

2 Restrictions to Technology Development and Adoption

2.1 Market Failure

To argue in favour of or against RES-E support schemes, a first decisive question is whether climate change is only attributed to negative externalities related to CO_2 emissions – or whether there are further market failures which may impede a proper choice of energy and abatement technologies. In other words: Given the EU ETS perfectly internalizes the external costs of CO_2 emissions, do individually rational decisions of market participants then result in an efficient level of technological innovation and diffusion of RES-E technologies in the long term? Economic theory suggests that if negative externalities are coupled with additional technology market failures, the EU ETS has to be supplemented by some kind of RES-E policy (for overviews of rationales for using a policy mix, see Bennear and Stavins, 2007; Lehmann, 2011).

The classical market failures associated with technological development are positive externalities of knowledge generation. New knowledge may be created through invention and innovation as well as the diffusion of new technologies (Schumpeter, 1942). The levels of invention and innovation are driven primarily by firms' investments in research and development (R&D). Knowledge advances during diffusion strongly depend on the extent of technology adoption and related learning effects. Throughout the production process, experiences are made which allow decreasing the unit cost of a product (Arrow, 1962a, p. 155). Such learning effects have been found to be significant for RES-E technologies (see, e.g., Christiansson, 1995; IEA, 2000; Isoard and Soria, 2001; Kouvaritakis et al., 2000; Neij, 1997).

New knowledge generated through innovation or diffusion by one firm may "spill over" to other firms (Arrow, 1962a, p. 168). These firms may benefit from this knowledge without having invested in R&D or technology adoption and without compensating the innovator or adopter. Thus, a knowledge spillover in fact represents a positive externality. Despite patents, which are meant to protect intellectual property rights, firms are usually unable to appropriate the complete social returns of their knowledge (Neuhoff, 2005, p. 97). Their incentives to invest in knowledge generation are reduced to their private returns. This typically results in significant underinvestment in R&D and suboptimally low levels of technology adoption (Jaffe et al., 2005, p. 167).

Spillovers may arise due to personnel movements and communication between firms, joint participation in meetings and conferences, or "reverse engineering" (Argote and Epple, 1990, p. 923; Irwin and Klenow, 1994, p. 1205). There are numerous studies which empirically confirm the existence of spillovers related to R&D (see, e.g., Bernstein and Mohnen, 1998; Jaffe, 1986;

Mansfield, 1985; Margolis and Kammen, 1999). Likewise, spillover effects related to learning have been observed (see, e.g., Barrios and Strobl, 2004; Irwin and Klenow, 1994; Lester and McCabe, 1993; Lieberman, 1984; Zimmerman, 1982). These findings indicate that knowledge spillovers may also be an issue for RES-E technologies. However, there are hardly any empirical analyses available. Some studies provide an indication at least. The IEA (2000, p. 56) observes that learning effects for wind turbines are stronger in Germany than in Denmark. The IEA argues that knowledge spillovers may be one explanation of this difference. German manufacturers may have "imported" experience from Denmark. Hansen et al. (2003, p. 328) highlight that the Danish wind industry is dominated by four firms, which account for 90 percent of Denmark's production of wind turbines and operate in an industrial cluster. They draw on the same pool of highly skilled labour and profit from the same public-sector facilities. Hansen et al. find it therefore reasonable to assume that learning spillovers between Danish firms are existent.

If knowledge spillovers exist, the EU ETS, which is designed to correct for the externalities from CO_2 emissions, is unlikely to set sufficient incentives to induce technological change. Grubb et al. (1995, p. 428) highlight that the effects of emission mitigation policies may be dominated by knowledge spillovers. They estimate that the benefits of stimulating R&D and technology diffusion directly may be up to seven times larger than the direct Pigovian benefits from initial emission reductions. Parry (1995) shows that firms subject to a Pigovian emissions tax may invest too little in R&D in the presence of knowledge spillovers. The optimal tax rate has to be higher than the Pigovian tax rate. However, this solution is only efficient if all emission-reducing investments carry the same potential for innovation. Otherwise, increasing the tax beyond the Pigovian level will result in undesirable distortions for emitters and technologies with little potential of technological advances (Grubb and Ulph, 2002, p. 94). In this case, an emissions policy should rather be supplemented by a more focused stimulation of innovation and diffusion to attain a dynamically efficient solution.

Kverndokk and Rosendahl (2007), Fischer and Newell (2008) and Lehmann (2009) show that RES-E support schemes are justified in the presence of learning spillovers. In their models, the optimal policy mix encompasses an emissions policy set equal to the marginal damage from emissions and an output subsidy per unit of RES-E. Bläsi and Requate (2010) and Kalkuhl et al. (2011) adopt a more differentiated model of the energy sector. Apart from fossil-fuelled generators, they distinguish between operators and producers of RES-E plants. Learning is experienced by the latter only. They find that, in this case, the emissions policy should be complemented by an output subsidy to producers of RES-E technologies, e.g. per wind turbine produced. In turn, operators of RES-E plants do not receive any support. Bläsi and Requate

(2010) admit, however, that direct subsidies to technology producers may be ruled out by international competition and trade law. Under this restriction, an output subsidy to operators can be considered a second-best solution. A higher RES-E generation can usually only be realized by a higher production and installation of RES-E technologies. In this sense, promoting RES-E generation also fosters the output of RES-E technologies. Yet, the quantity of electricity generated does not solely depend on the technology employed. It may also be a function of other variables, such as weather and site characteristics. Therefore, the incentives set out by RES-E support schemes with respect to technology adoption may be distorted. Kalkuhl et al. (2011) find, however, that the corresponding welfare losses are small. Moreover, they show that RES-E schemes respond less sensitively to deviations from the optimal level than direct output subsidies to technology producers.

It is sometimes argued that RES-E support schemes may also be a useful policy instrument to address R&D spillovers (see, e.g., Sorrell, 2003, p. 24; Sorrell and Sijm, 2003, p. 429). However, in this respect, a direct subsidy to R&D expenditures, rather than an output subsidy to RES-E generation, should clearly be preferred as a complement to the EU ETS (see, e.g., Fischer, 2008; Goulder and Schneider, 1999; Katsoulacos and Xepapadeas, 1996). Otherwise, a double distortion is produced. First of all, the link between RES-E generation and RES-E technology production is not perfectly straightforward, as has been pointed out above. Secondly, there is neither a direct relationship between output and R&D investments. Consequently, RES-E support schemes should only be considered where direct R&D schemes are ruled out.

2.2 Policy Failure

So far, market conditions have been addressed as a barrier to employing RES-E technologies. However, technology choices may also be distorted by policy choices of governments. Two types of distortion have to be distinguished. Firstly, governments may not take sufficient action to overcome existing market failures, i.e. they fail to reduce market distortions. Even though an efficient correction of these market failures would require other policy instruments in the first place, RES-E support schemes may be second-best in the presence of policy failure. Examples discussed in this section include the incomplete internalization of external costs from non-renewable energy sources and the sluggish liberalization of the electricity market. Secondly, policy choices may also create new distortions. In particular, there may be subsidies to non-renewable energy sources and investment uncertainties produced by policies. Both types of distortion may contribute to the fact that electricity generators do not face the full economic costs of non-renewable energy sources – or that the costs of RES-E are politically increased. Thus, the political framework may constitute an "uneven playing field" which puts RES-E at a disadvantage (Neuhoff, 2005, p. 93).

2.2.1 Incomplete Internalization of External Costs of Non-Renewable Energy Sources

First of all, the external costs of greenhouse gas emissions from fossil-fuel combustion are not completely internalized. It is fair to assume that the EU ETS emissions cap has come out of a political negotiation process and not been set at an efficient level (Isoard and Soria, 2001, p. 631; Matthes, 2010, p. 24). From a strict economic perspective, an efficient emissions cap would result in an allowance price equal to the marginal damage of one ton of CO_2. Marginal damage estimates are subject to substantial uncertainty. They may vary from 0 to 300 Euro per ton of CO_2 (Downing et al., 2005). This range indicates nevertheless that marginal damages may be significantly higher than current allowances prices, which have not exceeded 20 Euro per ton of CO_2 in 2010 (EEX, 2011). Moreover, the EU ETS incorporates yet another implicit subsidy which is related to the current process of allowance allocation. So far, existing and new fossil-fuel power plants receive allowances almost entirely free of charge (European Commission, 2008c, p. 9). When technology choices for new power plants are made, fossil-fuel technologies then have an undue advantage over RES-E technologies, to which no allowances are allocated.[1] Moreover, allocation free of charge results in windfall profits which particularly benefit large fossil-fuel electricity generators (Keppler and Cruciani, 2010; Sijm et al., 2006). In Germany, windfall profits were estimated to amount to 2.5 billion Euro in 2006 (UBA, 2008, p. 16).

In addition, there are further external costs which are not (entirely) reflected in the price of non-renewable energy sources. These include other environmental costs of fuel combustion, such as diseases caused by air pollution. External costs also arise in the process of fuel extraction and transportation, e.g. the ecological impacts associated with open cast mining for coal or oil spills resulting from tanker and offshore platform disasters. Nuclear energy technologies produce costs related to possible accidents and the final storage of nuclear wastes. These are typically not completely borne by operators, for example, due to relaxed liability rules (see, e.g., Heyes and Heyes, 2000). Moreover, there are also non-environmental externalities of non-renewable energy sources. The use of natural gas and oil imported from politically instable countries has a detrimental effect on the security of energy supply. This insecurity is a major rationale for

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[1] Moreover, it has been shown that tradable permit schemes with allocation free of charge provide lower innovation incentives than tradable permit schemes with auctions or emissions taxes (see, e.g., Milliman and Prince, 1989). Thus, the development of innovative technologies, such as those for using renewable energy sources, is hampered.

engaging in wars for oil to safeguard fuel supply. Again, the costs of these wars are imposed on the entire society.

These observations reveal that market prices of non-renewable energy sources do not reflect their true social costs. Consequently, market decisions cannot result in an efficient choice of technologies. If the internalization of external costs is incomplete, RES-E support schemes can serve as a second-best policy – as has been shown for externalities related to greenhouse gas emissions (Bläsi and Requate, 2007; Fischer, 2008).

Obviously, the first-best solution would be to provide for an appropriate internalization of external costs. However, it is questionable whether a necessary modification of policy instruments would be politically feasible. For example, implementing an efficiently tight emissions cap for the EU ETS may produce a substantial burden for participating industry sectors. This may give rise to distributional and industry policy concerns and result in strong opposition against climate policy. Thus, even though the EU ETS is continuously praised by economists for minimizing the cost of emissions abatement, it is not necessarily the most suitable tool to overcome political and societal barriers to climate policy. Such barriers may delay or impede the implementation of a stricter policy instrument. Due to these political-economy considerations, it has to be doubted that the EU ETS alone is capable of stimulating a level of technological change which would be sufficient to reach ambitious mitigation targets in due time. In contrast, the targeted support of low-emission technologies, such as RES-E, may produce less political hurdles. It sets a positive incentive for abatement. In turn, the surcharge to fund the subsidy is hidden in electricity bills and often imposed primarily on private households with little lobbying power.

The fact that the EU ETS emissions cap is necessarily the result of political negotiations, rather than of efficiency considerations, also sheds new light on a major criticism raised with respect to the policy mix: The argument that RES-E support schemes do not contribute anything to emissions reductions in the presence of the EU ETS has to be qualified. In Germany, for example, expected CO_2 reductions from RES-E promotion have been considered by reducing the cap accordingly (Matthes, 2010, p. 33). In fact, it can be argued that RES-E support schemes have been a political precondition for implementing a tighter cap. By offering a subsidy, the government facilitates the attainment of an ambitious emissions target and thereby "buys" the agreement of stakeholders which have to reduce their emissions.

Just as for CO_2 externalities, it must be doubted that other environmental and non-environmental externalities of non-renewable fuels will ever be perfectly internalized. For example, the implementation of an appropriate tax or tariff on imported fossil fuels to increase the security of energy supply is highly unlikely for political reasons – in theory it would have to be differentiated according to degree of uncertainty resulting from the political situation in the exporting country. If this is impossible, RES-E support may serve as a second-best policy (Hagem, 2010).

2.2.2 Sluggish Liberalization of Electricity Markets

Since 1996, the EU has attempted to liberalize the European electricity market. However, Member States have been sluggish in implementing the EU Directive. Consequently, electricity markets are still dominated by few large electricity utilities (Joskow, 2008). The impact of market power on technological change has been strongly debated. On the one hand, it is argued that investment in R&D may be larger under market power than in the case of a competitive market, e.g. because firms can realize economies of scale and have more financial resources available (Aghion and Howitt, 1992; Grossman and Helpman, 1991; Schumpeter, 1942). On the other hand, it has been pointed out that firms which do not face competition may not be forced to be efficient and to innovate (Arrow, 1962b; Nickell, 1996; Porter, 1990). Moreover, there are some fundamental problems of markets with limited competition. Firstly, dominant firms tend to invest mainly in incremental improvements of technologies that are currently in use rather than in fundamental technological change (Grubb, 1997, p. 162). This often results in process rather than product innovation (Unruh, 2000, p. 821). Secondly, firms having market power may impede the entry of new competitors, e.g. by price manipulations or – in a vertically integrated industry – by denying grid access (Neuhoff, 2005, p. 95). This may impair the installation of renewable energy plants as they are often operated by market entrants. Thirdly, market entry barriers imply that there are fewer operating firms investing in innovation, i.e. a reduced probability of a technological break-through (Geroski, 1990). Finally, a dominant market position may change the behaviour of firm managers providing for some "managerial slack" (Aghion et al., 1999; Geroski, 1990). Instead, firms may invest significant resources in rent-seeking to protect its existing market position and generation structure. So overall, there are arguments why an insufficient liberalization of the EU electricity market, which impedes ample competition, may also compromise efficient technology choice.

2.2.3 Direct Subsidies to Non-Renewable Energy Sources

The use of non-renewable energy technologies has also been promoted by enormous direct subsidies. Most notable are policies subsidizing the production of fossil-fuels (for an overview, see Ellis, 2010). In Germany, for example, subsidies to hard coal mining are most noteworthy. They amounted to 2.285 billion Euros in 2006. Moreover, nuclear-based electricity generation still benefits from a remarkable amount of R&D subsidies (UBA, 2008). These subsidies reduce the cost of non-renewable energy sources and make them inefficiently cheap. The first-best solution would again be to abolish the subsidies. However, this may not be possible due to opposition from affected mining companies, plant manufacturers and energy utilities.

2.2.4 Policy-Induced Investment Uncertainties

Finally, climate and energy policy introduces new drivers of uncertainty for investors in the electricity sector, in addition to classical market risks such as fuel prices. Policy measures typically follow an erratic process of political decision-making which is driven by a variety of short-term concerns and considerations. In Germany, this has been demonstrated recently by the government's decision to shut down nuclear power plants as a response to the Fukushima accident. This decision was taken only few months after the same government had agreed on prolonging the operation periods of existing nuclear power plants. This example illustrates that it is impossible to predict the future stringency and design of climate and energy policy. The corresponding policy-induced uncertainty implies that investments in mitigating GHG emissions and developing new abatement technologies, such as those using RES-E, will remain at suboptimally low levels.

Policy-induced uncertainties arise particularly in the context of the EU ETS. Its outstanding characteristic – in contrast to an emissions tax – is that it fixes the overall emissions cap for a certain period but not the emissions price. This results in two types of uncertainties for EU ETS participants. Firstly, there is inter-period uncertainty since the emissions cap is renegotiated after each trading period. Even though it is decreasing over time, the actual extent of the reduction is unclear and dependent on the political feasibility. As a consequence the level of the allowance price in future trading periods is unknown. Secondly, there is also intra-period uncertainty. Even though the cap was fixed for a couple of years, allowance prices have been extremely volatile in previous years of the EU ETS. This demonstrates that prices are also driven by other factors apart from the cap, such as available information on actual emissions or speculation (Alberola and Chevallier, 2009; Ellerman and Joskow, 2008; Hintermann, 2010). With these uncertainties, it is questionable whether the EU ETS can set appropriate long-term scarcity signals (Betz and Sato, 2006, p. 352; Kettner et al., 2010, p. 18). At best, it can serve as a clearing mechanism for marketable abatement options within the next 10 years approximately. Since investment and innovation cycles of energy technologies are way beyond this period, the EU ETS is unlikely to induce sufficient levels of development and deployment of innovative but not yet marketable low-carbon technologies, such as renewable energy sources (Matthes, 2010).

Moreover, risks produced by uncertain allowance prices under the EU ETS (and by uncertain climate and energy policy in general) aggravate existing barriers to financing RES-E investments via the capital market. Such barriers have various sources. Firstly, investors in RES-E technologies are often small and new market actors which can provide less security for loans than large producers and adopters of fossil-fuel technologies. In addition, they cannot rely on a long-lived relationship with banks (Walz, 2005, p. 265). Secondly, the relative importance of the risk premium is higher for RES-E technologies. This is because these technologies are relatively more capital-intensive than fossil-fuel technologies. The cost of generating one kilowatt-hour depends primarily on investment costs and hardly on variable input costs, such as fuels. Since investors in liberalized electricity markets prefer the least capital-intensive technologies, investment in renewable technologies is suboptimal. Thirdly, transaction costs of risk-management instruments may be relatively high for small-scale renewable energy projects (Menanteau et al., 2003, p. 801; Neuhoff, 2005, p. 95).

In the light of the uncertainties induced by the EU ETS, one may be tempted to plead for an fixed emissions tax instead. However, a tax can be considered as politically incompatible in the EU. The implementation of the EU ETS was the result of a lengthy political decision-making process. In the meantime, the necessary institutions and organizations have been established to administer the EU ETS. Overthrowing this system is unlikely to be politically feasible. In this case, RES-E support schemes are needed to reduce the political uncertainties surrounding RES-E investments and to stimulate sufficient levels of technology development and adoption.

2.3 Path Dependency and Carbon Lock-in

The welfare losses produced by market and policy failures are aggravated and perpetuated by the path dependency which characterizes technology choices in the electricity sector. Path dependency implies that the economics of future technology-related decisions depend crucially on previous decisions and investments (Arthur, 1989). As a consequence, suboptimal decisions taken today may lock the electricity sector into a high-emissions path for decades as changing to a lower-emission energy system may become prohibitively costly (Sorrell and Sijm, 2003, p. 430). This has been referred to as carbon lock-in (Unruh, 2000). Kalkuhl et al. (2011) demonstrate, for example, that the welfare losses from learning spillovers associated with RES-E technologies are significantly higher in the presence of lock-in effects.

The path dependency in the electricity sector is attributed to a variety of causes. Firstly, there are increasing returns from technology adoption. Four types can be distinguished (Grubb, 1997, p. 162; Unruh, 2000, p. 820):

- Scale economies, which arise because fixed costs are spread over an increasing production volume.
- Learning economies (not spillovers), which imply that the production and use of technologies are optimized by experience gained over time (see also Section 2.1).
- Adaptive expectations, which mean that the increasing adoption of a technology reduces the uncertainty about its quality, performance and permanence.
- Network economies, which result from the fact that production processes are embedded into a set of specific infrastructures, supplier relationships and customer outlets, often characterized by interdependent technologies throughout the value chain.

Increasing returns of technology adoption contribute to the fact that established fossil-fuel and nuclear technologies generate electricity cheaper than RES-E technologies. Moreover, increasing returns result in non-convex, S-shaped supply curves for energy technologies. These may imply multiple stable equilibriums in the supply market, and market forces alone may not be sufficient to reach the superior state with a higher share of RES-E (Bruckner and Edenhofer, 2009; Marschinski and Schmidt, 2009).

A second source of path dependency are the large-scale and long-term investments which are necessary in the energy sector (Matthes, 2010, p. 16; Neuhoff, 2005, p. 98; Sorrell and Sijm, 2003, p. 430). They include investments in manufacturing plants (typical lifetime 10-30 years), power plants (30-50 years), buildings (20-200 years) and transport and transmission infrastructures (40-200 years) (Grubb, 1997, p. 165). Many of the investments are irreversible, i.e. investment costs are sunk in economic terms. Within the lifespan of investments, firms making technology decisions will therefore compare only the operation and maintenance (O&M) costs of the technologies in use with the investment and O&M costs of emerging technologies.

Thirdly, electricity is a very homogeneous good. That is, electricity outputs from different technologies are almost perfect substitutes. New RES-E technologies can only compete on price, not on “quality”, with fossil-fuel and nuclear technologies. This is a major difference to other sectors, like those for IT and telecommunication, where product differentiation plays an important role in the adoption of new technologies (Kalkuhl et al., 2011; Neuhoff, 2005, p. 98).

Finally, technological path dependencies are reinforced by institutions which co-evolve with the technological systems – something which has been referred to as techno-institutional complex (Unruh, 2000). On the one hand, institutions are designed as a response to emerging technologies. On the other hand, they also shape the technology choices of economic actors.

These institutions are subject to path dependencies themselves. A variety of institutions may promote non-renewable energy technologies and put RES-E technologies at a disadvantage (Neuhoff, 2005, pp. 94-96; Unruh, 2000, pp. 822-824). Relevant private institutions include:

- the procedures for network control, e.g. the design of network tariffs and the timing of transmissions allocation decisions
- the mechanisms of industry and inter-industry coordination, most importantly industry standards like those of the International Organization for Standardization (ISO),
- financing mechanisms, e.g. if investments are primarily funded by internal cash flows or loans from risk-averse financial institutions,
- pro-fossil fuel lobbying by powerful networks, in which the fundamental interests of unions and industry associations often merge,
- the generally stronger acceptance for technologies in place due to adaptive preferences, and an aversion against new technologies.

Similarly, there are also publicly established institutions which reinforce the use of non-renewable energy technologies:

- the type of utility regulation,
- a framework of land use planning which favours centralized over decentralized solutions of energy supply
- the permitting process for new power plants, which may impose relatively higher transaction costs on small-scale RES-E projects than on large-scale fossil-fuel investments,
- the publicly (and possibly also privately) funded research and education system, which generates highly trained and specialized individuals and may even create entirely new academic disciplines.

Path dependencies and carbon lock-in imply that the change from non-renewable electricity to RES-E generation cannot be captured by the classical marginal calculus dominating economic thinking. In fact, not only the fuel but an entire set of technological and institutional systems has to be replaced or modified. Due to the inertia of these systems, the transition process usually occurs very slowly, and may exceed the time horizon where emissions reductions are required.

Under such conditions, the market process is unlikely to unfold an efficient level of technology discovery and adoption (Matthes, 2010).[2]

3 Multiple Policy Objectives

So far it has been assumed that the EU ETS as well as RES-E support schemes are primarily meant to address climate change. While this holds true for the EU ETS, RES-E support schemes pursue a variety of additional policy objectives. The EU particularly highlights environmental protection in a broader sense, security of electricity supply and industry policy as further rationales behind RES-E support (European Parliament/Council of the European Communities, 2001).

As already pointed out in Section 2.2.1, the use of RES-E may also provide environmental benefits apart from GHG mitigation when replacing non-renewable generation. Most notably are the reduction of air pollution from fossil-fuel combustions, the mitigation of nuclear hazards and the conservation of non-renewable resources. For Germany, the Federal Ministry of the Environment estimates that renewable electricity generation has abated some 45,000 tons of sulphur dioxide emissions and roughly 13,000 tons of nitrogen oxide emissions in 2007 (BMU, 2008, p. 18). In addition, the use of fossil fuels was reduced by 39.1 million tons of lignite, 14.2 million tons of hard coal and 8.78 billion cubic metres of natural gas in 2007 (BMU, 2008, p. 25).[3] From an economic point of view, though, an assessment of these effects is complicated due to difficulties in assessing the baseline (e.g. the level of RES-E generation in the absence of support schemes), indirect effects (e.g. due to interactions in allowance and output markets) and environmental benefits of alternative abatement options (e.g. fuel switching, energy efficiency).

The promotion of RES-E may also produce benefits related to the security of energy supply. Renewable energy sources substitute oil and natural gas, which are often imported from countries with an instable political environment. These fuels play an important role in energy generation. The interruption of their delivery may produce significant costs to society. RES-E support can be

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[2] Obviously, any technology policy instrument – such as RES-E support schemes – is subject to uncertainty about future technology development. Consequently, such instruments also run the risk of locking society into a new technological path which may turn out to be suboptimal in future (Kverndokk et al., 2004). However, this insight cannot be interpreted as an argument for abstaining from RES-E support schemes. Inaction would imply accepting the existing mix of fuels for electricity generation which is clearly suboptimal. Rather action is required based on knowledge available today. Currently, RES-E technologies seem to be the only sustainable means to achieve significant GHG emission reductions in due time.

[3] These figures refer to electricity as well as heat generation from renewable energy sources.

a means to hedge against these exogenous risks as it increases the variety of available domestic energy sources (Matthes, 2010, p. 31). In Germany, for example, fossil fuel imports in the amount of 1.0 billion Euro were saved in 2007 due to using RES-E (BMU, 2008, p. 25). Benefits in terms of security of energy supply are even acknowledged by critics of RES-E support (Sinn, 2011). The use of RES-support schemes as a means to address security of energy supply is sometimes criticized for distorting trade and division of labour at the international scale (Weimann, 2009, p. 258). This reasoning presumes, however, that international markets are organized efficiently – which is certainly not true for a variety of reasons (see Section 2.2.1), particularly for the case of energy markets being subject to strategic trade policy worldwide.[4]

Finally, RES-E support schemes are also understood by politicians as an effective tool of industry policy. They are expected to foster the leadership of European firms in future technology markets. The EU explicitly mentions possible positive impacts on regional and local development, export prospects and employment opportunities. In addition, it is emphasized that RES-E schemes may particularly benefit small and medium-sized undertakings and independent electricity producers (European Parliament/Council of the European Communities, 2001). Exemplary data for the German industry seems to confirm these expectations. The sales volume for renewable energy technologies produced in Germany amounted to 25.5 billion Euro in 2007. This figure corresponded to an increase by 155 percent from 2003 to 2007. Moreover, the renewable energy industry had roughly 250,000 employees in 2007. This implied a 55 percent increase since 2004. According to estimates of the Federal Ministry of the Environment, about 60 percent of this employment effect can be attributed to the existing RES-E support scheme (BMU, 2008, pp. 27-28). However, the net effects of RES-E policies are possibly smaller. Detrimental impacts on overall economic development may result from crowding-out effects in the fossil-fuel sector and increases of electricity prices (Frondel et al., 2008; 2010). Empirical estimates of net employment effects of RES-E support schemes are quite mixed. Some confirm an increase in employment (Lehr et al., 2008; Wei et al., 2010), while others find zero or negative effects (EWI et al., 2004; Hillebrand et al., 2006).

This brief discussion illustrates that there may be benefits from RES-E employment apart from climate change mitigation, even though the actual extent of these benefits is debatable. Obviously, RES-E support schemes are rather second- or third-best means to provide these benefits. Yet, it may also be questioned whether theoretically first-best policies to address the

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[4] With respect to supply security, however, particularly wind energy and solar radiation still face the challenge to generate or store electricity on a continuous basis (Frondel and Schmidt, 2006, p. 2).

underlying market distortions are politically feasible (see Section 2.2.1). In any case, a comprehensive assessment of RES-E support schemes must also take into account possible benefits which are not related to GHG mitigation.

4 Conclusion

In a perfect world with undistorted technology and energy markets except for a climate externality, with a simple marginal technology choice framework without positive feedbacks and a benevolent dictator providing efficient institutions and in a world whose one and only worry is about mitigating GHG emissions there is evidently no need for additional RES-E support schemes given a perfect EU ETS already implemented. Unfortunately, nary a condition of this imaginary setting holds true in reality. Against this background, one might argue, like some economic scholars do, that the relevant policy framework for technology choice should approximate to the theoretical requirements of model-based thinking in order to maintain theoretical efficiency. Thus, assessing RES-E policies by means of first-best optima runs the risk to apply the well-known Nirvana approach.

Instead, for the purpose of policy recommendations it might be reasonable to take into account the real-life conditions energy and climate policies have to cope with. In this perspective, with reference to RES-E support schemes a considerable modification of the general reproof of being needless and even harmful is required. This should not be mistaken for a plea for (steady) subsidizing politically desirable technologies. Rather, a differentiated analysis is needed in this field appreciating the theoretical assumptions as well as their practical relevance for a model-based assessment of real-world policies. Hence, the oftentimes observed disqualification of RES-E support schemes in academic literature on a general basis has to be replaced by a differentiated analysis of the relevant policy alternatives keeping in mind multiple policy objectives and real-world conditions for both political process and market performance. Our analysis has demonstrated that under such conditions a policy mix of the EU ETS and complementary RES-E support schemes may be justified for a variety of reasons.

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