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Environmental Innovation in Germany

Ivan Haščič

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ENVIRONMENTAL INNOVATION IN GERMANY

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ABSTRACT

This paper reviews the recent experience of Germany in encouraging innovation to reduce negative environmental impacts of economic activity. The essence of the German approach to policy-induced environmental innovation is discussed in the context of changing policy objectives, and illustrated with selected examples from waste management, renewable energy and transportation. The paper covers environmental and general innovation policies and the cross-cutting issue of policy co-ordination. Particular attention is paid to analysis of policies to promote renewable energy, including feed-in tariffs, and policies to promote advanced transportation.

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RÉSUMÉ

Ce document analyse le bilan de l’action menée dans un passé récent en Allemagne pour encourager une innovation tournée vers la réduction des effets négatifs de l’activité économique sur l’environnement. La nature profonde de l’approche de l’Allemagne, qui mise sur le développement d’innovations environnementales sous l’impulsion des politiques publiques, est examinée dans le contexte de l’évolution des objectifs de l’action publique, et illustrée par plusieurs exemples portant sur la gestion des déchets, les énergies renouvelables et les transports. Ce document aborde les politiques en faveur de l’innovation environnementale et de l’innovation en général, de même que la question transversale de la coordination des politiques. Une attention particulière est portée à l’analyse des mesures visant à promouvoir les énergies renouvelables – dont les tarifs de rachat – et des mesures visant à promouvoir les technologies avancées de transport.

Classification JEL: Q53, Q54, Q55, Q58, Q42, Q48, H23, O31, O33, O38, O52, R48.

Mots-clés: politique environnementale, technologie, innovation, éco-innovation, coordination des politiques.

FOREWORD

This paper has been authored by Ivan Haščič of the OECD Environment Directorate. The paper is an extended version of Chapter 4 of the *OECD Environmental Performance Review of Germany,* published in May 2012. It is based on information and data available up to the end of January 2012. Given the breadth of the subject, the paper cannot be exhaustive with respect to environmental domains, the range of policy instruments used, nor types of innovation responses. Interested readers will find complementary material in OECD (2012a) *Environmental Performance Review of Germany*, particularly in Chapters 3 and 5.

This paper benefited from discussions with officials of the German government, representatives of academia, industry and non-governmental organisations. Among all those, the author would particularly like to thank Klaus Rennings as well as Harald Neitzel and Nicolas Oetzel for valuable information and helpful clarifications. Ivana Capozza, Brendan Gillespie, Heymi Bahar, Nick Johnstone, Nils Axel Braathen and Margarita Kalamova provided precious inputs and comments on earlier drafts of this paper. Carla Bertuzzi and Fleur Watson helped with data and graphics. This paper also benefited from discussions with delegates to the OECD Working Party on Environmental Performance.

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LIST OF ACRONYMS

BMBF	Federal Ministry of Education and Research
BMU	Federal Ministry for the Environment, Nature Conservation and Nuclear Safety
BMWi	Federal Ministry of Economy and Technology
EEG	The Renewable Energy Sources Act (Erneuerbare-Energien-Gesetz)
EU-ETS	The European Union Emissions Trading System
FIT	Feed-in tariffs
GHG	Green-house gases
REC	Renewable energy certificates
R&D	Research and development
SME	Small and medium-sized enterprises

ENVIRONMENTAL INNOVATION IN GERMANY

1. Introduction

Germany is a rich source of experience on policy-induced environmental innovation thanks to its strong innovation framework and a long history of ambitious environmental policy. Indeed, Germany has long been a leader in environmental policy, and on many fronts it continues to be one today. While the world has widely benefited from German environmental innovation, it has equally a great deal to learn from her policy experience and practices.

The paper first summarizes the early efforts to induce technology development and diffusion in German environmental policy in the context of changing policy priorities. It goes on to briefly outline the process of setting environmental policy objectives, and then focuses on environmental and general innovation policies. It concludes with a discussion of the cross-cutting issue of policy co-ordination – one of the central elements of German experience. Throughout the paper, examples from the various focal areas (waste, energy and transport) are used to illustrate the best practices as well as potential weaknesses, but these examples are not exhaustive with respect to the mix of policy instruments used.

2. Encouraging technological innovation in German environmental policy: an overview

Historically, Germany has used stringent environmental policy to encourage innovation and thereby significantly improve environmental quality while also advancing its economic objectives. It has largely achieved these dual purposes.

The first set of environmental policies, dating back to the 1970s-80s, aimed primarily at reducing airborne pollutant emissions from power plants and other sources. In the 1980s-90s, waste management policies aimed to improve the rates of material recycling. In both cases, stringent environmental regulations led to domestic development of technologies that today are widely used internationally. These policies turned out to be very effective in inducing innovation (see *e.g.* Popp 2006).

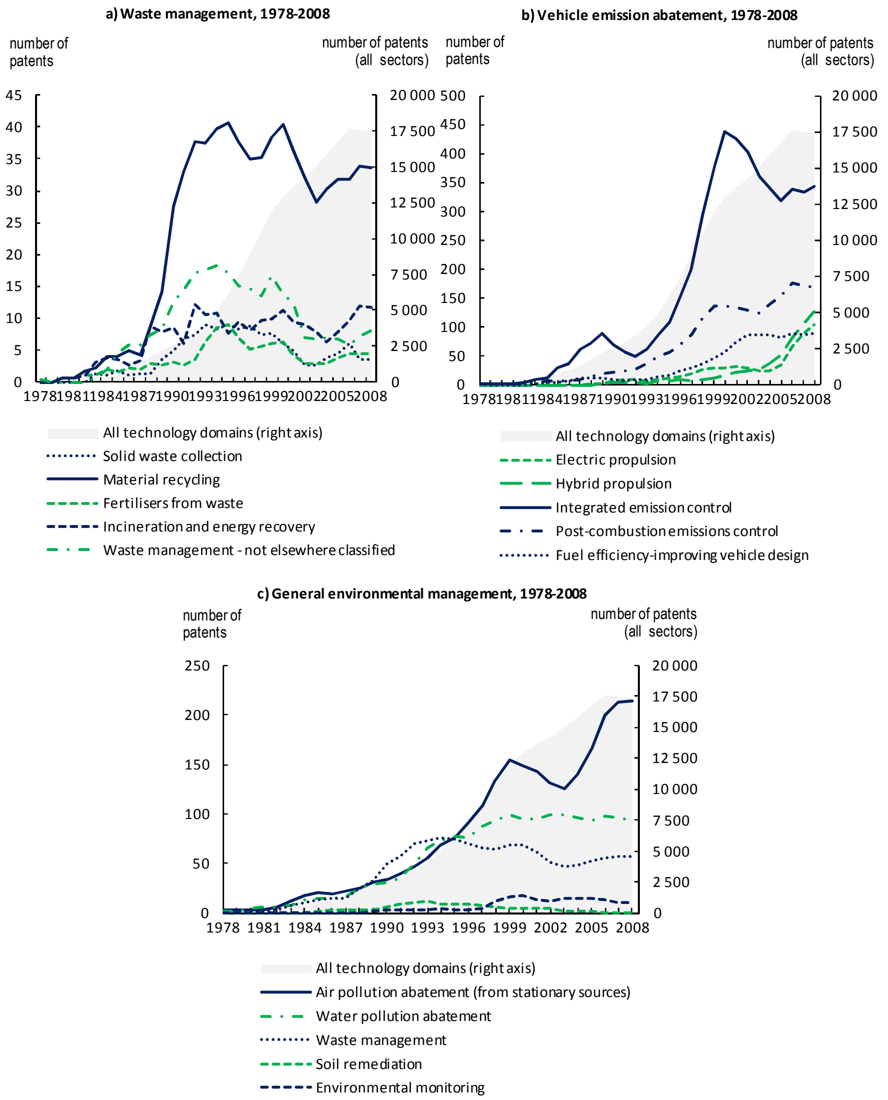
Figure 1a shows that the rate of inventive activity (measured using patent data) in material recycling increased significantly following major policy developments: mandatory waste recovery (1986), packaging waste recycling (1991) and the extended producer responsibility law (1996). More recently, the ban on landfilling of unpretreated waste (2005) was another step towards achieving the goal of near-zero landfilling by 2020.

As a result of these policies, Germany achieved one of the highest recycling rates of municipal waste in Europe in 2009 (63%). In addition, it is among the best performers in the world for recovery of industrial and commercial waste (80%) and of construction and demolition waste (90%).[1] The German waste management sector is thus an important contributor to resource efficiency. Moreover, according to estimates by the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU), it has become a powerful economic sector with annual turnover of EUR 50 billion, high export rates (25% of the world market for closed-cycle management technologies) and strong growth potential (exports are expected to generate production in Germany worth about EUR 9.7 billion by 2020).[2]

[1] For further discussion of Germany's waste policies, see Chapter 1 in OECD (2012a).

[2] For more information, see *www.retech-germany.net.*

Figure 10. Patenting activity in selected environment-related technologies by German inventors[a,b]



a) Patent counts are based on patent applications filed under the Patent Co-operation Treaty (PCT) at international phase (EPO designations), using priority date and inventor's country of residence (fractional counts).
b) Three-year moving average data.
Source: OECD (2011), *OECD Patent Statistics Database.*

The 1980s-90s also witnessed the onset of stringent emission standards for motor vehicles, later implemented at the EU level through the Euro standards (starting with Euro 1 in 1992). Again, these policies were very effective in encouraging inventive activity in motor vehicle emission control technologies, especially for integrated approaches involving innovative engine design (Figure 1b). However, since 2000 the rate of innovation has levelled off and even declined. Several factors may have played a role, including a relative decline in the tax share of automotive fuel prices, although Germany's tax share is still considerably higher than the OECD average.[3] Another factor that may explain innovation

[3] After a long period of fuel tax increases, in 2004 the tax share of automotive fuel prices started to decline. The share of taxes in the final price of diesel went from 68% in 1998 to 51% in 2008. This general trend (common to most OECD countries except Korea) was linked to soaring oil prices in the 2000s. In the late 1970s, Germany's tax share was 58%, double the OECD average of 29%, but this spread narrowed as other countries increased their tax rates faster than Germany.

trends is an increasing focus on alternative fuel vehicle technologies, which may have reduced the R&D effort on conventional vehicles: as Figure 1b shows, inventive activity in electric and hybrid cars increased significantly in the late 2000s (see also Section 6 below).

Since the late 1990s, the traditional domains of environmental policy (air, water, waste) have seen innovation rates flattening off or even declining – a phenomenon common to many countries. In Germany, this is particularly evident in solid waste management and in water/wastewater treatment. The evidence is mixed for air pollution abatement technologies (Figure 1c). Probable factors in this phenomenon include changes in the nature of innovations, with less after-treatment and more process-type innovations (which are, by definition, more difficult to identify in data), and the fact that these technological fields may have reached a certain degree of maturity. Further improvements in environmental performance are now more likely to arise through organisational or behavioural innovations, introduction of policies abroad to improve recyclability of imported products, or structural changes such as development of complementary technologies that would allow, for example, fossil fuels to be phased out or energy and material efficiency to be improved. Such structural changes are discussed in greater detail below.

More generally, it should be noted that stringent environmental policy is a necessary condition for innovation in environmental technologies. In addition, strong innovative capacity and a broad industrial base (or a high degree of integration in international trade) are also needed. All these elements have historically been present in Germany.

Germany has largely continued using technology-forcing policy to achieve environmental improvements while advancing economic objectives. However, in many cases this task has become more complex. First, this is because the changing nature of environmental objectives renders it increasingly difficult to target the negative environmental externality directly. Second, with rising policy ambition the nature of innovation induced shifts from end-of-pipe (after-treatment, post-combustion) to integrated solutions (product design, change in production processes). And while integrated approaches tend to be more cost-efficient, it is more difficult for firms to identify such solutions. Consequently, inducing innovation solely through stringent environmental policy becomes increasingly challenging for the regulator.[4] Moreover, other market failures may need to be addressed as well.

This trend reflects the shift in German environmental policy away from the traditional domains of environmental policy (air and water pollutants, waste material recycling) towards more cross-cutting goals such as addressing climate change mitigation and biodiversity protection. The decade up to 2010 was marked by the introduction of policies aimed at renewable energy sources, energy efficiency of buildings and, more recently, resource efficiency in manufacturing and alternative-fuel vehicles. For example, the 2010 *Energy Concept*, establishing Germany's energy policy framework to 2050, includes a number of measures to encourage diffusion of technologies that can help reduce greenhouse gas emissions (Box 1).

The implications of this shift include not only a reinforcement of the trend towards process-type innovations, but also an increased need for horizontal policy co-ordination. Another consequence is the sheer volume of investment required to achieve the objectives, which implies a "crowding in" of more private capital. Effective management of both these aspects requires, more than ever, broad public support. Involvement of the public in goal setting, policy planning and policy assessment is thus essential. The shift also has important implications for the day-to-day business of the Environment Ministry (BMU), with growing involvement of non-government organisations, consumer groups and industry associations.

[4] It is more challenging unless policy targets the externality directly (CO_2 emissions are perhaps the only case where this is possible). Instead, environmental policies tend to target a range of 'proxies' that correlate with the externality, such as fuel quality, combustion efficiency, speed limits to reduce SO_2, NO_X or CO emissions.

Box 6. The 2010 Energy Concept: Selected measures to encourage technology development and diffusion

The 2010 Energy Concept for an Environmentally Sound, Reliable and Affordable Energy Supply includes measures to encourage diffusion of energy-efficient technologies, for example, by considering life-cycle costs in awarding public contracts and by further strengthening the energy performance labelling of cars and buildings. This is similar to the EU Emissions Trading Scheme that provides incentives for energy efficiency improvements in participating sectors. In practice, such measures tend to harvest the low-hanging fruit (*i.e.* exploit the most cost-efficient opportunities) but have only a limited potential to encourage more radical innovation because making them truly binding is usually not politically feasible. To achieve this, other complementary policy instruments are needed to provide a stringent and credible long-term policy signal, and thus induce further technology development.

The Energy Concept thus also foresees establishing an energy efficiency fund to be used for actions such as supporting market introduction of highly efficient cross-application technologies (*e.g.* engines, pumps, refrigeration), funding efficiency-enhancing technologies to support their demonstration and encouraging development of model projects by local authorities. In addition to addressing environmental externalities, these measures are intended to deal with some of the other market failures leading to suboptimal rates of innovation.[5]

The Energy Concept also endorses the testing of carbon capture and storage (CCS) technology in the energy and manufacturing sectors. Besides addressing global warming, and hence providing a push by the government for closer international co-operation in CCS, support for domestic CCS development is viewed as creating a potentially attractive export opportunity for German industry to countries that continue to use coal. However, some scholars have suggested that supporting CCS development could be suboptimal because nurturing expectations of future CCS development could lead polluters to "postpon[e] some of their emission reduction efforts awaiting the silver bullet technology on the horizon" (Löschel and Otto, 2009), thus diverting investment away from renewables.[6]

Source: Bundesregierung, 2010.

3. Environmental policy objectives

Germany has put in place a set of ambitious environmental and innovation targets. The 2002 *Sustainable Development Strategy* defines 35 measurable objectives, including for example, doubling energy productivity between 1990 and 2020 (40.5% increase achieved by 2009), reducing GHG emissions by 21% between 1990 and 2010 (25% reduction achieved in 2010) and by 40% by 2020, increasing the share of renewable energy sources on electricity consumption to 12.5% by 2010 (17% share achieved in 2010) and 30% by 2020. The Strategy also includes a set of investment and education goals, such as to increase the share of R&D spending (public and private) on GDP to 3% by 2010 (2.8% achieved in 2009), increase share of investment in GDP (without a specific target) and raise the share of university educated 25-year-olds to 20% by 2020 (attained 8.8% in 2008).

Compared to many other countries, the process of setting environmental policy objectives in Germany is highly democratic and pluralistic. As a result, environmental policy is largely considered to be a reflection of the preferences and sense of responsibility of the German public. These underlying values are reflected in the ability of the non-governmental sector to exercise a strong influence over target-setting. In addition, or rather as a consequence of the public's demands, leadership in environmental policy is also seen as a driver of business opportunities and this view is widely supported by the German industry and service sectors.

[5] The literature on 'directed' technological change suggests that, in the context of climate change mitigation, a policy mix which includes both a carbon tax and targeted R&D support for 'clean' R&D is likely to be more efficient than one which relies upon a carbon tax alone (Acemoglu *et al.*, 2009). This is consistent with the empirical results obtained by Bosetti *et al.* (2011) using the WITCH model, who find that relying solely on a tax would be excessively costly. Cullen (2011) has similar findings.

[6] This argument is not dissimilar from the 'new source bias' arising from environmental policy that treats new versus old sources of pollution differently, thus reducing the rate of capital turnover in the electric utility industry with the effect of increased emissions (see e.g. Maloney and Brady 1988; Nelson *et al.* 1993).

In setting specific targets for environmental policy, the following three principles are applied: (a) the precautionary principle, (b) the polluter pays principle, and (c) the co-operation principle. For example, the *Energy Concept* – developed jointly by the Federal Ministry for the Environment (BMU) and the Federal Ministry of Economy and Technology (BMWi) – formulates guidelines for an environmentally sound, reliable and affordable energy supply. It builds on the commitment to reduce greenhouse gas emissions by 40% until 2020 and by at least 80% until 2050. The intention of the Concept is to set specific strategic goals to both provide long-term orientation while at the same time preserve the flexibility required for new technical and economic developments. The key element of the Concept is that renewable energies are defined as a cornerstone of future energy supply in Germany. It is envisaged that renewables will contribute the major share to the energy mix of the future, gradually replacing fossil fuel and nuclear energy sources.

4. Environmental policy instruments to foster innovation

Germany has introduced a number of policy measures intended to reduce the negative environmental impacts of economic activity. In principle, any environmental policy will, to some extent, spur an innovative response (although the rate and direction of innovation may be more or less optimal). This is because if governments affect relative input prices, or otherwise change the opportunity costs associated with the use of environmental resources, they alter the incentives for firms to seek improvements in their production technology. Indeed, since markets often fail to put a price on environmental resources, the price of many environmental assets is to a large extent formed by government regulation. Depending on the stringency of regulation, the change in opportunity costs of pollution translates into increased cost for some factors of production, and thus incentives to innovate in a manner which saves on the use of these factors.

Table 1 gives selected examples of the major policies in Germany aimed at environmental innovation. It lists both environmental policies (covered in this section) and general innovation policies (discussed in the following section).

Table 3. Innovation-oriented policy instruments and main innovation phases

	Phase		
Instrument	**Invention**	**Market introduction**	**Diffusion**
General innovation-related policy instruments			
Programmes meant specifically to promote technology development	High-Tech Strategy		
Promotion of business networks, technology transfer	PRO INNO InnoNet		
Environment-related policy instruments to promote innovation			
Taxes and charges	Ecological tax reform		
Tradable rights	EU Emissions Trading System		
Financial support measures	Renewable Energy Sources Act (EEG)		
Liability law			Environmental liability law
Regulatory law			Regulation on heating and energy efficiency in buildings
Voluntary commitments			Climate change declaration by German industry
Environmental management systems			EMAS, ISO 14001
Product labelling			Blue Angel
Green public procurement			Government purchases

Source: Adapted from Rennings *et al.* (2008).

4.1. Measures targeting relative prices

Pricing measures should be a cornerstone of environmental policy because changing relative prices provides a signal across the whole economy and thus allows achieving environmental objectives at least cost. In Germany, the most significant steps towards better pricing of environmental externalities include the *ecological tax reform* (Oeko-steuer) which was progressively introduced between 1999 and 2003, and the *EU emissions trading system* (EU ETS) which at first met with much resistance in Germany. They both provide incentives for energy efficiency improvements in targeted sectors. (For a detailed discussion of these policy instruments, see Chapters 3 and 5 in OECD, 2012a.)

Unfortunately, the 2010 Energy Concept is weak on pricing and taxation measures even though it contains over 100 measures. In the electricity market, it introduces a nuclear fuel tax to be levied for the six years to 2016 that was expected to raise some EUR 2.3 billion a year (Bloomberg, 2010), about 36% of the expected annual increase in nuclear industry profit. This expected effect has since been somewhat attenuated by a partial shut-down of the country's nuclear plants. In the heating market, the Energy Concept envisages a revenue-neutral reform of the energy tax so that it differentiates by fossil fuel used and by CO_2 emissions. The German government also plans to examine further adjustment of the emission-based vehicle tax and fuel taxes. While reforming automotive fuel taxation to equalise implicit carbon prices between diesel and petrol fuels should be a priority, the intentions remain vague.[7] Given the higher carbon emissions from diesel combustion, the tax rate per litre of diesel ought to be higher than the tax rate per litre of petrol. The Energy Concept also lists a number of administratively costly tax exemptions and tax rebates.[8]

A clear signal about long-term future taxation of energy carriers (including fossil and nuclear fuels, automotive fuels, and electricity) would provide permanent incentives for innovation and investment, and would help achieve environmental objectives at lower costs. However, for reasons of political acceptability or other, taxation and related pricing measures frequently lack sufficient ambition and hence fail to provide a sufficiently strong incentive to reduce negative environmental externalities. In such cases, additional measures are needed to make it profitable for investors to engage in pollution reduction efforts.

4.2. Measures targeting market diffusion: the case of renewable energy technologies

In the early 2000s, emphasis was placed on increasing the penetration of renewable energy sources in electricity and heat generation, complemented with support for diffusion of fuel-efficient heat generation technologies (combined heat and power), building renovations and performance standards for new buildings. Among these measures, the renewables feed-in tariffs (FITs) typify German financial incentive programmes.[9] Germany pioneered the initial version in 1991. It was reformulated in 2000 and contributed to a boom in renewables. As a result, by 2011 the shares of renewables had risen to about 20% in electricity generation and 10% in heat generation. While wind and solar provide more than a half of all renewables-based electricity, biomass is the dominant fuel for heat generation (Figure 2). This helped Germany reduce its fossil fuel imports and achieve its CO_2 mitigation targets. The growing renewables industry also attracted investment and generated new employment opportunities, although the net (general equilibrium) effects are difficult to assess.

The key features of the German FIT programme are:

- *Guaranteed price* for producers: the FITs are paid at a defined, declining rate over a period of 20 years (the formula for calculating the payments is fixed at the time of commissioning and does not change thereafter).
- *Guaranteed market* for producers: grid operators[10] must provide grid access to producers using renewables, and purchase and transmit all electricity fed into the grid (except in emergency situations) – a requirement referred to as 'priority dispatch'.
- *Independence from general budget revenue*: the cost of the FITs is apportioned to the electricity price paid by end-use consumers (*i.e.* the burden falls on electricity consumers rather than on taxpayers) through what is referred to as the 'EEG surcharge'.

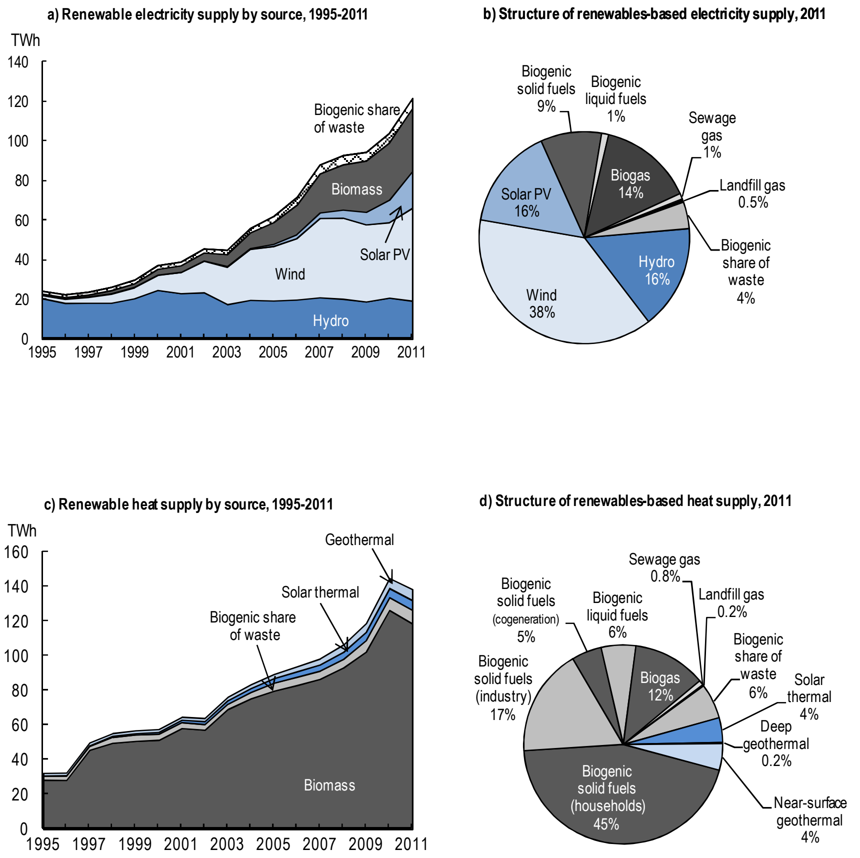
[7] While we do not have exact figures for Germany, it is telling that in France automotive fuel taxation implies a price of carbon in diesel fuels that is about five times less than for petrol fuels (see *OECD Economic Surveys: France 2011*).

[8] For a discussion of environmentally motivated tax relief measures, see OECD (2011a).

[9] For more information see the Renewable Energy Sources Act, also known as the EEG after its name in German, Erneuerbare-Energien-Gesetz, see *www.erneuerbare-energien.de*.

[10] The German electricity market has been deregulated. There are four large electricity utilities (E.ON, RWE, EnBW and Vattenfall) and four transmission system operators (EnBW Transportnetz, Tennet, Amprion and 50 Hertz).

Figure 11. Renewable electricity and heat supply in Germany, by source



Source: BMU (2012), *Development of renewable energy sources in Germany in 2011.*

The combination of these features means that the programme provides a predictable and credible long-term price signal to potential investors. In broad terms, these features are not unique to the German scheme and are included in support programmes of many other countries. However, the greater uptake of the German scheme may be explained by several important differences, including the stability of the scheme and predictability of the price signal provided; the introduction of the grid access mandate in 2004, which reduced investment uncertainty and made it easier for investors to raise the necessary financing; the lack of major administrative barriers in permitting (*e.g.* construction permits), at least with respect to the situation in other countries; and finally, the cross-subsidy (the third bullet above), which insulates the scheme from public budgets, thus increasing its credibility in the eyes of potential investors as well as innovators (R&D being a risky and slow process, a long-term planning horizon is helpful).[11]

[11] There is empirical evidence suggesting that policy uncertainty may have disruptive effects on innovation. For example, Barradale (2008) argues that in the United States, uncertainty over annual renewal of the federal production tax credit discouraged investment in renewables, a position supported by anecdotal evidence in Wiser and Pickle (1998) on wind and solar power. In comparing wind power development in Denmark, Germany and Sweden, Söderholm *et al.* (2007) attribute the relatively slow pace of development in Sweden more to instability in the policy framework than to the level of support, several subsidy programmes having been implemented successively for short periods. More recently, Johnstone *et al.* (2010a) show that differences across countries in stability and clarity of their environmental policies have a negative effect on innovation.

In contrast, FIT programmes in some countries (*e.g.* Spain, the Czech Republic) dramatically downscaled the tariff rates offered (sometimes retroactively) – a phenomenon known as stop-and-go policies. Indeed, Germany has been perhaps the only country without any interruption in its FITs since their introduction in 1991. The cross-subsidy is one of the key factors in the scheme's survival and predictability.[12] Nevertheless, there are critics of the FIT programme because of the costs incurred by German electricity consumers.

The differences between the rates of the tariffs supporting various renewables are intended to reflect the current state of the art in the technology as well as expected market developments that could drive down investment costs (Figure 3; Table A1 in the Annex).

Consequently, designing the tariff structure poses high information requirements on the regulator. In the past, tariff rates were typically revised every four years. However, in 2010 they were exceptionally revised downward several times (Figure 3a) because of a massive increase in solar photovoltaic (PV) installations in 2009 that was largely driven by cost decreases in the Chinese market. The tariffs offered at any given time are guaranteed for 20 years at a defined, decreasing rate. As a result, revised rates apply only to new installations commissioned after the revision. Implications are discussed further below.

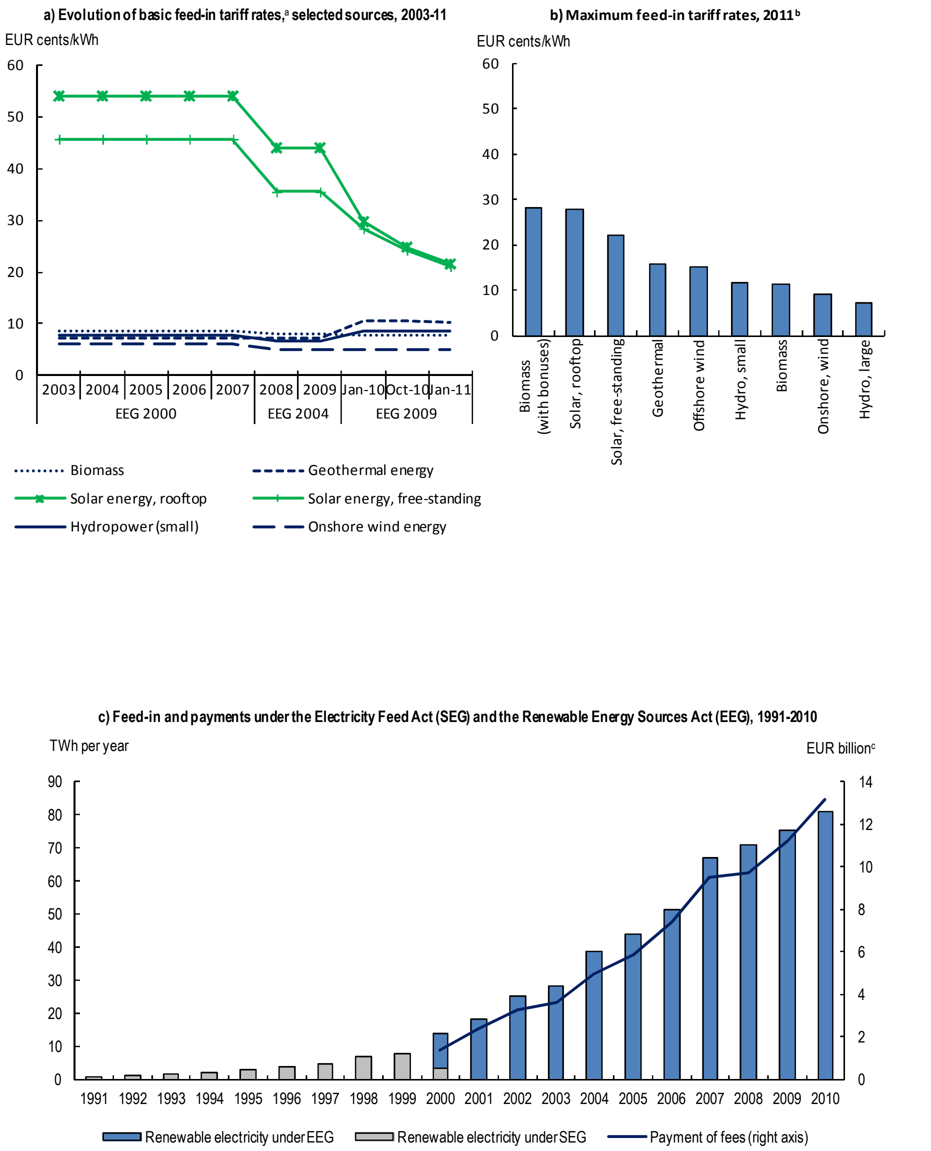
As an alternative to FITs, some countries have introduced portfolio obligations (quotas), also called renewable energy certificates (RECs). Compared to RECs, the German-style FITs have both advantages and potential drawbacks. Some studies have suggested that FIT schemes may be more efficient than other instruments. For example, Butler and Neuhoff (2008) and Mitchell *et al.* (2006) found Germany's FIT programme less costly and more likely to foster investment in renewables than the UK scheme of green certificates (UK Renewables Obligation). Conversely, other studies conclude that the FIT scheme is inefficient and should be reformed (see *e.g.*, Frondel *et al.* 2010; Andor *et al.* 2010). For example, the latter paper has suggested to remove 'priority dispatch' to improve efficiency.[13]

Differentiation of the FIT rates by technology type allows maintaining a degree of diversity in generation sources and thus creating niche markets for technologies in early stages of diffusion. In contrast, REC programmes that do not distinguish between technology types let the regulated utility meet the quota using the least-cost option, such as wind power technology (see *e.g.* Johnstone *et al.*, 2010b). RECs may thus provide insufficient incentives for early-stage technology development. However, setting the

[12] Moreover, introduction of Germany's FITs was based on a broad consensus of political parties. This too may have helped the system remain stable despite changes in government.

[13] It must be noted that the argument between supporters of FIT or REC schemes is, to a certain degree, misleading because the discussion often fails to recognize the differences in the underlying characteristics of the schemes – for example, are the alternative policy instruments of equal ambition (stringency), do they provide an equally foreseeable and credible signal, and do they leave the same freedom to firms to choose the means by which they comply with the policy? In other words, how high would need to be the portfolio obligation for a REC scheme to be of equivalent ambition as a FIT scheme? Answering this question is necessary before one can assess the relative effects of instruments (see OECD 2011b).

Figure 12. Feed-in tariffs for renewable sources



a) Basic or minimal rates offered. The figure provides a highly simpllified summary of the programme, based on information provided in Table A1. For a complete overview of applicable rates, see *www.erneuerbare-energien.de.*
b) Rates offered as of January 2011.
c) At 2010 prices.
Source: Adapted using data from BMU (2011), *Development of Renewable Energy Sources in Germany in 2010.*

differentiated rates necessarily involves picking winners to a certain degree. There is indeed a fine balance between not picking winners and encouraging diversity in renewables penetration.[14]

[14] REC programmes can in principle be designed with multiple quotas differentiated by technology type (maturity), and possibly remunerated with varying amounts of credits. Multiple-quota RECs would be, in many respects, equivalent to differentiated FITs. They would allow management of diversity in renewable sources but, like FITs, would suffer from high information requirements for the regulator. Recently, several countries, including Italy and the United Kingdom, have introduced differentiated REC schemes for solar power. The REC system introduced in Australia specifies ‘multipliers’ to encourage deployment of selected technologies (solar PV, wind, micro-hydro). Insofar as such multipliers vary across technologies, the information requirements for the regulator are identical to those of a FIT.

However, the potentially most significant drawback of the German FIT scheme is the inability of the regulator to directly control how much new capacity investors install in a given year.[15] This may introduce uncertainty because of the direct link between new installed capacity and FIT cost apportionment to the final electricity price. To a certain degree, the electricity price thus may become unpredictable. In countries where the cost was paid from public budgets, this unpredictability made such schemes collapse. While the German programme may be more resistant to such shocks, rising costs and electricity prices could undermine public support of FITs.

This was not an issue until recently, when rapid growth in solar PV installations started to increase the cost apportionment, known as the EEG surcharge. After a fast increase in solar PV capacity in 2007-09, the EEG surcharge increased from 1.20 EUR cents per kWh for 2009 to 2.05 EUR cents for 2010 and 3.53 EUR cents for 2011 (14% of the household electricity price). The German government reacted to these developments by a swift revision of the FITs in 2009-10 that helped contain the speed of the increase. However, while regular evaluation and adjustment of the tariffs is important in keeping the costs in check, such a trial-and-error approach will be increasingly difficult to manage amid fast-developing technology markets and FIT commitments from previous years, which accumulate because the revised tariffs only apply to newly commissioned installations.

While it is important for governments not to add to market uncertainty, they need not try to predict the future better than markets. A predictable signal means putting in place a set of rules. The 2010 FIT revision goes in this direction by introducing the concept of dynamic degression for solar installations: instead of fixed degression rates to determine tariffs to be offered in future years, the degression rates are now linked to market developments. As a consequence, the FITs offered to installations commissioned in future years might increase or decrease by a predefined percentage depending on the volume of new capacity installed in the previous year (see Table A2 in the Annex). Nevertheless, once an installation is commissioned the schedule of FIT payments remains fixed for 20 years.[16]

In short, the German FIT programme has been a very effective policy instrument thanks to a set of incentives that create a well-protected market – a desirable characteristic for technologies in early stages of diffusion. However, this protection comes at a cost of high information requirements on the part of the regulator. And with the continuing rapid expansion of renewables in Germany and elsewhere in the world as the renewables market is scaled up to become a 'mass' market, the risks involved are increasing. This may be a suitable moment to relieve the regulator of the increasingly complex task of FIT adjustments and introduce more flexibility into the scheme, at least for the more mature technologies.

[15] Despite the lack of an explicit cap on new capacity, it is possible that the permitting process may itself allow for an indirect cap.

[16] Traber et al. (2011) predict a significant moderating effect of dynamic degression on FIT cost apportionment.

There are several possible alternatives for introducing greater flexibility into the scheme:

- Offer a schedule of price premiums; that is, a mark-up above the market price of electricity.
- Place a cap on annual growth in new capacity, an option sometimes viewed with scepticism on the grounds that it could undermine one of the basic virtues of the programme – the guaranteed market, which facilitates investors' access to investment financing (although the new dynamic degression approach implicitly creates such a cap).
- Introduce "reverse auctions" (competitive tenders), with potential investors bidding the lowest tariff at which they would be willing to feed renewably-sourced electricity into the grid.

In addition, there may be alternatives for designing the cross-subsidy:

- Currently, the FIT cost apportionment (the EEG surcharge) effectively works as a tax on electricity, providing energy-saving incentives in electricity use. However, unless taxes on other energy carriers increase proportionally, the EEG surcharge will strengthen incentives to replace electricity with forms of energy that may be based on non-renewable fuels. This runs counter the initial objectives of the programme.
- Alternatively, the FIT cost apportionment could be spread over a basket of energy carriers, rather than only on the price of electricity; they could include automotive fuels, especially given the effort to encourage diffusion of electric vehicles.

The latest amendment of the Renewable Energy Sources Act (EEG 2012) includes new elements to strengthen the efficiency and flexibility of the scheme. The dynamic degression for solar installations has been further improved, and an optional market premium and a flexibility premium for biogas have been introduced as supplementary, more market-based elements. These elements, as well as the Act in its entirety, will be closely and regularly monitored by the German government, which will also take into account ongoing scientific discussions on options for the further development and improvement of the FIT programme.

Moreover, EEG 2012 adds new incentives for grid integration of electricity from renewable sources: *i)* it introduces the concept of a "flexibility premium" for electricity generated from biomass (biogas) on a demand basis; and *ii)* it extends the obligation to pay minimum FITs to electricity that is stored prior to being fed into the grid. These measures incentivise the development of flexible back-up and energy storage capacities with the aim to facilitate integration of intermittent renewables into the grid; *iii)* The amended law also defines grid operators' liability in case of grid bottlenecks and thus an obligation to compensate renewable electricity producers for lost income. While this is intended to avoid curtailment of intermittent renewable sources, mandating a zero rate of curtailment is hardly optimal in the absence of other incentives to improve grid flexibility and expand transmission capacity (Benatia *et al.* 2013). (For a related discussion, see Mennel 2012.)

Some studies have expressed concern over the fact that the FIT programme is being implemented in combination with the CO_2 emission cap of the EU ETS. Using multiple policy instruments to target the same environmental externality (greenhouse gas emissions, in this case) might shift abatement to more costly technologies without adding any climate mitigation benefits (Braathen, 2011). In practice, many governments have introduced such complementary policy instruments to facilitate achievement of more ambitious environmental objectives in the longer run, or "dynamic efficiency" gains (Philibert, 2011a; Philibert, 2011b). It should be also emphasised that such policies may target not only CO_2 mitigation but also other environmental objectives ("co-benefits"), such as reducing local air pollution. Moreover, markets for environmental innovation may suffer multiple failures and barriers, necessitating a mix of policy instruments. Still, while the debate remains, the potential interaction of these instruments should be carefully considered.[17]

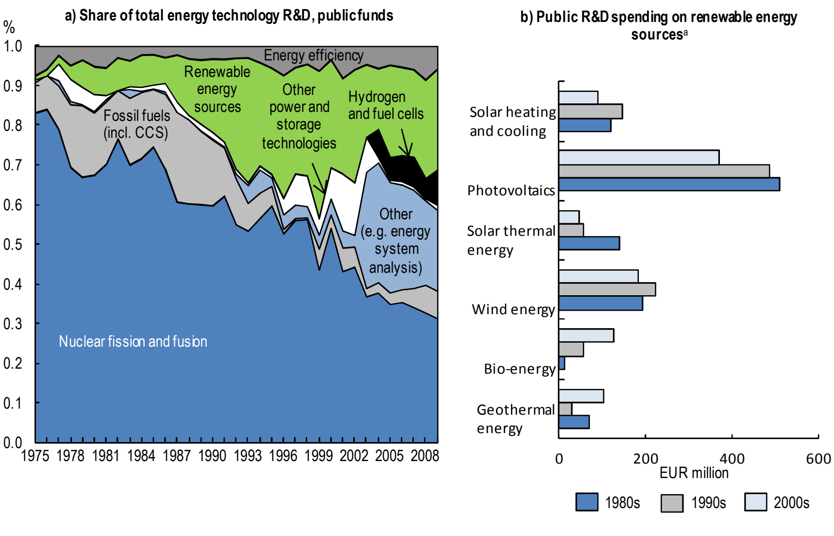
To summarise, governments worldwide have introduced a wide range of policy instruments to encourage development and diffusion of renewable energy technologies, including price-based feed-in tariffs and feed-in premiums, quantity-based portfolio obligations, and competitive bidding schemes (tenders, auctions) that combine price and quantity features; yet others have introduced tax credits. More recently, the so-called 'hybrid' systems have been introduced in several countries – that is, a mix of uniform quotas (REC) with differentiated subsidies (FIT) for selected technologies. To date, feed-in tariffs remain the most widely used. To a great extent, this trend has been driven by the effectiveness of this instrument in Germany. If Germany is to continue offering inspiration as a role model, it is important that her policies be not only environmentally effective but also demonstrably cost-efficient.

While differentiated FIT schemes (or differentiated REC, or some combination of the two) help to achieve diversity in energy generation from renewables, upstream measures – such as targeted differentiated support for technology development – present an alternative and are discussed next.

4.3. Targeted R&D support

In an effort to develop domestic industry, the learning-by-doing benefits of FIT-supported diffusion of renewables have been complemented with targeted R&D support measures. Since the mid-1980s the share of public support for nuclear and fossil fuel R&D has decreased, with priorities gradually shifting to renewables, hydrogen and fuel cells, and other power and storage technologies (Figure 4a). Interestingly, support for energy efficiency R&D has remained stable, although at relatively low levels, probably because of the introduction of a range of other instruments that aim at energy efficiency.

Figure 13. Public R&D spending on energy technologies



a) Cumulated spending over ten years (excluding negligible amounts on ocean energy and hydropower); 2009 prices.
Source: OECD (2011), *OECD Science, Technology and R&D Statistics Database*.

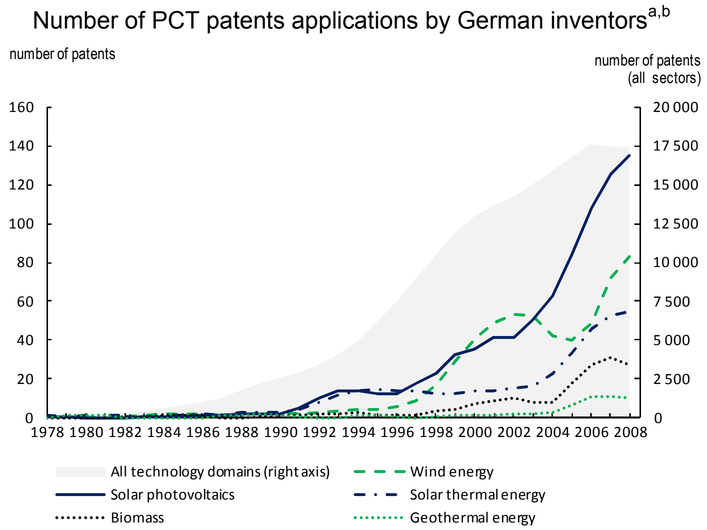
[17] For further discussion, see Chapter 5 in OECD (2012a).

Within renewables, priorities seem to have shifted somewhat over time, with support for wind and solar energy decreasing and emphasis on biomass and geothermal energy increasing (Figure 4b). As a consequence of direct support (R&D grants) and indirect support (learning-by-doing from diffusion), inventive activity in selected renewables technologies has increased sharply in Germany (especially as regards wind and solar) (Figure 5).

The large renewables market created by the FIT scheme allowed development of domestic R&D capacities and mobilized the domestic renewables industry. For example, in 2010 alone, investments in new renewables installations amounted to EUR 26.6 billion (of this total, 73% was directed at solar photovoltaics, 9% at wind power, 10% at biomass heat and electricity, 4% at solar thermal energy, and 3 % at geothermal energy), according to BMU (2011).

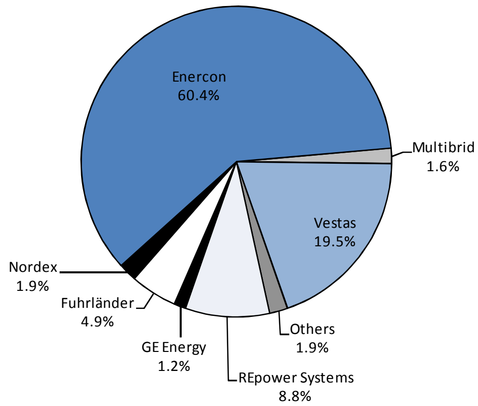
In 2009, Germany became the world's primary market for solar PV installations, absorbing 53% of all new installed capacity worldwide. In wind energy, the German market ranks fourth (5% of all new capacity worldwide). German technology manufacturers have supplied large shares of these markets. Domestic wind equipment manufacturers (including Enercon, Nordex, Fuhrländer, REpower Systems and Multibrid) supplied over 77% of the German market alone in 2009 (Figure 6). They have also benefited from growing renewables markets internationally: as much as 80% of German-made wind power equipment is exported. German solar equipment manufacturers have thus far been less successful, supplying 30-35% of the domestic market, with the rest imported from China, Japan and Spain.

Figure 14. Patenting activity in technologies for energy generation from renewable and non-fossil sources



a) Patent counts are based on patent applications filed under the Patent Co-operation Treaty (PCT) at international phase (EPO designations), using priority date and inventor's country of residence (fractional counts).
b) Three-year moving average data.
Source: OECD (2011), *OECD Patent Statistics Database.*

Figure 15. Wind energy equipment suppliers[a]



a) Share of new installed capacity in Germany up to end of 2009; provisional data.
Source: DEWI (2010), *Wind Energy Use in Germany.*

5. General innovation policy

Environmental policy is a key factor that can encourage development of innovative approaches to reducing negative environmental impacts of economic activity. What is also needed is innovation policy that provides a suitable framework for such innovations.

5.1. Measures targeting positive information spillovers

The German innovation system is characterised by a generally high level of protection of intellectual property rights (IPR) – 4.5 out of 5 on the IPR index in Park and Lippoldt (2008). The Federal Ministry of Education and Research (BMBF) provides public funding for basic and applied research in a number of areas, including efficient energy generation and conversion, energy storage, energy transport and greenhouse gas (GHG) mitigation. The BMBF has established "innovation alliances" intended to co-ordinate and support joint research in companies, universities and extra-university research institutions, and "crowd-in" additional private investment (*e.g.* development of prototypes of a new generation lithium-ion batteries is funded by a EUR 60 million public grant which is to be complemented with EUR 360 million in private research funding (BMBF, 2009)).

When it comes to environmental innovation, the funding of BMBF for applied research is very important. For example, a BMBF framework programme called Research for Sustainable Development is intended to intensify and enhance Germany's position as a technology and market leader in the fields of climate protection and adaptation to climate change, sustainable resource management and innovative environmental technologies. The funding policy activities are concentrated on fields that develop future markets and further enhance the export orientation of Germany. The primary focus is on the challenges posed by climate change and scarcity of raw materials.

Increasingly, international collaboration in research and technology development also plays a role. Table 2 gives German co-invention rates for selected climate change mitigation technologies. As expected, the highest co-invention rates tend to occur in technologies where either the public-good aspect or network effects are most pertinent (*e.g.* GHG capture, grid management, CCS). Conversely, technologies with important private good aspects (and, therefore, high appropriability potential, such as renewables) tend to have below-average co-invention rates. Comparing the co-invention rates in the 2000s and the 1990s (not shown here), it appears that in the case of Germany co-invention tends to be rare in the early stages of technology development but rises with increasing maturity of the technology. Indeed, the only case where co-invention did not increase between the two periods is conventional hydro, which has long been mature.

Table 4. International collaboration in development of selected climate change technologies, 2000-09

Patent applications invented and co-invented by German residents

	Total inventions	Co-invention	Top five OECD partner countries[a]					Top five non-OECD partner countries[a]				
Greenhouse gas capture and disposal (non-CO_2)	152	24%	US	SE	CH	NL	GB	RU	ZA	BY	CN	
Grid management	224	21%	US	FR	SE	GB	DK	RU	VN	CN	AR	
CO_2 capture or storage	190	19%	US	GB	JP	CH	NL	CN	HK			
Biofuels	491	19%	US	GB	CH	NO	MX	CN	ZA	PE	SG	LI
Energy storage	2 699	16%	US	CH	GB	AT	FR	CN	UA	MT	RU	HK
Solar PV energy	2 076	15%	US	CH	AT	FR	GB	SG	LI	RU	IN	MY
All technology fields (total patents)	571 492	14%	US	CH	FR	GB	AT	CN	IN	RU	SG	BR
Hydrogen technology	463	13%	GB	US	CH	FR	AT	RU	CN	HR	IN	
Fuel cells	3 549	12%	US	CH	CA	GB	FR	CN	IN	RU	ZA	HK
Combustion technologies (CHP, IGCC, etc.)	565	12%	CH	NL	US	SE	FR	ZA				
Solar thermal energy	1 395	6%	US	CH	ES	AU	FR	LI	EG	TN	CN	HK
Wind energy	1 885	6%	US	NL	DK	ES	GB	TH	IN	RU	CN	BA
Hydro, conventional	308	5%	CH	US	MX	KR	IT	RU				
Marine energy	91	4%	GB	PL								
Hydro, tidal and stream	143	3%	DK	GB	IE	KR						
Geothermal energy	230	2%	AT	CH	IT							

a) The two-letter standard international codes refer to Argentina (AR), Austria (AT), Australia (AU), Bosnia and Herzegovina (BA), Brazil (BR), Belarus (BY), Canada (CA), Switzerland (CH), China (CN), Denmark (DK), Egypt (EG), Spain (ES), France (FR), the United Kingdom (GB), Hong Kong China (HK), Ireland (IE), India (IN), Italy (IT), Japan (JP), Korea (KR), Liechtenstein (LI), Malta (MT), Malaysia (MY), Mexico (MX), the Netherlands (NL), Norway (NO), Peru (PE), Poland (PL), Russia (RU), Sweden (SE), Singapore (SG), Thailand (TH), Tunisia (TN), the United States (US), Ukraine (UA), Vietnam (VN) and South Africa (ZA).

Source: OECD Project on Environmental Policy and Technological Innovation (*www.oecd.org/environment/innovation)*, based on data extracted from the PATSTAT database.

5.2. Measures targeting availability of factors of production

Germany is facing potentially serious labour shortages. By some estimates, thousands of engineers are needed in the engineering sector alone, and the whole economy will be short of up to 2 million qualified workers by 2020 (New York Times, 2011). The German Chambers of Industry and Commerce found that "32% of companies viewed labour shortages as the single greatest risk to their future prosperity – double the 16% that expressed that concern a year ago" (Reuters, 2011). A similar conclusion was reached in a study reporting that "family-owned German companies see labour shortages as their greatest challenge in the recovery" (Financial Times, 2010).

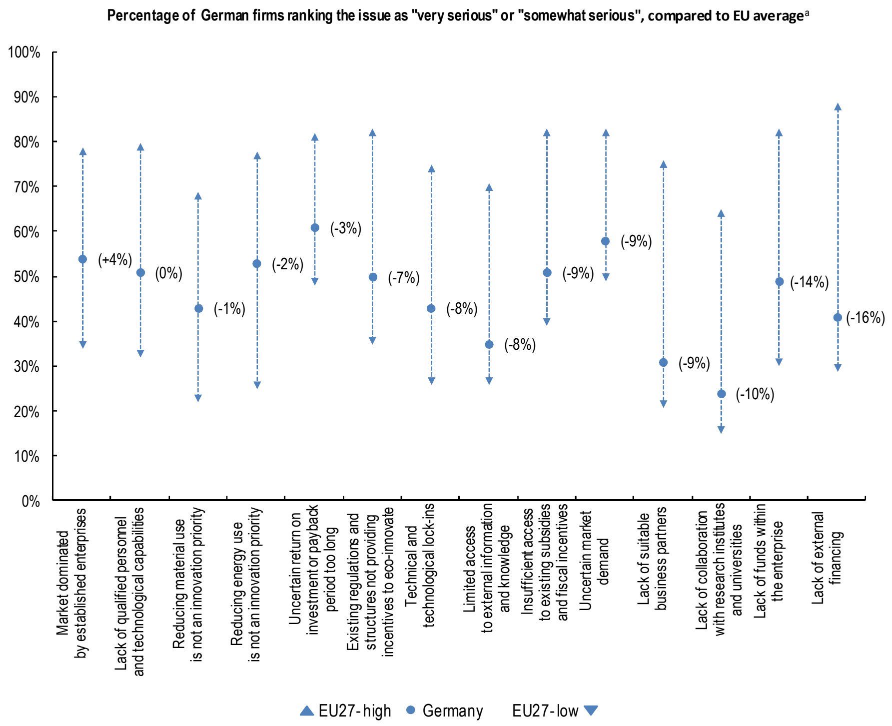
These trends are likely to be aggravated against the backdrop of the demographic trends that Germany is facing. While this is a broader issue, and the shortages do not concern all sectors and professions equally, R&D personnel (especially in science and engineering) and high-skilled workers (manufacturing) are among the categories where the potential shortage is greatest. This is important for the capacity of the country to achieve its ambitious innovation objectives. Maintaining high quality in education, encouraging EU-wide labour mobility and facilitating immigration are some possible approaches.

5.3. Measures targeting market structure and barriers to firm entry/exit

In a recent Eurobarometer survey (EC, 2011), firms in EU countries were asked to assess the importance of various factors as “barriers to accelerated eco-innovation uptake and development”. Figure 7 summarises the seriousness of these barriers as perceived by enterprises in Germany, compared with those in other EU countries. On the positive side, in all but two cases German firms were less apt to consider these factors as barriers than firms elsewhere. The two exceptions were lack of qualified personnel and market dominated by established enterprises. The former confirms the labour market concerns. The latter points to the issue of market power and indicates that German industrial policy might be creating conditions that suit incumbents but are unfavourable to new entrants.

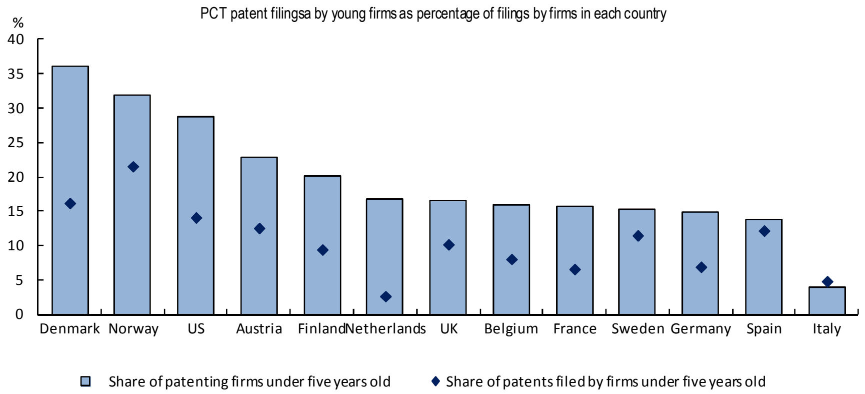
Reducing barriers to market entry and exit is important because newly created firms can be highly innovative. While they tend to account for a large share of patenting in OECD countries, their share is relatively low in Germany (Figure 8). One way of reducing barriers to entry is through simplifying and reducing start-up regulations and administrative burdens. Reducing barriers to exit is also important because firms planning to enter the market may have little idea of their chances of survival and costly exit can discourage them from entering (OECD, 2010a).

Figure 16. Barriers to companies for accelerated eco-innovation uptake and development



a) Results of a Eurobarometer survey carried out over a sample of SMEs in the 27 EU Member States between January and February 2011. The figures in brackets indicate the different perception of eco-innovation barriers between Germany and the EU average.
Source: Adapted using data from EC (2011), *Attitudes of European Entrepreneurs Towards Eco-innovation: Analytical Report.*

Figure 17. Patenting activity of young firms, selected OECD countries, 2005-07



a) Data refer to patent applications filed under the Patent Co-operation Treaty (PCT) by firms with a priority in 2005-07. Counts are based on a set of patent applicants successfully matched with business data. US firms account for 33.5% of overall PCT filings by firms, and 14% of these are applied for by firms under five years old.
Source: OECD (2010), *Measuring Innovation: A New Perspective.*

5.4. Measures to support commercialisation and market introduction

Germany has a wide range of programmes to support market introduction, largely under the aegis of the Federal Ministry of Economics and Technology (BMWi) and the BMBF. These include the High-Tech *Gründerfonds* (foundation), the Business Angels network, spin-off activities of universities and support of new business models. KfW, a state owned development bank, also provides support. In addition, selected environmental priorities are supported specifically, for example through pilot projects backed by the BMU.

Public support of market introduction plays an important signalling role in the ability of private firms to raise further financing (*e.g.* in the form of venture capital). Hence, it is important for such signals to be provided rapidly and at low administrative costs. This is particularly vital for survival of start-up companies and innovative small and medium-sized enterprises (SMEs) (see Box 2).

Box 7. Overcoming the challenges of commercialisation by SMEs

Zenergy Power GmbH is an example of a highly innovative company that grew from a small start-up enterprise into a leader in the field. It specialises in transforming results of basic research on superconducting materials into commercial applications – high-temperature superconductor systems, components and wires. These products have a wide range of potential applications in the metal industry, power generation, power transmission and power distribution networks. According to the company, the benefits of these applications are in increased energy efficiency and performance. For example, a superconductor fault current limiter reduces the risk of blackouts, improves grid reliability and prepares the grid for integration of intermittent renewables; a superconductor generator for a hydropower plant allows a 30% increase in generator capacity; a superconductor generator for a wind energy turbine achieves a 50% reduction in generator losses and allows reductions in turbine size and weight, bringing down offshore wind power costs by 25%; and an industrial metal billet heater achieves a 50% reduction in energy consumption.

Zenergy Power is headquartered close to Bonn and has two other facilities, in the USA and Australia. It employs about 100 people, including 30 to 40 PhD-level researchers in science and engineering. Zenergy's development has been assisted by entrepreneurial managers, a local innovation cluster, support by local authorities and a solid network of potential suppliers, thanks to the broad industrial base in Germany (*e.g.* in metallurgy and metal products). Availability of skilled workers, whether graduates of local universities or staff found by facilitating international mobility, is essential. German and European R&D grants have been key in providing support for developing feasibility studies, scaling up prototypes and eventual pilot projects. In the process, speedy and transparent grant procedures have been helpful. Achieving improvement on this front is important because some form of public support (grants, risk guarantees, product purchase commitments) is essential as a signal in firms' efforts to raise private financing.

5.6. Measures to improve supply-side co-ordination

Markets for innovation frequently suffer co-ordination problems resulting from high transaction costs (*e.g.* between inventors and adopters, between innovators and investors). Governments often encourage development of innovation clusters and industrial networks with the objective to facilitate interaction between the various actors, and hence decrease the 'transaction' costs of (market) co-ordination.

In addition to the role of the federal government, many responsibilities for innovation support in Germany are decentralised to the state (*Land*) level. However, proximity is a double-edged sword, decreasing information asymmetry, on the one hand, but increasing the risk of rent seeking and vested interests of local industries on the other. There are some indications that these risks are present, although it is difficult to assess their significance.

However, in the domain of environmental innovation the need for co-ordination is much greater – not least because the role of government in environmental policy is essential. Such policy co-ordination is all the more important in the case of innovations that involve multiple domains, and hence require co-ordination between several ministries. The *German Water Partnership* (Box 3) and the *National E-Mobility Platform* (Box 4) are examples of such measures. Due to the importance of co-ordination between environmental and innovation policies, Section 6 discusses these issues in greater detail.

Box 8. The German Water Partnership

The German Water Partnership (GWP) is an innovation platform initiated by the German government in 2008. It brings together stakeholders from research, industry and civil society, pooling resources and activities. The GWP helps German businesses achieve a stronger long-term position in the export market for the water sector by allowing them to present themselves as a unified group. Benefiting from the contacts and networks of its more than 400 individual members by exchanging information and experiences, the GWP helps promote Germany's expertise in the water sector at a global level.

Source: German Water Partnership, *www.germanwaterpartnership.de.*

6. Policy co-ordination

Co-ordination between different branches of government (ministries, agencies) or different levels of government (federal, state, local) is important in order to achieve coherence of incentives provided by a package of policy instruments, along with development of the necessary infrastructure.

In some countries, this is addressed by creating "super-ministries" in charge of a range of issues (economy, environment, research and technology). While such an approach can internalise co-ordination problems, it is not without risks. There is a trade-off between splitting responsibilities (and formal co-ordination) and merging responsibilities (and thus informal co-ordination). The big question is to what extent institutional division is a useful tool or a barrier to reconciling conflicting policy objectives. In Germany, the former approach has been adopted, resulting in a range of co-ordination efforts (see also Rennings 2011).[18]

For example, the 2008 *Master Plan on Environmental Technologies*, a step towards implementing the over-arching *High-Tech Strategy for Germany* (EUR 2.5 billion of federal funding), was initiated jointly by the BMU and the BMBF. It was designed as a cross-sectoral environmental and innovation policy measure. Its aim is to speed up the innovation process from the research stage to the development of national and international markets in environmental technologies. It comprises a range of measures aimed at improving the framework conditions for innovation (promoting basic research and its conversion into applications, assisting market introduction, providing targeted support for SMEs and assisting diffusion of these technologies in national and international markets). The *German Water Partnership* is a component of the Master Plan on Environmental Technologies (Box 3 above).

6.1. Co-ordination between branches of government

6.1.1. The case of advanced transportation

Another component of the Master Plan is the Electric Mobility Development Plan, a recent step in efforts to encourage development of alternative-fuel vehicle technologies in Germany (Box 4). E-mobility has attracted a great deal of attention, but it is important for the government to try to prevent technology lock-in by avoiding a focus on too narrow a set of options. As a large industrial country, Germany is experimenting with a wide range of transport-related technologies, including new fuels (biofuels), conversion technologies (fuel cells), storage (batteries), charging devices and propulsion technologies (electric car drive trains). Overall, the government has committed up to EUR 2 billion in public support for various research, development and demonstration programmes. However, it is difficult to assess the relative magnitudes of resources devoted to these areas, as few R&D data are publicly available on support directed at the automotive sector as a whole. Nevertheless, there is evidence that inventive activity in electric and hybrid drives has picked up recently in Germany (Figure 9), though it remains modest compared to emission reduction efforts aimed at conventional drives (Figure 1b).[19]

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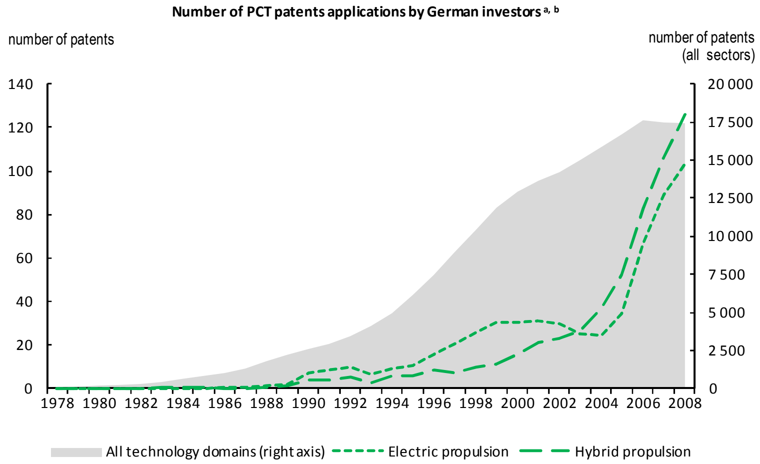
[18] Examples of 'gaps' in policy co-ordination abound. For instance, origins of the large 'tariff deficit' accumulated by Spanish power utilities can be traced to the wedge driven between environmental policy (generous feed-in tariffs for renewably-sourced electricity) and economic policy (regulation of end-use prices for some groups of electricity consumers).

[19] The German government believes short- and mid-term GHG mitigation in motorized individual transport will heavily depend on advances in the conventional vehicle sector, as such vehicles are expected to dominate new car sales at least until 2030.

Figure 18. Patenting activity in electric and hybrid motor vehicle technologies



a) Patent counts are based on patent applications filed under the Patent Co-operation Treaty (PCT) at international phase (EPO designations), using priority date and inventor's country of residence (fractional counts).
b) Three-year moving average data.
Source: OECD (2011), *OECD Patent Statistics Database.*

Box 9. National Platform for Electric Mobility

The National E-Mobility Platform is a key element of the Electric Mobility Development Plan. It was established to facilitate inter-sectoral dialogue involving four federal ministries[20] and other stakeholders. Current priorities include major investment in battery R&D (EUR 4 billion by 2013, including EUR 500 million of public support), development of electric car drive trains, support for education and qualification (especially in electrochemistry and power electronics) and promotion of spillovers through networks and demonstration.

A key objective is development of the necessary infrastructure for a large-scale introduction of electric vehicles in Germany. This includes a co-ordinated deployment of renewables-based power supply and intelligent charging of batteries to achieve twin objectives: the stabilisation of the electricity grid and the integration of intermittent renewable energy sources. The goal is to have 1 million electric vehicles on German roads by 2020 and 6 million by 2030.

In addition to environmental objectives, the e-mobility plan aims to achieve industrial policy objectives so as to keep a major part of the value added in Germany by using the key competences of German industry along the whole value-added chain (research, development and production).

Another important goal is international standardisation (in terms of legal and technical norms) of the charging infrastructure and associated vehicle components so as to reduce overall infrastructure investment costs and increase consumption spillover effects.[21]

When it comes to supporting diffusion, no financial incentives for the purchase of electric vehicles (EVs) are currently in place. This most likely reflects the dominant role of foreign EV suppliers. Rather, non-financial incentives are being considered, such as free parking for EVs, dedicated lanes and free battery charging. Until recently, government procurement programmes were missing, even though a single big buyer is exactly what is needed given the important network effects involved (positive demand spillovers) (see OECD, 2003). Following the adoption of the Government Programme for Electric Mobility in May 2011, the German government set a procurement goal of 10% of EVs in government fleets. Nevertheless, the focus of the programme remains on R&D support, as the government believes this will

[20] Including the BMU, the BMWi and the Ministries of transport and of building and urban development.

[21] For more information, see NPE (2010) or *www.bmu.de/english/mobility/doc/44799.php*.

help lower costs and improve technology more effectively in the current phase than fiscal incentives for consumers.[22]

Overall, the transport policy mix appears rather incoherent. On the positive side, the vehicle ownership tax is now differentiated by vehicle CO_2 emissions, and a preferential VAT rate on rail transport as well as road charging for heavy duty vehicles has been introduced (UBA, 2011). However, a number of issues remain unresolved and provide incentives that run counter to Germany's stated goals. This includes tax treatment of company cars used for private purposes (which account for a large share of the car fleet, especially in the high-emission bracket) that effectively amounts to a permanent subsidy for the car industry; a car allowance for commuters; the tax treatment of automotive fuels (a lower tax rate on diesel despite its higher carbon content); and, insufficient use of measures targeting traffic volume (*e.g.* road tolls, kilometre charges). In addition, the 2008 scrapping programme largely wasted EUR 5 billion by supporting undifferentiated car purchases (the only criterion was car age). Such policy incoherence is probably a result of the long history of industrial policy aimed at German car manufacturing, which has created powerful incumbents with vested interests in opposing change. This undermines the potential for effectiveness and efficiency of the sectoral policies implemented so far, as well as the environmental policy agenda more broadly.

6.1.2. The case of renewable energy

In many ways, renewables and advanced transportation policies introduced in Germany represent two alternative policy mixes with characteristics of 'technology forcing'. They both employ a combination of diffusion incentives and R&D support measures (on top of the more general taxes on energy carriers, etc.) and they both face network externalities that may potentially hamper diffusion of the respective technologies. However, while diffusion incentives have historically played a more central role in renewables policies, electric vehicle policies have been more R&D-driven with diffusion incentives only forthcoming. This is partly because, unlike the renewables industry, the car industry was already well-developed in Germany. Another difference is that for electric vehicles the network externality (arising out of positive consumption spillovers) places the greatest constraint for diffusion at low levels of penetration, while for renewables the network externality only applies to intermittent energy sources (*e.g.* wind, solar) and it rises with increasing levels of penetration. That is why German policies directed at electric vehicles need to address infrastructure needs at early stages of diffusion, while German renewables policies have yet to start fully addressing the infrastructure challenge.

In particular, as the penetration of intermittent renewable energy sources increases it is necessary to encourage investments in electricity transmission capacity, provide incentives for dispatchable power plants to remain in the market and serve as 'back-up' sources of balancing power, encourage energy systems integration and demand management as a means to help balance electricity supply and demand (Box 5), reduce existing constraints on trade in electricity between grids and across borders (see OECD 2012b and OECD 2012c for a discussion of constraints that arise out of renewable energy support policies), and encourage continued innovation in advanced energy storage and grid management technologies (Johnstone and Haščič, 2012). Such policies have the potential to help achieve ambitious renewables targets at lower costs. (See Benatia *et al.,* 2013 for an analysis of the importance of increasing grid capacity and system flexibility for the productivity of intermittent renewable power plants.)

[22] For a related discussion, see Haščič and Johnstone (2011) who compare the effects of several alternative policy instruments on inventive activity in alternative fuel vehicle technologies in OECD countries and find that fuel taxes have had primarily an impact on innovation in technologies that are close to being competitive (hybrid propulsion), while performance standards were necessary to encourage early-stage technology development (electric propulsion).

In general, policy-makers should consider introducing incentive-based measures, rather than mandates, which would allow achieving these objectives more cost-efficiently. For example, the 'priority dispatch' as implemented in the German FIT scheme for renewables effectively imposes a zero rate of curtailment of intermittent sources – a policy that is unlikely to be optimal, and might become increasingly costly as penetration rates continue to rise.

In addition, given the important network effects in the energy sector and the monopolistic nature of electricity transmission, addressing these challenges also requires co-ordination between environmental policies, energy policies, transport policies and local land use planning. Consideration should be given to strengthening the role of the independent network regulator (the Federal Network Agency) so that it oversees grid extension and investments in grid stability, especially where co-ordination with local authorities is essential to deal with land use planning and "not-in-my-backyard" issues.

Box 10. Mini E-Berlin powered by Vattenfall

Installed capacity of intermittent renewables (wind and solar) in Germany is expected to increase from 43 GW in 2010 to about 100 GW sometime after 2020. There are currently few alternatives for closing the growing gap in intermittency of renewables; the only realistic option is investment in pumped storage capacity at home and abroad (chiefly in Norway, Austria or Switzerland). Alternative energy storage facilities based on compressed air or flywheels are still under development. Without the appropriate technologies, a large-scale introduction of electric vehicles could pose a serious threat to grid stability. To avoid such complications, smart charging systems could turn threat into opportunity.

Vattenfall Europe AG has developed charging stations that allow intelligent charging to balance demand against electricity supply. A small fleet of electric Mini E-Berlin cars, a model developed by BMW, is being field tested in Berlin to determine the most suitable locations for the remotely operated charging stations, along with corresponding pricing options. According to Vattenfall, users will be able to buy a portable charger for the home or use public charging stations. In both cases, a user will specify the speed and duration of the charging procedure. Charging will be price-differentiated to provide incentives for charging during periods of excess supply (peak wind and off-peak load, also called "wind-to-vehicle") and for serving as a power source during periods of excess demand (off-peak wind and peak load, or "vehicle-to-grid"). Such a system allows optimising demand and supply by setting priority rules at spots with excess demand (local load management). However, obstacles remain, including municipal land use issues such as whether to have dedicated public parking space exclusively for EVs.

The charging stations can be used by e-vehicles of all kinds and by customers of different energy suppliers. Vattenfall intends to sell its charging equipment not only to individual car owners but also to electricity distributors as a means of improving grid stability by cutting peaks and shifting demand on hourly and daily fluctuations. A study at Humboldt University in Berlin calculates that the opportunity costs are high, estimating that, if all 45 million cars in Germany were electric, the maximum daily load (the volume of power transmitted by the grid) would need to increase by a factor of 2.5.

6.2. Co-ordination between levels of government

In Germany, environmental policy making is centralised at the federal level while policy implementation and enforcement are delegated to state and local authorities.[23] This is a special case of the principal-agent problem: there are no direct incentives for the central government to design policies in a manner that allows cost-effective implementation (*i.e.* low administrative and monitoring costs), while the budget-constrained local authorities, that are charged with implementation and enforcement, have no direct influence over policy design. This has not only an array of fiscal implications, but also important innovation implications, as poor enforcement of a policy undermines its innovation incentives. It would seem that the two possible solutions are to improve co-ordination between different levels of government with the aim of designing more cost-effective policies or to design self-funded programmes with innovation incentives, such as Sweden's NO_x charge (OECD, 2010b).

[23] For further discussion, see Chapter 2 in OECD (2012a).

7. Concluding remarks

Germany has successfully implemented several environmental policies by translating ambitious objectives into a predictable and long-term policy signal. While ambitious environmental policy has been a key factor, the performance is underpinned by a strong innovation framework as well as ability to co-ordinate policies across sectors and levels of government. In many cases, environmental objectives are cross-cutting in nature and achieving them requires co-ordination to ensure that policy instrument mixes provide a coherent set of incentives and address related market barriers.

Germany's rich experience with policy-induced environmental innovation provides inspiration for other countries. In turn, Germany herself should actively promote this experience to nurture environmental policy-making processes internationally, not least because regional (EU-level) and foreign environmental policy increasingly influence the direction of innovation domestically. However, for these processes to be successful, Germany needs to demonstrate that her policies are not only environmentally effective but also cost-efficient. Introducing more incentive-based policy mechanisms and reinforcing the culture of policy assessment would be important steps in this direction.

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ANNEX

OVERVIEW OF TARIFFS UNDER THE RENEWABLE ENERGY SOURCES ACT (EEG)[24]

Table A1. Tariffs according to year of commissioning in cents per kilowatt-hour

	EEG 2000	EEG 2004	EEG 2009			EEG 2012
	Commissioned in 2003	Commissioned in 2008	Commissioned 1 January 2010	Commissioned 1 October 2010	Commissioned 1 January 2011	Commissioned 1 January 2012
Biomass (without bonuses)	8.5 - 10.0	7.91 - 10.83	7.71 - 11.55	7.71 – 11.55	7.63 - 11.43	6.0 - 14.3
Biomass (with bonuses)	-	9.91 - 25.01[a]	9.17 - 28.38[a]	9.17 – 28.38[a]	9.08 - 28.10	8.5 - 22.3
Geothermal energy	7.16 - 8.95	7.16 - 15.00	10.40 - 15.84	10.40 - 15.84	10.30 - 15.68	30.0 (25.0)
Solar energy (rooftop)	54.0 - 57.4	43.99 - 46.75	29.70 - 39.57	24.79 - 33.03	21.56 - 28.74	18.33 - 24.43
Solar energy (free-standing)	45.71	35.49	28.43	24.26 - 25.37	21.11 - 22.07	17.94 – 18.76
Hydropower (large > 5 MW)	6.65	3.54 - 7.36	3.47 - 7.22	3.47 - 7.22	3.44 - 7.15	3.40 – 5.50
Hydropower (small < 5 MW)	7.67	6.65 - 9.67	8.65 - 11.67	8.65 - 11.67	8.65 - 11.67	6.30 – 12.70
Wind energy (onshore)[b]	8.80 (6.0)	8.03 (5.07)	9.11 (4.97)	9.11 (4.97)	9.20 (5.02)	8.93 (4.87)
Wind energy (offshore)[b]	-	8.92 (6.07)	15.0 (3.5)[c]	15.0 (3.5)[c]	15.0 (3.5)[c]	15.0 (3.5)

Notes:

a) The upper limit of the interval takes account of all bonuses that are accumulable in principle. In practice, such tariffs are only paid in exceptional cases. Tariffs of up to EUR 0.25 per kWh for 2010 are realistic (small biogas installation with CHP, energy crops and manure use).

b) The basic tariff for wind energy is given in brackets. The increased initial tariff is paid for at least five years. This period may be extended depending on the reference yield.

c) Increased initial tariff (13.00) + quick-starter bonus (2.00). Increased initial tariff for offshore wind energy is paid in the first 12 years.

d) The basic tariff for geothermal energy is given in brackets. The increased tariff is paid for utilisation of petrothermal technology.

Source: Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (*www.erneuerbare-energien.de).*

24 Based on information available on 19 January 2012. Tariffs for electricity generated using landfill gas, sewage gas, mine gas and biowaste gas are also specified in the law but are not listed here.

Table A2. Degression of tariffs, % per year

	EEG 2000	EEG 2004	EEG 2009			EEG 2012
	Applicable in 2003	Applicable in 2008	Applicable on 1 January 2010	Applicable on 1 October 2010	Applicable on 1 January 2011	Applicable on 1 January 2012
Biomass (without bonuses)	1.0%	1.5%	1.0%	1.0%	1.0%	2.0%
Biomass (with bonuses)	-	1.5%	1.0%	1.0%	1.0%	2.0%
Geothermal energy	n/a	1%	1%	1%	1%	5% (0%)[c]
Solar energy (rooftop)	5%	5%	8-10% (+ 1%)	16%	9% (+ 4%)[a]	9% (+ 6%)[d]
Solar energy (free-standing)	5%	5%	10% (+ 1%)	11%	9% (+ 4%)[a]	9% (+ 6%)[d]
Hydropower (large > 5 MW)	n/a	10%	1.0%	1.0%	1.0%	1.0%
Hydropower (small < 5 MW)	n/a	n/a	n/a	n/a	0%	1.0%
Wind energy (onshore)	1.5%	2.0%	1.0%	1.0%	1.0%	1.5%
Wind energy (offshore)	-	2%	0%	0%	5% (0%)[b]	7% (0%)[c]

Notes:

a) If the new capacity installed in the previous year exceeds 6 500 MW.

b) The 0% rate applies until 2014.

c) The 0% rate applies until 2017.

d) If the new capacity installed in the previous year exceeds 4 500 MW.

Source: Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (*www.erneuerbare-energien.de).*