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Energy Efficiency and Renewable Energy Supply for the G-7 Countries, with Emphasis on Germany

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Energy Efficiency and Renewable Energy Supply for the G-7 Countries, with Emphasis on Germany

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Abstract

This paper discusses structure, impact, costs, and efficiency of renewable energy supply in the eight largest advanced economies (the G-7 plus Spain), with focus on Germany. Renewables production costs are compared to benefits, defined as reductions in net carbon emissions; technological innovation, and increased energy security. The latter part of the paper centers on Germany, the main European producer of non-traditional renewables. We question whether the level of subsidies can be justified, relative to other means to increase energy security and reduce carbon emissions. We also find an excessive emphasis on current productive activity, relative to development of new technologies.

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I. INTRODUCTION

This paper deals with issues at the intersection of climate and energy policy. A prominent issue in the current climate policy debate is to determine the balance or choice between policies that serve to limit the emission of greenhouse gases (GHGs), such as carbon taxes or cap-and-trade schemes, and policies where the direct aim is to promote renewable alternatives to GHG emissions-generating energies, thus potentially contributing to reducing such emissions.

Two sets of externalities are involved in this discussion. The first set is global negative externalities caused by GHG emissions providing few immediate incentives for individual countries—let alone individual emitters—to reduce these, and leading to excessive emissions on a global scale. Secondly, rents due to technological development of new (renewable) energies are often difficult or impossible to appropriate for individual inventors, thus leading to sub-optimal technology investments.

Recent developments have seen movements on both fronts. The limitations on GHG emissions imposed by the Kyoto Protocol have forced some countries to take rather strong actions in their attempts to fulfill the Protocol. For renewable energies, activity has been particularly high in the EU area, with Germany as a "showcase" with particularly heavy engagement in the sector, and with a significant production of renewable energies.

A number of questions arise in this discussion. One of these is whether the support given to renewables from the respective government is "worth it."

A main purpose of this paper is to add to the debate surrounding the latter question, in particular, by contributing to the analysis of "total costs to society" of renewables support, including an analysis of the true cost of reducing carbon emissions by substituting out an equivalent amount of fossil fuels.[1] This is difficult, for several reasons. First, the costs of climate change themselves, and the benefits of efforts to avoid it (such as the efforts of developing renewable energies), are highly uncertain. Secondly, it is conceptually difficult and demanding to get a complete overview of all cost components that go into the process of producing renewables, and in calculating the overall rate of public support to these. Thirdly, there are great inherent uncertainties embedded in the processes of renewables research and development, where an important component of benefit is the technological development and learning that goes into the renewables production process. By their nature, the future renewables technologies, supported through subsidies, are of course unknown, and their cost and production potential thus unknown.

From a welfare point of view, public support to renewable energy, so as to supply and replace fossil fuels in the overall energy balance, can be justified for three main reasons.

[1] The paper will thus not address the wider issue of efficient energy policy, including choice and strength of policy instruments apart from renewables production and support.

The first reason is related to the focus, in today's energy policy, on reducing overall carbon emissions from energy use. Renewable energy is in its nature "carbon neutral" in the sense that its use does not, on net, lead to an increase in global carbon emissions.[2] Thus, being able to replace fossil fuels with renewable energy will bring benefits in terms of overall reductions in carbon emissions.

Note, however, that this is a separate argument for direct public subsidy only when fossil fuels are not properly taxed for their carbon emissions. When they are taxed, the tax "takes care of" this externality and there is no further argument for subsidy of renewables.[3]

The second reason is the possibility of technology spillovers leading to reduced energy production costs elsewhere, due to R&D efforts for their development, and learning-by-doing effects of renewable energy production activity. Such benefits are not likely to be (fully) appropriated by the developer, thus leaving such development activity generally underfunded from a social perspective. This gives a separate possible reason for public support, independent of (but enhanced by) the ability of renewable energies to reduce overall carbon emissions.

Several countries within the European Union (EU) are now vigorously pushing renewable energy developments. The EU has set as an indicative target for 22 percent of all electricity generation in the EU to be based on renewable energy by 2010 (against 14 percent today, mainly hydropower based).

The third main reason, applying to energy-importing countries, is the simple need for importers of fossil fuels to reduce their fuel demand and thus import need. Such demand reduction can be achieved by either reduction in overall energy demand, or through substituting renewables for fossil energy. Although not all countries are equally suitable for all types of renewables production (the amount of sun and wind, relevant for solar and wind power yields, vary by natural conditions, and so does biomass yields), all countries do have a variety of options for such production, which may be tempting to use in reducing the dependence on imported fossil fuels such as oil and natural gas.

This main factor behind this argument is that security of energy supply is valuable for any individual country. The international supply of energy goods may be interrupted for a variety of reasons, putting a true economic cost on the lack of alternative supply. Overall supply security is likely to be underprovided by private agents, thus creating a justification for public support of alternatives that reduce supply dependence.[4]

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[2] We are ignoring the issue that some renewable energies, in their production, require the use of fossil fuels, as is the case for biofuels.

[3] Note, however, that there may be other environmental externalities associated with fossil fuel use, such as local air pollution and water contamination, that may be avoided when using renewables, thus giving reason for higher taxes to fossil fuels and/or greater subsidies to renewables, than those justified by the difference in carbon emissions alone.

[4] An illustration of the related public benefits of additional energy security is represented by the Strategic Petroleum Reserve in the United States, which is maintained at public expense, and is designed to maintain a

(continued…)

These three arguments are all compelling justifications for public subsidies to renewables. It is more difficult to arrive at particular numbers for optimal support. As a matter of basic principle, this support should be at least at the level of the imputed value of the net carbon replacement when fossil fuels are replaced by renewables (including value of other reductions in environmental damage). But the upper limit is difficult to decide, in particular, since the net benefits in terms of R&D are unknown, in terms even of their order of magnitude.

These justifications for subsidizing renewables must be balanced against subsidy costs. Two types of such costs are particularly important: a) the foregone tax revenue that would otherwise be available for public-sector purposes (including public investment or other spending or the reduction of distortive taxes; and b) energy subsidies (for traditional or nontraditional energies) tend to stimulate overall energy demand—a better overall policy would tend to discourage it. The case for subsidies is thus often not clear-cut, but must be studied carefully in each individual case.

There is a final, strategic, reason why some countries wish to reduce their energy demand, namely, in order to exercise market power in markets for internationally-traded fossil fuels, primarily petroleum, where resource rents are vast.[5] In particular, major petroleum-importing countries may affect petroleum market prices through demand reduction, taxation or supply from alternative sources.[6] This argument, however, gives less of a welfare reason for support to renewables, at least not from a global perspective.

In the following, we will, in Chapter II below, consider some issues common for all advanced economies, focusing on renewables supply, the effectiveness of policy in reducing carbon emissions, and a more specific discussion of biofuels. In Chapter III we will focus on some issues specific to Germany, in particular, the electricity sector. Chapter IV concludes.

I. Renewables in Advanced Economies: General Issues

A. Introduction

Renewable energy comprises several different sources.[7] Two major renewable sources exist within more traditional energy supply in the G-7 group and elsewhere, namely, biomass (mainly wood) for heat generation, and hydropower for electricity generation. More recently, other

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reserve of at least 30 days of average petroleum consumption. Reducing the daily consumption of petroleum would permit a reduction of this reserve, and thus reduce the public costs of maintaining it.

[5] The resource rent is, essentially, the difference between the market price and the cost of extraction. It is generally assumed that the average extraction cost of oil today is in the range US$15-20 per barrel (and generally lower in exporting countries), which leaves an overall gross rent in excess of US$60 per barrel (with a current market price exceeding US$80 per barrel).

[6] See Strand (2007) for the basic argument, and a technical analysis.

[7] For a useful general reference on renewables policies and production, see the International Energy Agency website, at http://www.iea.org/textbase/pamsdb/grindex.aspx.

renewable energy sources have become important in advanced countries. Of particular importance are photovoltaic solar-cell electricity generation (PV); biofuels production and heat/electricity generation (CHP) based on biomass; and wind power for electricity production. In this section we will discuss some major features of supply and carbon replacement for renewables in advance countries.

Subsidies to renewable energy can be provided in several ways. We will mention here some important issues that are of relevance to the ensuing discussion.

First, subsidies can be *paid directly to renewable energy producers*, in lump-sum fashion or depending on location.

Secondly, subsidy disbursements can be *tied to renewable energy outputs*, e. g., as a fixed support per unit of output for a specific type of renewable energy produced.

Thirdly, *current factor inputs* can be supported. A leading example is for biofuels, where the raw material typically comes from the agricultural sector where outputs may be subsidized, as is the case both in Europe and the United States.

Fourthly, *support to capital* can and is often provided, typically in the form of subsidized financing, but also as direct support to capital purchase.

Fifthly, renewable energy production can be supported by *guaranteed producer prices*, over a shorter or longer time, that are at least at the level otherwise achieved in the respective markets (and generally higher). A prominent example, used in several countries, is so-called feed-in-tariff schemes.

A sixth form is to provide support implicitly in the form of *avoided taxes*, when taxes are paid on other energies that can be replaced by renewables. Typically, such subsidies do not lead to a direct disbursement, but rather to loss of potential government revenue. This type of support is particularly important for motor fuels in Europe, where excise taxes are high. It can also lower the cost of capital, in the form of corporate tax credits, which are applied widely to renewable sectors, also in the United States.

The seventh and last point to mention is government support to renewable energy developers' and producers' *research and development (R&D) efforts*. Support to basic research is most easily distinguishable from the categories above (in particular, support to "development" is hardly distinguishable from output or input support). Research support is provided in several ways, some going directly to producing firms. But it also takes the form of regular research programs (such as, the EU Framework Programs for Research), where research funding is provided in competitive processes and where particular program areas (in particular renewable energy development) have their own funding basis.

B. Support to and Supply of Renewables in Major Advanced Countries

We now consider main types and costs of renewables support, by major country, rather briefly.[8]

The United Kingdom provides capital grant support for offshore wind and small-scale technologies up to a specified budgetary limit, with the money coming from central government funds. A large scheme for supporting electricity production from renewable sources, funded through increases in power utility rates (10 percent by 2010, increasing to 15 percent by 2015), exists for all types of renewable electricity production. Estimated cost is GBP1 billion by 2010 for the certificate scheme.

Germany is probably the G-7 country that does most overall to support renewables developments today. Renewables (apart from hydropower) now make up 6.4 percent of overall energy consumption in Germany.[9] A number of different incentive mechanisms exist, including grants, feed-in tariffs,[10] reduced-rate loans and preferential tax treatment schemes, which all apply to heat generation from biomass, solar power, geothermal energy, and wind power. These items will be detailed in Chapter 3 below.

Other European G-7 countries have at the moment less ambitious schemes. **France** also has a feed-in tariff scheme for delivered electric power produced from renewables, but with limited effect so far. In **Italy**, public efforts to support renewables production are also limited. A feed-in tariff scheme, with rates of about €0.45 per KWh, exists since 2002; it is in particular less generous than the German scheme (discussed below) and has so far had only a small effect on supply. Some level of technology-specific capital support is also available in Italy.

Japan applies a range of support measures, with a strong focus on small-scale solar technology. In 2002 (last available figures), total central government support was ¥145 billion. A small portfolio standard scheme is in place (1.35 percent by 2010).

In **Canada**, renewables support is handled mainly on the province level, with a wide variety of approaches. But, on the whole, the support for renewables outside of traditional sources (hydro for electricity and biomass for heating) is small. This may, of course, be due to the very large energy production from these traditional sources today (as is clear from Figure 1 and Table 2), and the fact that the potential for increased production is still substantial here. It is clear that

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[8] The information on country-specific measures has been provided to us by Andreas Biermann of the International Energy Agency.

[9] See German Ministry for the Environment, Nature Conservation, and Nuclear Safety (2006). The share of renewables in electricity generation is 10.2 percent, in heat generation 5.4 percent, and in fuels 3.6 percent.

[10] Feed-in tariffs, in Germany and elsewhere, are schemes whereby electricity producers are guaranteed certain minimum prices for their delivered electricity (and with security of delivery), for a minimum future period, which can run up to 20 years. Electric utilities are then required to purchase the delivered power at the preset prices, and are, in turn, usually allowed to charge any price increases to utility customers.

these are still far less costly sources than more exotic alternatives such as solar, wind and geothermal energy.

In **the United States**, the energy policy act of 2005, together with agricultural subsidy policies, imply substantial favors to renewable energy developments.[11] Biofuels (bioethanol and biodiesel) are particularly favored. The repeal of federal and local fuel excise taxes for alcohol-based fuels and biodiesel alone correspond, according to Metcalf (2006), to an implicit subsidy amounting to approximately US$12 billion for the period 2007–11.

The United States also applies a number of corporate tax credits, which in effect serve to make wind- and bio-based power generation competitive with traditional electricity generation. Solar-powered electricity generation receives considerable favors, yet remains far from competitive with other forms of electricity generation, due to its generally much higher cost level. There is additional support of renewables at the state-level (as in Canada), which can be very diverse.

Note, however, that the energy policy act, combined with several other policies, imply substantial direct or implicit subsidies also to traditional fossil fuels, which makes the situation in the United States different from that of most European countries (and less favorable for renewables). Given these other supports to traditional energy, it becomes necessary to support renewables much more directly (and not just indirectly in the form of avoided fossil-fuel charges and taxes), in order to achieve the same level of renewables supply.

Figure 1 and Table 1 below indicate the importance of renewable energies, for the G-7 countries and Spain, in the most recent year for which we have comprehensive data (2004). We see that renewables as a whole are quite significant in some countries. In particular, in Canada they represent about 60 percent of total electricity supply and 35 percent of overall energy supply. But here (and in similar cases) hydropower for electricity generation makes up the bulk (non-hydro's share in electricity in Canada is less than 2 percent).[12]

Since in most of these countries the major part of their hydropower potential has already been exploited, the most interesting numbers are for renewables excluding hydro, where numbers are moderate. The highest overall shares in energy were, in 2004, for France (4.7 percent) and Spain (4.4 percent), while Germany had a more moderate 3.9 percent.[13] These numbers have increased

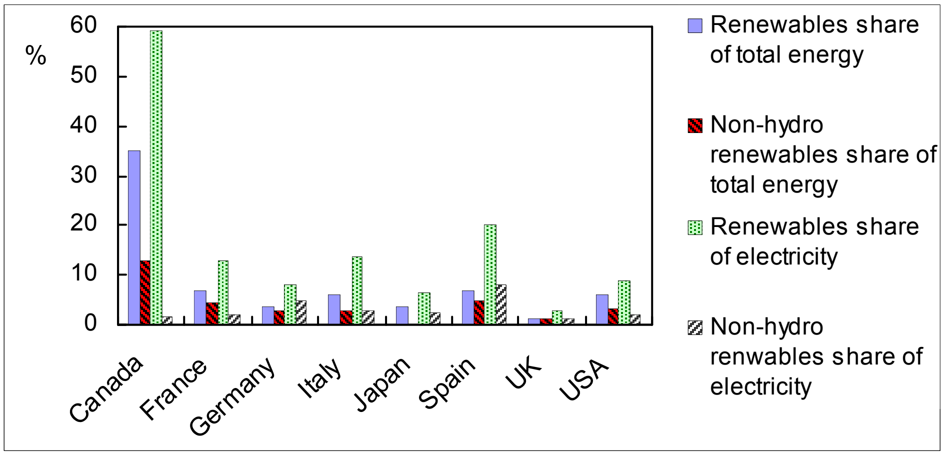
[11] See Metcalf (2006) for a more careful analysis of the energy policy act.

[12] Among similar, and even more extreme, cases is Norway where electricity supply is 100 percent hydro (representing about 120 tWh).

[13] These figures are based on primary energy consumption, and would have been somewhat higher if instead based on final energy consumption (for example, 5.5 percent for Germany). The difference between the two measures originates in the electric power sector, where power generation from hydro and wind power is compared to the basic *energy content* of other fuels used for power generation under the "primary energy consumption" measure; while compared to the *power generating capacity* of these other fuels under the "final energy consumption" measure. Arguably, the latter measure is the more meaningful of the two, as it describes more directly the final energy consumption implications of the different fuel supplies.

after 2004 (in particular for Germany, as seen in Chapter III below); but there is still a long way to go before (non-hydro) renewables can be said to play the role that some observers visualize it to play.

Figure 1. Distributions of Renewable Energy in Major OECD Countries, 2004



Sources: German Ministry of Environment (2006), Energy Information Administration (2006).
Note: Figures represent energy-equivalent percentage shares of totals.

Table 1. Renewable Energy, More Detailed Source Classification, Major OECD Countries, 2004

Energy source	Canada	France	Germany	Italy	Japan	Spain	United Kingdom	United States
Biomass	200	119.9	76.3	22.9	0.8%	49.6	13.4	285
Hydro power	353	59.7	20.6	41.3	-	31.6	5.0	270
Wind energy	6	0.6	25.0	1.8	-	14.2	1.9	13
Geo-thermal	1	1.5	1.6	8.0	-	0.1	0	34
Solar	0	0.4	3.1	0.2	-	0.3	0	6
Total renewables	560	182.1	126.6	74.1	-	96	20.3	608
Overall share in energy (percent)	35	6.7	3.9	6.1	3.5	6.9	1.4	6.2
Non-hydro share in energy (percent)	13	4.7	2.9	26	n a	4.4	1.0	3.3
Overall share in electricity (percent)	59.2	12.9	7.9	13.6	6.5	20.3	2.8	9
Non-hydro share in electricity (percent)	1.6	2.0	4.9	3.0	2.5	8.1	1.4	2.2

Sources: German Ministry of Environment (2006); and Energy Information Administration (2006).
Note: Figures in TWh equivalents.

Of particular interest is electricity supply, where non-hydro renewable sources contribute in excess of 8 percent in Spain, and about 5 percent in Germany. Among individual renewable sources, wind power is clearly the most significant in Spain and Germany (and even more in Denmark, not in the table), in addition to electricity generation from combined heat and power generation based on biomass (CHP). Other sources, such as geothermal and photovoltaics still play very marginal roles.

C. Public Renewables Support and Carbon Emissions Reductions

One important aspect of effectiveness of public support schemes for renewables is with respect to achieving reductions in overall carbon emissions. Table 2 provides summary information based on OECD estimates regarding the effectiveness of public support schemes, for a variety of renewable energy sources (including explicit and implicit subsidies), in the European G-7 countries and the United States. The table indicates the subsidy costs per ton of CO_2 emissions avoided, when fossil fuels are replaced by respective renewables in the countries' overall energy supply.

Table 2. Average Cost, Euros Per Ton of CO_2 Displaced, When Fossil Fuels Are Replaced with Renewable Energies

Country	Biomass	Biofuels	Photovoltaic	Hydro	Geothermic	Wind
France	86		328	155		154
Germany	195		1200	118	163	167
Italy 1/	200		200	200	200	200
United Kingdom 1/	117		117	117	117	117
EU 3/		260–3,400				
United States	39	315 2/				49
World 4/	135	150				

Source: OECD (2006); European Renewable Energy Federation (2003); Koplow (2006); Kutas and Lindberg (2007); Anderson (2006).

1/ For Italy and the U.K., generalized composite estimates for all renewables.
2/ Based on Koplow (2006).
3/ Based on Kutas and Lindberg (2007).
4/ Based on Anderson (2006).

These figures are generally not flattering to renewables: in all cases costs are far higher than accepted levels of marginal damage cost of CO_2 emissions (typically US$10–30 per ton). The figures are lowest for the United States, a main reason being that support schemes here (so far) are smaller and less generous. For biofuels (bioethanol and biodiesel), figures are higher; see also the discussion below.[14]

The bottom line in Table 2 is based on Anderson's (2006) background document for the Stern Review. Anderson's calculations indicate global average cost of abating carbon emissions through increased use of biofuels, of US$250 per ton carbon, equivalent to about €55 per ton CO_2. His total figure is not entirely comparable to others in the table, as they describe a mix of energy sources, including nuclear energy, and widespread application of carbon sequestration and storage (CCS) technologies to coal-fired facilities.

Table 2 cannot give a final verdict with regard to the true *overall social value* of developing renewable energy. Cost figures are rapidly improving; and subsidies may as noted be justifiable if fundamental technological breakthroughs are possible. Anderson (2006) assumes that the (central estimate of) net costs of abating carbon will fall over time, as a result of less expensive renewables, from currently US$250 per ton of carbon to US$100 (€21 per ton CO_2) by 2020, and to US$60 (€13 per ton CO_2) by 2050.[15]

A more recent European Commission (2006) document has attempted to assess the costs to the EU, per ton of CO_2 displaced, of achieving a 20 percent target for renewables by 2020, as share of overall final energy consumption. This estimate is, in general, far lower than the numbers given in the table, and in the range €40-60 per ton CO_2 displaced. A common presumption is, however, that renewables production will become generally more efficient over time and fossil fuels more expensive, making renewables relatively more "competitive."

Figure 2 indicates a similar but independent set of estimates for the EU alone. The calculations are made at two different oil prices (the idea being that, at a higher oil price, the excess cost of renewables production is smaller, and the net cost of substituting out oil lower, as the opportunity value of the saved oil is greater). These figures are compared to the net costs of substituting out fossil fuels using biomass for heat generation. The figures indicate tremendous differences in costs, with a great cost advantage to direct biomass use. This may, however, conceivably change over time, as direct conversion of biomass to fuels becomes a more attractive option.

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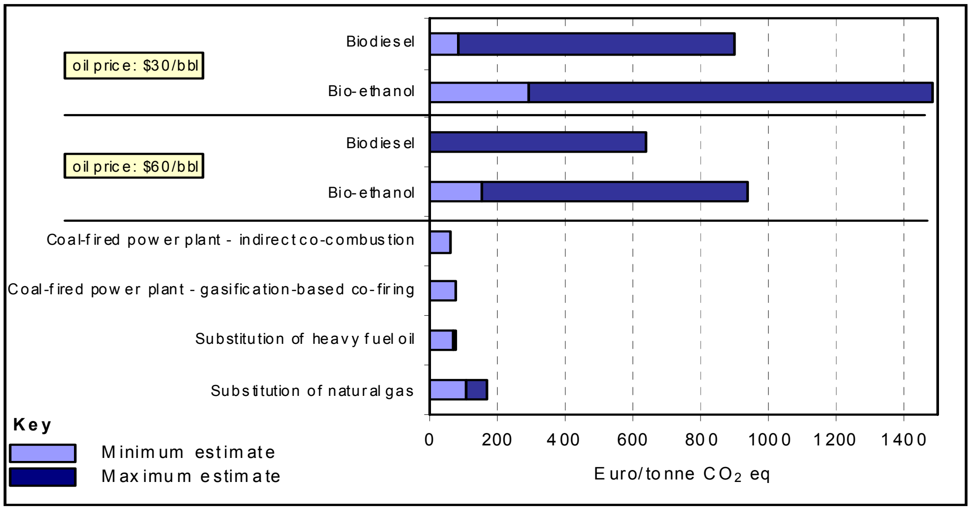
[14] There are two main reasons for this high cost figure in abating carbon through biofuels support: first, biofuels are less efficiency than gasoline, so it takes more than a gallon of biofuels to replace one gallon of gasoline; secondly, net carbon displacement is far less than gross displacement due to biofuels on the average being relatively carbon intensive in their production.

[15] Anderson (2006), Table 2.1 and Figure 2.1. These figures are, however, highly uncertain; Anderson's net cost range for 2050 is from €-75 Euros to +300 Euros per ton or carbon (-20 to +80 Euros per ton of CO_2). The possibility of negative costs is due to the possibility that renewables will be more cost efficient than fossil fuels at that time, for at least some applications.

Figure 2: Cost-Effectiveness in Carbon Abatement, Different Uses of Biomass



Source: ECMT (2006).

D. Biofuels and Their Support in Advanced Economies

Among the G-7 countries, biofuels (bioethanol and biodiesel) are a significant energy source mainly in the United States (bioethanol) and Germany (biodiesel). Table 3 gives an overview for the United States and the EU. The table clearly shows that G-7 biofuels production is in quantitative terms completely dominated by US bioethanol, representing almost 80 percent of the total; and German biodiesel representing about half of the rest.

Table 3 includes values of excise tax exemptions for bioethanol and biodiesel. These values are generally higher in Europe than in the United States (which is intuitively reasonable, as motor fuel excises themselves are much higher in Europe). They are highest in Germany, which is not surprising, as this country is Europe's most significant biofuels producer.[16]

Note, however, that even in the United States exemption values are substantial and far higher than the nominal values of motor fuel excises (which are currently in the range €0.6–0.7 per liter). The reason is that exemption is given on the entire value of the fuel (also on its regular part), provided that the biofuel content is above a threshold of percent (thus magnifying the support to the biofuel component).

[16] From the table, the implicit subsidy rate for Germany is higher for bioethanol than for biodiesel, despite bioethanol production being low. This is explained by production conditions for bioethanol being relatively unfavorable in Germany (compared, e.g., to Spain and the United States).

Table 3. Production Volumes (thousand tons), and Values of Tax Exemptions (Euro/cents per liter), for Bioethanol and Biodiesel in Major European Countries and the United States, 2006

Country	Bioethanol Production	Bioethanol Exemption	Biodiesel Production	Biodiesel Exemption	Total Biofuels Production
France	297	38	671	33	968
Germany	608	65.5	3,039	47–32	4,440 1/
Italy	0	0	223	41.3	223
Spain	227	37	79	27	306
United Kingdom	93	28	162	29	255
United States 2/	19,000	15	880	20	19,880

Source: Koplow (2006); Kutas and Lindberg (2007), German Ministry of Environment (2007).

1/ Includes plant oils.
2/ Numbers are estimates based on production capacity and expected utilization figures in Koplow (2006).

Koplow (2006) has made a more complete calculation of subsidies for bioethanol and biodiesel for the United States, including capital and agricultural production subsidies. For 2006, he estimates total government support to bioethanol at about US$6 billion, and support to biodiesel at about US$450 million, on volumes of 4.9 billion and 245 million gallons in that year, respectively.[17] Since this is a sector in rapid expansion and much of the public support is volumetric, minimum subsidies are predicted to increase to US$7.5 billion (on a volume of 6 billion gallons) for bioethanol, and US$2 billion (on a volume of 1.4 billion gallons) for biodiesel, by 2009. This is equivalent to subsidy rates of US$1.5–2 per gallon gasoline equivalent, for both fuels.[18] Note that, if the total volume of biofuels reaches 7.5 billion gallons by 2009, the biofuels share in total motor fuel consumption in the United States will reach about 4.5 percent (out of a total a volume of about 170 billion gallons), or a somewhat higher share than in Germany, which has the highest biofuels share today among the G-7 countries (3.6 percent). This share, however, comes at a high cost. If the subsidy is counted relative to the amount of carbon displaced by the fuels (in reducing the consumption of fossil-fuel based motor fuels), the average production cost for bioethanol in the United States is close to US$400 per ton CO_2 displaced.[19] For (hypothetical) cellulosic ethanol, it is potentially lower but still

[17] These numbers are considerably higher than those for the United States in Table 7. The reason is a considerable scaling-up of biofuels production in the United States in 2006 relative to 2005, in particular, for biodiesel; see Koplow (2006).

[18] The subsidy rate is higher per gallon petrol equivalent for bioethanol, since this fuel has about one-third lower energy content per gallon than petroleum-based petrol.

[19] One reason for the high subsidy rates per ton of CO_2 displaced is that biofuels only displace a fraction of the carbon in fossil-fuel based motor fuels: about 40 percent for bioethanol, and about 48 percent for biodiesel. These displacement rates are expected to be much higher, close to 96 percent, for cellulosic ethanol.

US$100–150 per ton CO_2 (against a current quota price in the EU ETS of about US$20 per ton; and on the Chicago climate exchange for 2007 delivery, about US$4 per ton).

Part of the government support to biofuels, accounted for by Koplow (2006), takes the form of a tariff on imported bioethanol, which is (a low) 2.2 percent plus (a much more significant) US$0.1427 per liter. The total support constitutes about US$0.60 per gallon, or about US$0.80 per gallon of gasoline equivalent.[20] Central America and the Caribbean are (subject to certain restrictions) exempted from this tariff, as are Canada and Mexico under the NAFTA agreement. Importantly, Brazil, the main bioethanol producer outside of the G-7 countries (and with substantially lower production costs than the United States), is not exempted.[21] Biodiesel tariffs for import into the United States are much lower—only 1.9 percent on an ad valorem basis. But here there is no significant import threat, as there is no major biodiesel producer apart from the United States in the western hemisphere.

In the EU, bioethanol tariffs are even higher than in the United States; the (volumetric) rate is €0.192 per liter (corresponding to US$1.25 per gallon of petrol equivalent). 101 developing countries are exempted from this tariff; but Brazil is not among them. As for the United States, the biodiesel tariff is significantly lower, as also in the EU, at 6.5 percent in ad valorem terms.

It is difficult to justify high tariff rates for bioethanol on purely environmental grounds. Two alternative or additional motivations may be suggested. First, biofuels production could serve an energy security purpose by shielding the United States (respectively, Europe) against petroleum supply disruptions.[22]

The other possible justification is positive externalities resulting from biofuels production facilitating the development of future and more efficient energy technologies. One must here, however, distinguish between the current support schemes in the United States, directed at corn-based ethanol production,[23] and schemes directed specifically at developing alternative technologies. The current schemes are of the former type and give little incentive for alternative developments. Kojima and Johnson (2005) argue that current technologies for ethanol production based on agricultural crops such as sugar and corn are mature and large-scale, and with limited potential for further technological improvement. The subsidy argument thus has little merit for this technology. A totally different issue would, however, be ethanol production based on general biomass, such as grass and wood fibers, where technologies are currently

[20] See Morgan (2006).

[21] See the discussion in Kojima, Mitchell and Ward (2007).

[22] For further discussion of these issues, and questioning the rationale for this motivation, see Kojima and Johnson (2005).

[23] The same argument applies to the current, largely rapeseed based, support schemes to biodiesel in Germany. Also here the potential for substantial future technical progress is small; see Kojima and Johnson (2005).

immature and the potential enormous. Not even the latest plans by the Bush administration, however, embed subsidies for such technologies.[24]

If positive production and R&D externalities are the main motivation for subsidy to biofuels, the logic of the argument should dictate that such subsidies be phased out as the respective technologies mature and make biofuels competitive with traditional fossil fuels (given appropriate correction for environmental externality effects). There is a certain recognition of this argument in the EU today. In particular, the major biofuels producing (and subsidizing) country, Germany, has just started a process of stepping down its preferential treatment of biodiesel versus petroleum based diesel, by imposing an excise tax of €0.06 per liter in August 2006, to be stepped up gradually, to €0.45 per liter in 2012 (at which point the differential treatment will have been essentially eliminated).[25] The results of this policy shift remain to be seen. No official data are yet available for the impact of this tax policy change on production; indications are, however, that German production of biodiesel is no longer growing, and may be falling.

Most analyses indicate that, at least currently, the conversion of agriculturally harvested plants to produce biofuels is relatively inefficient, as a means both of producing energy, and substituting out carbon-releasing fuels. Kutas and Lindberg (2007) have recently attempted to account for some of the elements of the overall public support to biofuels (but not all these elements), for the EU as a whole. This is a necessary step in arriving at efficiency measures of this support. It is seen that the public support (at least the fraction accounted for by the authors) is substantial, and from Table 4 is in energy-equivalent terms equal to €0.68 per liter for biodiesel, and €0.87 for bioethanol (but is likely to be higher since some of the support elements are missing in the background data).

Table 5 gives a perhaps more interesting overview, of the implicit cost, in the form of public subsidies, per ton net reduction in CO_2 emissions within the EU. These costs are extremely high at least for ethanol produced from corn, and are lowest for biodiesel produced from cooking oil (where, however, the supply is quite limited). Considering the most common product in the EU, biodiesel from rapeseed, costs are in the range US$1000 per ton of CO_2 displaced; or in the same range as for Photovoltaics for Germany, in Table 2 above.

[24] The Bush plan implies scaling up biofuels supply in the US to 35 billion gallons by 2017. This seems impossible without large-scale expansion of fuels production from general biomass, for which there is not general support yet.

[25] The latter policy may appear to be "overkill": there is then no longer hardly any reward to the environmental advantages of biodiesel relative to petroleum-based diesel. Presumably, other taxes on the carbon content of petroleum may correct for this.

Table 4. Calculated Average Public Support to Bioethanol and Biodiesel in the EU, by Support Category, 2006
(Million euros, and euros per liter)

Type of support	Bioethanol	Biodiesel
Direct output-linked support	829	2,131
Support for intermediate inputs	N.A.	N.A.
Support for value-adding factors	39	270
Hereunder investment support	N.A.	N.A.
Payments for crops on set-aside land	29	232
Payments under energy crop scheme	10	38
Distribution and consumption support	N.A	N.A.
R&D support	30	35
Total support	898	2,436
Total consumption, million liters	1,740	4,680
Average support, euros per liter	0.52	0.50
Authors' estimates of total support	0.58	0.62
Equivalent support, euros per liter of fuel based on energy content 1/	0.87	0.68

Source: Kutas and Lindberg (2007).
1/ Figures are higher here than in the lines above since the energy content per liter is lower for ethanol than for petrol, and for biodiesel relative to petroleum-based diesel (the difference is small in the latter case).

Table 5. Calculated Average Public Support to Bioethanol and Biodiesel in the EU, Per Unit of Fossil Fuels Displaced, by Supply Category, 2006

Indicator	Ethanol from sugar beets	Ethanol from corn	Biodiesel from cooking oil	Biodiesel from rapeseed
Support euros per liter of petroleum equivalent	0.87	0.87	0.68	0.68
Net gain in non-fossil energy, percent	50–68	22–32	77–89	45–63
Support, euros per liter of fossil fuel equivalent displaced	1.25–1.70	2.70–3.80	0.59–0.68	0.84–1.17
Support, euros per ton CO_2 displaced	450–620	1,600–3,400	260–270	750–990
Support, US$ per ton CO_2 displaced	590–820	2,130–4,520	340–360	990–1,300

Source: Kutas and Lindberg (2007).

II. Further Aspects of Renewables Policies in Germany

A. Introduction

Germany is the largest economy in Europe, with total primary energy supply of 345 million tons of oil equivalent in 2005, or about 20 percent of total EU supply (and emissions). Germany has made domestic commitments to raise the shares to 12.5 percent and 6.5 percent, respectively, for electricity and road transport by 2010.

The policies impacting on the carbon intensity of these markets are many and complex, with interventions affecting each stage of the economic cycle, and often administered under different jurisdictions including at EU, Federal and state level. They include interventions via a number of objectives and instruments, including the EU ETS, feed-in tariffs, and biofuels obligations; a diverse range of capital grants, exemption from fuel excise taxes, and research and development (R&D) programs affecting inputs; and policies affecting patterns of electricity and road fuel demand.

Table 6 gives an overview of the production of renewable energy in Germany in 2006. Comparing to the data for 2004, in Table 1, supply increases are substantial, both for biomass (which includes biofuels) and electricity generation. A further interesting issue in the table relates to turnover in the sector (comprising investment activity, and sales of energy products). Sector turnover per unit of energy produced varies considerably, both between and within energy types. For electricity, this reflects the effects of feed-in tariffs, and how they vary with type of renewable supply. PV here enjoys dramatically higher average electricity prices than the rest. Note also that prices for hydropower are considerably lower than any other, implying effectively that prices for other sectors are subsidized directly. In fact, the subsidy is even greater than appears from the table due to the relative flexibility of hydropower supply (making it relatively easier to supply at times of relatively high prices). Note also the much lower value per kWh for heat generation than for the two other supply categories. Part of this difference is simply due to the fact that a share of this energy is consumed directly and not sold in markets. It is, however, a question whether the very large difference can be justified; it may indicate relative undersupport to the heat generation sector which is likely to substitute out electricity in many applications.

Table 6. Overview of Main Renewable Energies, Germany 2006

Type of Energy Source	Total Energy Supply, TWh	Investment, € billion	Revenue, € billion	Revenue per kWh Supplied, €	Emissions Avoided, Million tons CO_2
Electricity generation	73.9	4.5	6.6	0.089	68.1
Hereunder: Wind	30.5	2.9	2.7	0.089	
Hydro	21.6	0.1	1.2	0.056	
Biogenics	19.7	1.4	1.6	0.081	
PV	2	4.3	1.1	0.550	
Heat generation	89.3	3			20.7
Hereunder: Biomass	84.1	1.5	1.4	0.017	
Solar	3.3	0.9			
Geothermal	1.9	0.6			
Biofuels	39.9		3.3	0.083	12.7
Hereunder: Biodiesel	28.9				
Bioethanol	3.6				
Vegetable oil	7.4				
Total, renewable energies	202	11.6	11.3	0.056	101.5

Source: German Ministry of Environment (2007).

B. Renewables for Electricity Generation in Germany

Germany generated 613 terawatt-hours (TWh) of electricity in 2005. Industry, residential, and commercial and public sectors accounted for 45.5 percent, 27.4 percent and 22.4 percent of total electricity consumption in 2004.[26] Overall, consumption has grown by an average of 1.4 percent annually over the last decade, but is projected to stabilize and fall slightly toward 2030.

Coal and lignite, nuclear, gas, and renewables (including hydro power) made up 49.8 percent, 26.6 percent, 11.3 percent, and 10.5 percent of the generation mix respectively in 2005. The coal share has fallen in recent years (from 62 percent in 1985 to nearly 50 percent in 2005). In addition, the Federal Government has begun a phase out of its nuclear generation capacity, to be completed by 2030.

The relative importance of natural gas and renewables is expected to grow rapidly. By 2010, the supply of renewable energy is expected to increase by 75 percent since 2000 (an average annual

[26] http://www.iea.org/Textbase/stats/electricitydata.asp?COUNTRY_CODE=DE&Submit=Submit.

rate of almost 12 percent).[27] Further growth is anticipated, driven by policies outlined below, designed to deliver targets of at least 12.5 percent by 2010, and 20 percent by 2020.

Germany operates a system of "**feed-in**" **tariffs**, provided for as part of the Renewable Energy Sources Act (EEG) 2004, which guarantees renewables suppliers a rate for production, priority access to the grid, and also obliges customers to purchase their output. This imposes direct costs due to the high price of renewables relative to conventional generation sources, as well as indirect costs such as those associated with grid congestion and the management of intermittency.

Payments to energy producers under this scheme were about €4.4 billion in 2005 for the production of 44 TWh of electricity (equivalent to an average rate of about €0.10 per kWh). It is estimated that by 2012, the feed-in tariff will provide 89.4 TWh of electricity with customer payments amounting to about €9.4 billion, at an average rate of €0.105 per kWh.[28] Between 2000 and 2012, total tariff payments for an anticipated 650 TWh of renewable energy production are expected to amount to some €68 billion, including additional costs of €30–36 billion.[29]

The 'feed in' tariffs are differentiated by technology to equalize expected profitability, with much higher payments for solar generated electricity (see Table 7). This reflects, in part, the relative immaturity of solar compared to other technologies such as wind (which provides over 58 percent of renewable electricity), and the desire to spur development and diffusion of PV technologies. The extent of this differentiation implies that solar is expected to provide 4.5 percent of total renewable electricity, while taking up nearly 20 percent of the total fees (see Figure 3). The justification for such differentiation can be questioned, as it, likely, implies not fully efficient production and R&D incentives (not all least-cost alternatives will be exploited). This policy is still understandable as, otherwise, substantial additional private profits would be made for the most efficient units, which may be politically difficult (as these profits stem to a large extent from public support). Lack of differentiation would also, obviously, all but eradicate PV electricity production, where there may be independent (technology-based) arguments for support.

[27] International Energy Agency (2007a).

[28] The BMU projects somewhat lower figures: 82 TWh of electricity and payments of €8.1 billion, equivalent to just under €0.01 per kWh.

[29] Additional refers to costs over and above those of procuring electricity without a feed-in tariff. This assessment is dependent on the price of electricity generated from conventional energy sources to be paid by industry and private customers.

Table 7. Feed in Tariffs by Technology, 2006

Technology	Tariff for Installations Built in 2006 (euro/cents/kWh)	Guaranteed Term of Payments (In years)	Yearly Degression Rate (In percent)
Large hydropower (5–150 MW)	3.62–7.51	15	1.0
Small hydropower (5< MW)	6.65–9.67	30	0
Biomass (<20 MW)	3.78–21.16	20	1.5
Geothermal energy (<20 MW)	7.16–15.00	20	1.0 2/
Wind energy (onshore)	8.36/5.28 1/	20	2.0
Wind energy (offshore)	9.10/6.19 1/	20	2.0 3/
Photovoltaics	40.60–56.80	20	6.5

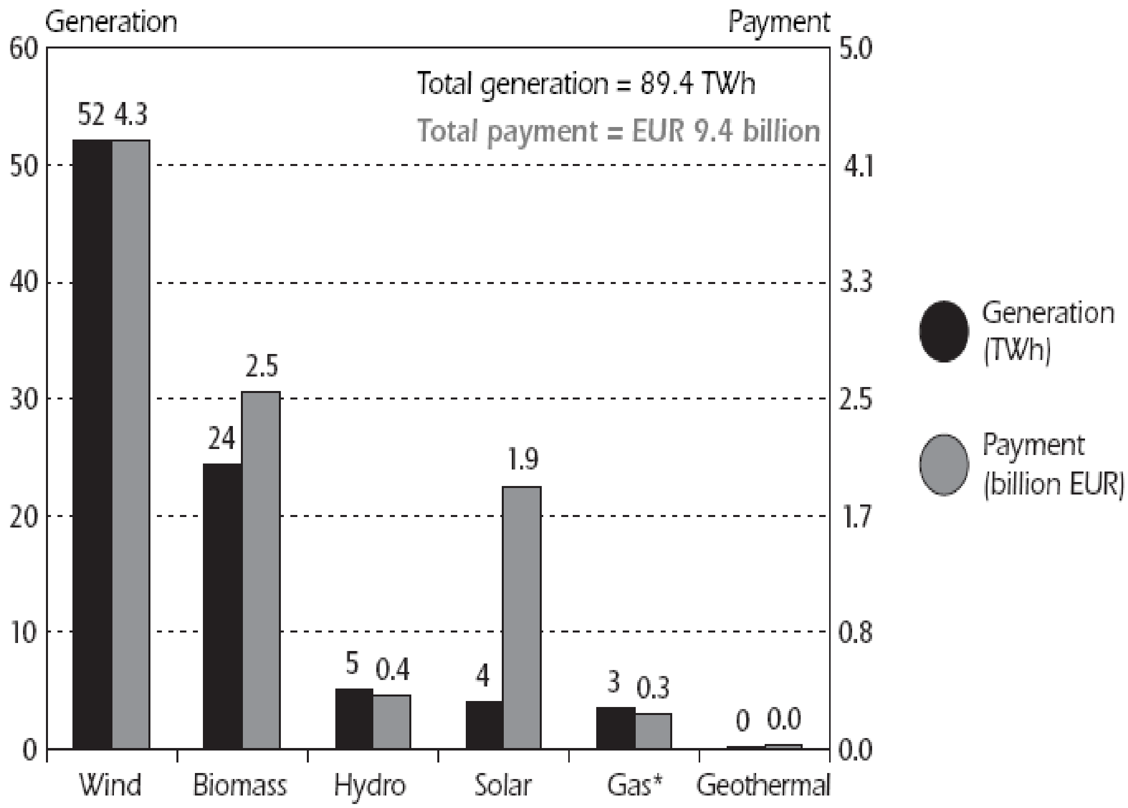
Source: German Ministry of Environment (2007).

1/ Installations receive the first rate given (the initial tariff) for X years, then the second rate given (the basic tariff) for the remainder (20-X); X depend son the quality of the site.
2/ Starting in 2010.
3/ Starting in 2008.

The German federal government employs ‘feed-in’ tariffs also to combined heat and power (CHP) technologies.[30] The objective is to reduce CO emissions, by 23 million tons annually over the period 2000–10, in combination with a voluntary agreement with the industrial sector. The current tariff scheme, established under the 2002 *Kraft-Wärme-Kopplungs-Gesetz*, and summarized in Table 8 below, is generally less generous than under the EEG. For example, payments for exported electricity produced using CHP are currently between 1.23 and 2.25 Cent/kWh.

[30] Including coincineration of biomass in conventional power plants and biomass-fired CHP power plants exceeding a production capacity of 20 Mwe.

Figure 3. Forecast Quantities and Fees of Feed-in Tariffs, by 2012



	Wind	Biomass	Hydro	Solar	Gas*	Geothermal
Share of generation	58.2%	27.3%	5.8%	4.5%	3.9%	0.3%
Share of fees	46.0%	27.1%	4.0%	19.9%	2.7%	0.3%
Avg. fee/kWh (Euro¢)	8.3	10.4	7.3	46.0	7.2	10.9

* includes landfill gas, sewage sludge gas, biogas and coal-bed methane.

Source: VDN, *EEG-Mittelfristprognose Entwicklungen 2000-2012*, 29 September 2006.

Source: International Energy Agency (2007b).

Table 8. Supplementary Payments for Electricity Exports to the Grid
(€ cents/kWh)

	2002	2003	2004	2005	2006	2007	2008	2009	2010
Existing old CHP plant (Start of operation before 31/12/89)	1.53	1.53	1.38	1.38	0.97				
Existing new CHP plant (Start of operation between 31/12/89 and the date when the new Law comes into effect)	1.53	1.53	1.38	1.38	1.23	1.23	0.82	0.56	
Modernised CHP Plant (Start of operation after the new Law came into effect)	1.74	1.74	1.74	1.69	1.69	1.64	1.64	1.59	1.59
New small-scale CHP plant between >50 and 2000 kw_e	2.56	2.56	2.40	2.40	2.25	2.25	2.10	2.10	1.94
New small-scale CHP plant ≤50 kW_e, which start continuous operation before the end of 2005, and fuel cell units	5,11 cent for a period of 10 years beginning from the start of continuous operation								

Supplementary payments for small scale CHP plant up to 2 MW_e (this includes also units <50 kW_e) will only be made up to a total electricity export of 14 TWh from these plants.

Source: German Ministry of Environment (2007).

The **EU Emissions Trading Scheme** (EU ETS) is designed to create disincentives for carbon intensive electricity generation in Germany (and other EU states), by limiting overall emissions as defined by the National Allocation Plan (NAP). Scarcity of emissions rights across the EU increases the cost of carbon intensive production, and may create long-run incentives for capital substitution. Under Phase I of the scheme (2005–07), large fossil-fuel based electricity generators (particularly coal) have received generous free emissions rights; while in Phase II (2008–12) free allocations are still very substantial, amounting to at least 90 percent of 2000–05 emissions. It is very likely that the EU ETS has created expectations that future free emissions rights will be a function of current emissions, substantially reducing these potential incentives to abate.

A detailed assessment of the impacts of the EU ETS on investment and prices in the German market, based on its current allocations methodology, is beyond the scope of this paper. Note, however, that under phase I, German electricity generators have received approximately 394 million tons $C0_2$ in annual emissions rights.[31] The market value of these emissions rights

[31] The Phase I German NAP limited average annual emissions under the scheme to 499MtC02 between 2005-07 of which an estimated 79 percent went to electricity generators. German Emission Allowance Trading Authority DEHST (2004).

has fluctuated, averaging roughly €15 per ton $C0_2$.[32] Based on these assumptions, it implies an annual implicit subsidy valued as roughly €5.9bn (and an even higher €9bn when based on the Stern Review's (2007) US$30 per ton CO_2 assessed social damage cost of emissions).

Thus, arguably, implementing the EU ETS in a way which is inconsistent with the 'polluter pays' principle has resulted in new and entrenched implicit subsidies to carbon intensive energy sectors in the EU, which are substantially greater in magnitude than the explicit costs of the feed in tariffs which promote the complementary development and diffusion of substitute technologies.

A further consideration concerns the impact of the decision by the German Federal Government in 1998 to phase out the German nuclear generation capacity by 2030, in response to political and public concerns. According to the International Energy Agency (2007), a reversal of this decision coupled with a refurbishment of these assets would substantially promote secure supplies, at the same time reducing the overall costs of mitigating carbon emissions. While the shortfall in electricity supply created by nuclear close-down might be bridged with greater use of renewables and natural gas, and higher energy efficiency, this decision illustrates well some of the existing tensions between political and economic priorities.

C. Policies Affecting Value-Adding Inputs

This section outlines a number of policies which directly support electricity generation from renewable sources including public sponsored R&D, capital grants, and subsidized loans administered at the EU, Federal and local levels. These are designed to promote the long run marginal product of capital, and overcome shorter-term capital constraints. We also outline policies supporting substitute technologies, particularly conventional power generation, and wider policies affecting capital or labor productivity.

Support for technological research and development

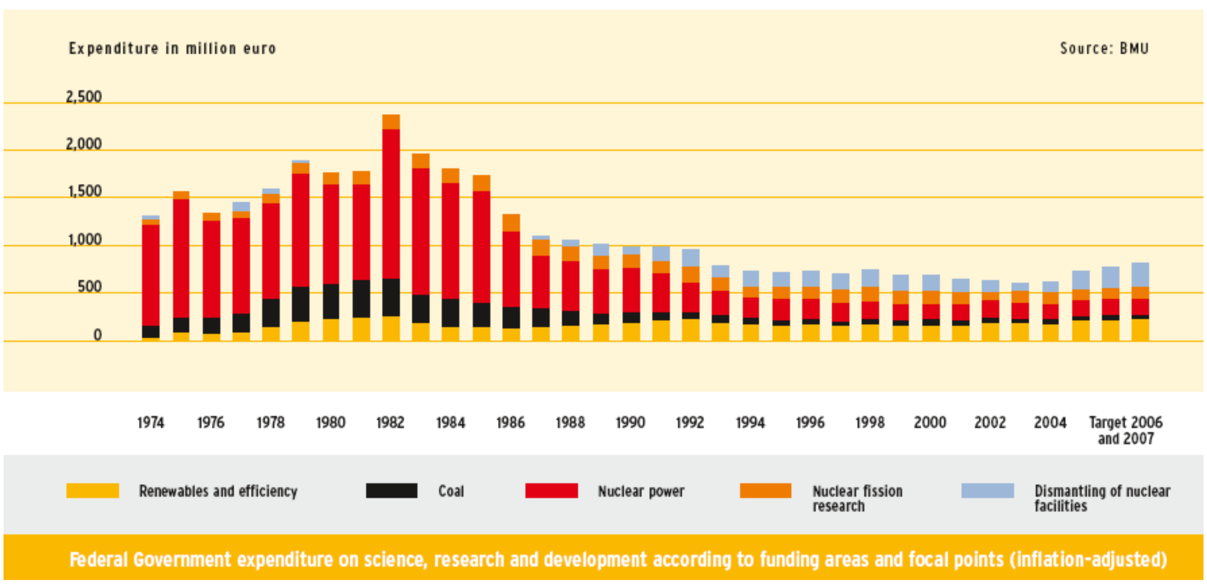
At the *EU level*, the current **7th Framework Program (FP) for Research (FP7)** supports R&D in sustainable energy systems designed to: reduce energy-related greenhouse gas emissions (including accelerated adoption of renewable energy technologies), enhance European energy security, and improve energy efficiency and productivity. Under the previous FP6 (2002–06), the budget for non-nuclear technologies was approximately €815m, while the total budget for the development of nuclear technologies was €1.23bn. Overall FP budgets have increased by over 250 percent since the first program. However, the share of energy-related research expenditure within the program has fallen from 50 percent to 14 percent.
Renewables technologies also receive R&D support at a *Federal level*. Note that the overall support for energy-related research has fallen relatively sharply—by two-thirds or more since the early 1980's. This is largely due to reduced expenditure on nuclear energy, which previously dominated the German energy research portfolio. The German Federal Government has,

[32] Note however that Stern (2007) estimated the expected climate damage costs at US$30/t$C0_2$, or €22/t$C0_2$, under a strong mitigation scenario; and higher in other alternatives.

however, begun to gently reverse this trend, with funding for overall federal energy R&D increasing from about €0.6 billion to about €0.7 billion between 2005–08 under the 5th energy research program 2005–08 (shown in Figure 4), and rising a bit further to €0.8 billion between 2006–09 under the '€6 billion' and 'high tech' strategies. In the latter years, however, most of this increase goes to dismantling of nuclear facilities, a component not useful for increasing future German energy supply. There is today little clear indication that basic R%D support to renewable energies by the German federal government is substantially increasing. This level has been more or less stable since the early 1990, seen from Figure 4.

Figure 4 shows a breakdown of expenditure across different energy technology development themes and Government organizations, taken from the 2005 5th Energy Research Program. It shows that overall increases in federal research expenditure in renewables have been modest. Data for 2006 and 2007 are, however, unclear, and some outturn data for 2006 appear to reflect the increased expenditure budgets announced thereafter. For example, reported expenditure by the German Ministry of environment (BMU) on renewables R&D in 2006 was €98 million, with approximately €15.7 million targeted at wind energy, and €32.3 million at solar energy.[33]

Figure 4. German Federal Government Support for Basic R&D, 1974–2007[34]



Source: German Ministry of Environment (2007).

[33] BMU-Pressedienst No. 108/07 Berlin, 19.04.2007 Environment Minister Gabriel: Strengthening leading position on the global market through cutting edge research.

[34] The 5th Energy Research Program of the federal government www.bmwa.bund.de.

Table 9. Breakdown of German Federal Government Energy R&D
by Research Theme/ Ministry, 1974–2007[35]
(in €1,000)

	Actual 2003	Planned 2004	Projected Data 1/ 2005	2006	2007	2008
BMWA						
Efficient energy conversion	65,958	78,496	71,244	70,994	70,994	70,994
Nuclear safety and repository research	24,125	25,500	23,605	23,480	23,480	23,480
BMU						
Renewable energies	67,798	60,083	80,394	83,366	88,366	93,366
BMVEL						
Bioenergy	5,422	5,117	10,000	10,000	10,000	10,000
BMBF *Centers of the Helmholtz Association*						
Efficient energy conversion	36,621	39,607	42,155	42,012	42,134	44,270
Renewable energies	24,396	26,442	28,267	28,307	28,613	30,271
Nuclear safety research	29,260	31,178	31,147	31,133	31,126	31,022
Fusion research	115,298	115,000	115,000	115,000	115,000	114,900
Networks of basic research into renewable energy and energy conservation	6,600	9,830	11,100	10,100	10,100	10,100
Total	375,478	391,253	412,912	414,392	419,813	428,403

Source: The 5th Energy Research Program of the German Federal Government (www.bmwa.bund.de).

1/ The 2005 to 2008 figures partly include funds from the Innovation Initiative of the Federal Government: they are subject to approval by parliament.

Support for technological diffusion

Support to technological diffusion may be warranted when the rate of private uptake of technology is sub optimal. This may occur due to lack of information on possible technology options by small private actors (households and small businesses). A wide range of policies,

[35] The 5th Energy Research Program of the federal government www.bmwa.bund.de.

including grants and subsidized loans, support the diffusion of less carbon intensive electricity generation technologies. Analysis of the precise extent of this is complicated by the fact that program support for renewable generation is often bundled with efforts to promote thermal energy production or energy efficiency. As a result, it is unclear to what extent the conditions for efficient abatement are met. Box 1 provides an overview of the most important policies in this area. Major programs for power-generation support include:

- **Producing Solar Power Program**, introduced in 2005, offers low-interest loans administrated by the Reconstruction Loan Corporation (KfW), to support small investments in solar PV generation. Private projects with an overall investment up to €50,000 are supported. 100 percent of the investment cost can be financed at rates between 3.6 percent and 4.15 percent, with payback period of 10–20 years with a redemption-free initial phase of 2–3 years. Between 2005 and July 2006, more than 25,000 loans were provided, with a total of €784 million and a capacity of 199 MW in PV systems.

- **Market Incentive Program** was introduced using earmarked funds resulting from the decision to tax electricity universally (also when generated from renewable sources). It primarily serves to expand heat generation from biomass, solar power and geothermal energy. The budget was €190 million in 2002 and 2003, rising to €213 million in 2007. Since its launch in 2000, the program has supported around 625,000 projects with funding of €827 million. Total investment triggered is, however, far larger, estimated at €6.5 billion.[36]

- **ERP-Environment and Energy-Saving and Environment Programs**, provide low-interest loans, administered by the KfW (formerly the Deutsche Ausgleichsbank), for private companies, freelancers and public private partnerships who take suitable energy efficiency measures. Since 2003, this has been applicable to investment in renewable energies. Credit terms are 20–30 years with a redemption-free initial phase of 2–5 years. Interest rates depend on credit rating, but are typically slightly below market level, 4–7 percent in 2006. A maximum of 50 percent of the total investment is eligible for funding. Loans taken out with this program can be combined with loans offered under the KfW-Environment-Program. Loans of €10.7 billion were extended between 1990 and 2005.

- Several other soft loans schemes exist, administered by the KfW, to support the use of renewable energy sources as well as the conversion of heating systems. These include the **Mittelstandsprogramm** which applies to enterprises, and the **Infrastrukturprogramm**, which applies to municipalities. Public institutions and non-

[36] http://www.bmu.de/english/renewable_energy/press_statements_speeches/doc/394
http://www.iea.org/Textbase/pamsdb/detail.aspx?mode=gr&id=83

profit organizations. The latter targets the energetic modernization of communal buildings (e.g. schools, kindergartens). Typical credit terms are 10–20 years with interest rates at 1–2 percent below market levels.

- **100 000 Roofs Program** supported the installation or extension of PV systems larger than 1 kW between 1999 and 2003. It contributed to a boom in the photovoltaic market in Germany, funding 55 000 installations with a total capacity of 261 MW at a cost of approximately €560m. The terms were very favorable as support could be combined with other programs such those under the Renewable Energy Sources Act. It provided subsidized loans for up to 100 percent to a maximum sum of €500 000, available at 4.5 percent below market interest rates, and repayable over ten years with a two-year repayment holiday together (particularly as support could be combined with other programs such those under the Renewable Energy Sources Act).

- **Solar Power Development Center** provides testing facilities and equipment for manufacturers interested in testing and developing large-scale production of new products. The Photovoltaic Technology Evaluation Center (PV-Tec) forms part of the public-private Fraunhofer Institute for Solar Energy Systems (ISE) and has received €11.7 million in support since 2005.

- **250 MW Wind Program** promoted 1560 wind turbines with a total capacity of 362 MW through the provision of grants for the installation and operation of wind turbines at suitable sites, together with monitoring support for 10 years thereafter as part of the "Scientific Measurement and Evaluation Program." Until the end of 1996, grants of DEM 200 (€102)/kW, up to a ceiling of DEM 100,000 (€ 51,300) for facilities larger than 1 MW were available. Grants up to 60 percent of the total investment to a maximum of DEM 90 000 (€ 46,000) were provided. Reported payments under the scheme were €7.6 million in 2001.

- **Regional support programs**. Funds available at the federal level or due to federal law have been the main driver for the deployment of renewable energy technologies. However, the states (Länder) have also provided considerable support, with some states such as Nordrhein-Westphalen particularly active. Table 10 below shows support for renewable energy technologies by all states across program types including R&D expenditure, capital grants and subsidized loans. Overall support is here shown to be decreasing (although data do not include the most recent years), in particular to wind energy, and support to PV technologies taking over to some degree.

Table 10. Combined Federal States (Länder) Support for Deployment of Renewable Energy Technologies
(by year and energy category)
(€ million)

	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	1991–2001
Wind power	13.2	16.4	40.0	46.7	39.9	27.1	31.0	20.4	14.9	7.7	2.4	259.6
Hydro power	4.9	4.7	8.2	5.8	5.4	3.7	3.8	4.7	3.9	2.6	2.2	49.8
Solarthermal	5.7	17.6	22.6	20.4	25.5	31.2	25.4	31.6	23.2	18.8	12.6	234.6
Photovoltaic	5.4	10.5	9.0	9.9	9.0	14.6	19.6	15.6	19.4	22.8	27.9	163.7
Biomass	2.8	7.0	18.0	17.6	38.9	30.6	38.6	37.8	28.2	38.4	37.1	295.0
Heat pumps	1.0	2.8	2.4	2.6	2.4	4.2	2.3	4.2	3.6	6.6	9.0	41.1
Geothermal	0.5	1.7	2.1	2.8	2.3	3.8	0.2	0.3	0.7	0.4	1.8	23.6
Education	1.5	1.7	1.4	1.6	3.2	4.3	6.8	5.1	3.9	6.2	6.2	41.9
R & D	12.5	20.5	28.1	27.1	27.1	21.8	30.0	53.2	53.0	38.0	23.1	334.4
Others	49.5	48.4	48.7	46.5	28.0	23.3	26.8	15.7	8.8	23.6	29.7	349.0
Total	96.9	131.4	180.5	181.0	181.6	164.6	184.4	188.4	159.6	165.2	151.9	1785.5

Source: German Ministry of Education and Research (2005).

Policies affecting inputs

Demand for renewables is affected by the tax treatment of fossil fuels, which affects the costs of conventional electricity generation and alternative systems of energy conversion. From a theoretical perspective, input taxes may be an appropriate corrective response to the existence of cross-border externalities or wider tax competition.[37]

Mineral and environmentally motivated taxes have been subject to a series of reforms by the German Federal Government implemented since 1999. These are designed to provide incentives for energy saving and promote the use of renewable energies. However, coal is generally exempt from these taxes.

Assessing the impact of these mineral taxes is made complicated by a variety of special provisions designed to prevent competitive disadvantage and social hardship and promote environmentally friendly transportation and electricity generation. Specific measures include reduced energy tax liabilities on industry, a cap on the effective tax rate for energy intensive industries (together with certain exemptions), exemptions for electricity generation, and various reductions for less carbon intensive forms of transport.

Subsidies for domestic coal extraction, designed to support domestic production, are substantial but falling, with subsidies cut from €4.7 billion in 1998 to €2.7 billion in 2005, and further falling to €5.7 billion in aggregate for the period 2006–08.[38]

Micro level costs are reported in the annual subsidy report. For example, the sum of reported allowances on electricity and heating fuels amounted to €3.9 billion and €2.3 billion, respectively, in 2005. However, analysis presented by the BMU suggested that the macro-fiscal costs of these exemptions are significantly higher at €6.2 billion and €4.8 billion, respectively, (and much higher in absolute and proportionate terms for transport fuels).[39]

D. Biofuels for Transport

Germany is the world's largest producer of biodiesel and biological oils for fuel purposes, and by far the main overall producer of biofuels with the EU. The total production of biodiesel in 2006 was about 3 million tons, and about 600 000 tons for bioethanol.[40] Production of both fuels

[37] See for example, Keen and Strand (2007) relating to taxation of the aviation sector.

[38] In February 2007, the government reached an agreement to phase out all subsidies, resulting in the shutdown of the remaining eight plants in North Rhine-Westphalia and Saarland by 2018.

[39] Subsidies to energy consumption with special focus on energy intensive industries in Germany Contribution to Ad Hoc Group on "Environmentally-harmful subsidies" Bettina Meyer Federal Ministry for the Environment, Nature Conservation and Nuclear Safety'[49/30/28550–3664 bettina.meyer@bmu.bund.de] BMU, December 2006.

[40] Kutas and Lindberg (2007).

has been rising rapidly in recent years, and is still rising. It is estimated that production of biodiesel will reach about 4.2 million tons within the next three years.[41] For bioethanol, the relative increase in production has been even more dramatic, rising from a low base of only about 20,000 tons in 2004. Germany is today Europe's leading producer also for bioethanol, and plans are for additional plants that could increase production capacity up to about 2 million tons within few years.[42] The background for this is an ambitious set of targets for future biofuels supply in Germany, with a preliminary target for a market share of 5.75 percent by 2010, and further increase to 10 percent by 2020.

Public support for liquid biofuels in Germany is of various forms: to output directly; as excise tax exemptions, as support to energy crops; as rural development support; as capital grants; as subsidies to feedstock used for biofuels production; as R&D support; and as support to consumption. At this stage, it has not been possible for us to obtain a full overview of these support elements.

A preliminary conclusion is, however, that the public support to biofuels in Germany, up to the current time, is an expensive as a means of phasing out petroleum in the transport sector, and of reducing overall German carbon emissions.

III. Overall Assessment of Renewables Policies in Advanced Countries

In evaluating the cost efficiency of renewable energy support in the EU, the OECD in 2004 concluded: "From the standpoint of climate change policy, specific targets to expand the use of renewable sources appear to be less efficient than pricing emissions and letting market forces determine the appropriate energy mix."[43] We agree to the basic content of this statement. We, however, wish to include a few additional comments.

- There is no general efficient pricing of emissions with which to compare current renewables support policies. It is e g clear that emissions are at least in some cases under-priced. Given a lack of will to implement more correct emissions pricing, there may be room for subsidy to renewables as a means of offsetting excess emissions.

- On the other hand, the optimal subsidy of renewables for this purpose is an open question. Expenditure on feed-in tariff schemes to support renewable electricity generation is large and rising, in particular in Germany, with photovoltaics receiving particularly large support relative to output. It is not clear whether these high rates are justified from an economic cost-benefit point of view.

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[41] Kutas and Lindberg (2007), page 12.

[42] Kutas and Lindberg (2007), page 15.

[43] OECD (2004), page 94.

- There is a possibility of very high returns from current energy renewables research and development, with a possibility of developing "breakthrough" technologies in some cases. Only a small fraction of overall social returns from technology breakthroughs in this area can likely be appropriated by the technology developer. This leads to arguments for public support to such developments in principle. It is, however, today not possible to attach concrete probabilities to developing "breakthrough" technologies within the time frame in question; this makes it difficult to assess the optimal rate of public support. In particular, the numbers in Table 2 and Figure 2 are not necessarily indicative of the real social value of renewables public support schemes when technological developments are taken into account. The possibility of significant breakthroughs is greater in certain energy areas (such as solar-cell technology) than in others, thus justifying the higher cost per unit of carbon emissions avoided that was found there. It is still unclear whether e g the very big differences in support per energy unit, between PV technologies and other renewables in Germany, are justified.

- There are indications that public support to R&D in the renewable energy sector may be biased with too much emphasis on "development" (principally, support to production so as to permit achieving economies of scale), and too little emphasis on "research" (the invention of totally new products and production processes and methods). This appears to be the case for Germany, where support to research in the renewables sector has been relatively stable since the early 1990s.[44] The data for the last two years are, however, uncertain; there may be indications that basic research support to renewables in Germany is now on the rise, which would be fortunate.

- There still exist large direct or implicit subsidies to traditional fossil fuels, in the EU as well as the United States. There are still subsidies to the coal sector in Germany (although these are currently in a phase-out process), and to the petroleum and natural gas sector in the United States. Secondly, we argue that the implementation of the EU ETS in the EU area, based on free initial allocations of carbon emissions rights, embeds large implicit subsidies to carbon intensive producers, and has reduced dynamic abatement incentives for these. These distortive subsidies ought to be discontinued. However, as long as they remain, they give an added justification for renewable energy subsidies, beyond levels that would otherwise be optimal.

- A specific concern is biodiesel and bioethanol for road transport. These are heavily supported, both in the EU and the United States. In these countries biofuels are generally exempted from regular excise taxes;[45] bioethanol is supported via high import tariffs;

[44] See also Runci (2004) for similar arguments.

[45] Note again that the production of biofuels may involve substantial carbon emissions, in particular, when produced from agricultural crops, as discussed above.

and a number of additional subsidies apply. In aggregate, the rates of subsidy appears to be at least in the range €0.5–0.7 per liter in the EU, and about US$2 per gallon for bioethanol (when considered in fuel- equivalents of petrol) in the United States. It is an open question whether regular excise tax rates for biofuels ought to be substantially lower than rates for traditional fuels. Many or most externalities associated with road transport are due to factors not related to carbon emissions (such as road congestion and wear, and local pollution), and are similar when biofuels are used instead of regular petrol or diesel. If the motivation is solely the differential impact on CO_2 emissions, the tax difference between fuel types is clearly not justified today, since as we have shown above, the effective reduction in overall CO_2 emissions, when producing and consuming biofuels instead of fossil-based fuels, is very small.

- The policy landscape, at least in the EU, is highly complex, with the market being affected by many different policies implemented under local, federal and international jurisdictions. This makes it very difficult to get a full overview of total effects of the different policies in aggregate.

In order to develop a more detailed understanding of the extent of support for renewables and wider policies affecting the carbon intensity of electricity production in Germany, it is desirable to try to quantify, further than what has been achieved here, the *efficiency* of different policy measures. This also requires additional policy analysis work, to which we intend to contribute.

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