Climate Change Impacts and Policy: **Student ID 3748154**

Much ado about nothing: Photovoltaic policy in the EU and its implications for climate change mitigation

Introduction

Of all the prominent renewable electricity sources, photovoltaics (PV[1]) is by far the most expensive per Watt and the least efficient in terms of energy conversion. Typical PV efficiency has risen from around 6% in the mid 1950s to around 18% now, a doubling every 32 years[2]. By comparison, computer power has consistently doubled every 2 years[3]. If computer power followed the same curve as PV, we would still be using the computers of 1958.

PV works by the brightness of the sun, yet Germany, where it is most heavily subsidised, installed and accepted, is relatively dull. German PV subsidies now amount to almost a billion euros per year (PV Policy Group 2006, p. 28), with mushrooming cash commitments for subsequent years. Ironically, if this money were spent instead on pure PV research and development (R&D), PV technology might advance faster, and installed PV pay its way much sooner. Yet PV advocates tend to ignore this apparent misallocation of funds (e.g. Erge et al. 2001, Jäger-Waldau 2007, Reiche and Bechberger 2004).

PV could potentially make a huge contribution to climate change mitigation, as it is completely fossil-free in operation and its ‘energy payback time’ (see below) is considerably shorter than the life of a typical unit. If intensified R&D were to bring PV to its economic breakeven point earlier rather than later, it could replace a significant portion of fossil fuel and even nuclear generation. This paper argues that this opportunity is being squandered by misguided German policies that serve to promote premature deployment of an immature technology at a ridiculous cost.

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[1] A list of the abbreviations used in this essay is given in Appendix 5.
[2] Since 6 x 2^(50/31.64) = 18.
[3] The number of transistors per centimetre of silicon chip has followed Moore’s Law (1965), doubling every 18 months. Allowing for other limitations, a more modest overall trajectory is a doubling of overall computer power every 2 years.

We first outline the technical features of PV that policy makers need to take account of. We then explore the place of PV in EU climate change and related policy development. Since Germany is the motor of PV expansion within the EU, we look extensively at German PV policy and its effects, with lesser reference to other EU countries. Finally, we make recommendations for policy makers.

Photovoltaics in electricity production

Due to the high cost, low efficiency and small power output of PV cells, early interest in their use was mostly confined to the space industry and remote low power appliances. In 1955 efficiency[4] was typically 2% and the cost per Watt of production capacity (PWC[5]) $US1,750, though efficiencies of 6% could be achieved at very high cost (Lenardic 2008). Efficiencies rose to 9% by 1958, and today 15-18% is typical. Costs fell to below $US20 PWC in the mid 1970s, and are around $US2.70 PWC today. Since the cost PWC of fossil fuel generators is around US 80c, the relatively high cost PWC of PV electricity has significant implications for policy development.

Another important issue for PV usefulness is ‘energy payback time’ (EPBT). This is the time it takes for a PV installation to generate the amount of power that was used in its manufacture, installation, etc. (Alsema and Nieuwlaar 2000). For a PV unit to be a viable source of energy it must make up for this input, and produce yet more power, during its lifetime.

A further criterion is ‘carbon payback time’ (CPBT), the time it takes a PV unit to produce the same amount of electricity that was generated from fossil fuels in its manufacture, installation, etc. CPBT for PV made in Sweden would be far shorter than for PV made in Germany, as Sweden’s power is almost entirely renewables and nuclear (see Table 2). However, since various elements of a PV system come from different geographical sources, it is not usually feasible to distinguish between power

[4] ‘Efficiency’ is a measure of the percentage of sunlight energy falling on the PV surface that is converted to useable electrical energy.

[5] Cost PWC needs to be distinguished from cost per Watt of power produced. The former is an idealised figure based on the amount of power a PV system could produce in expected conditions. The latter is a measure of how a system actually performed in given location.

mixes in manufacturing (but see Kannan et al. 2006). Since CPBT is always less than EPBT[6], the latter figure is a sufficient measure of PV's usefulness in GHG mitigation.

Alsema and Nieuwlaar (2000) examined a range of crystalline silicon and thin film[7] PV types in 2000 and found EPBTs of 2 to 8 years, depending on cell type, type of mounting, and level of solar radiation (See Table 1). In high irradiation countries, such as Spain and Italy, EPBT is 60% shorter than in zones of medium irradiation, such as southern Germany, and about half as long as for low irradiation areas such as northern Germany, Britain and Scandinavia.

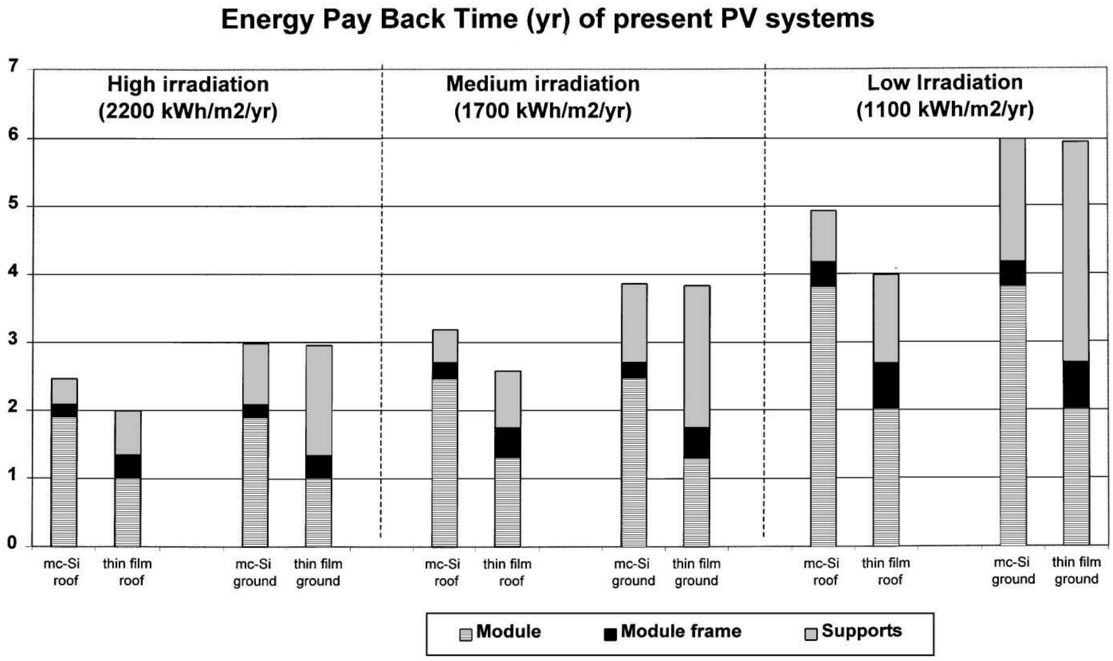

Table 1. The energy pay-back time (in years) for present-day PV applications. Two di!erent module technologies (multicrystalline silicon and thin film amorphous silicon) and two types of installation (ground-mounted and roof-integrated) are distinguished. Source: (Alsema and Nieuwlaar 2000)

More recently, Battisti and Corrado (2005) found EPBTs of 3-4 years on rooftop installations in Rome, while Alsema et al. (2004) found EPBTs of 1.7-2.7 years in South-European locations.

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6 This is because at least some of the power used to manufacture a PV system is likely to have come from renewables.

7 Crystalline silicon is the most common type of commercial PV. Others include 'thin film' and 'concentrator'.

Even shorter EPBTs have been reported with more sophisticated PV types, such as 'concentrator' cells. In these, mirrors are used to concentrate[8] sunlight up to 450 times its natural intensity onto multi-layered cells, each of which is designed to absorb a different frequency. Minassians et al (2006) found EPBTs of 1.5 years in California and 1.2 years in Arizona for the 'SolFocus Gen1' high concentration PV system. Peharz and Dimroth (2005) recorded an EPBT of 1-1.2 years for a 'FLATCON' high concentration system installed in southern Germany, by far the most impressive result, given Germany's mild sunshine.

Provided a PV unit survives its expected lifetime of 20 or more years[9], these EPBTs make PV a viable means of abating GHG emissions. But is deployment of PV a cost-effective way to do this, compared to other renewables? And would the money be better spent on PV R&D? We explore these questions in relation to EU and, in particular, German PV policy.

EU Energy and PV policy

PV policy in the EU comes under the broad headings of energy policy, climate change policy and technology policy[10].

Energy concerns were at the heart of the EU's founding, in 1951, with the European Coal and Steel Community Treaty. **Security of energy supply** has been an issue for the EU since the oil crisis of 1973. It was sharply focused recently when Russia cut off gas supplies to Ukraine in January 2006 and to Belarus a year later. Since these countries act as gas transits to EU states, these actions led to crises of supply. The European Commission proposed a new Energy Plan for Europe (EPE) in April 2007 (EU Commission 2007), which will eventually lead to a Common Energy Policy (CEP).

[8] These should not be confused with 'concentrating solar power', which is a totally different technology that concentrates sunlight on a water boiler that drives a turbine generator.
[9] There are notable examples, such as in a University of East Anglia, UK, building, of PV units failing long before their expected lifetime is complete. But this is not an apparent problem among the huge number of rooftop PV systems manufactured and installed in Germany.
[10] The EU's complex decision making structure is outlined in Appendix 1.

The priorities lying behind the proposed EPE are security of supply, common foreign policy on energy, enhancing the EU internal energy market, promoting renewable energy and promoting research in energy technology (EU Commission 2007).

Parallel to the quest for energy security has been a growing concern over **climate change.** This issue has its own history within EU policy development, but is also represented in texts concerned primarily with energy security. Paragraph 1.1 of the EPE, for example, points out that current EU policies, which lead to high GHG emissions, are 'not sustainable.' (EU Commission 2007, para. 1.1).

The EU launched its 'European Climate Change Programme' (ECCP) in March 2000. This has led to the adoption of a wide range of policies and initiatives, including the EU Emissions Trading Scheme, launched on 1 January 2005, and a focused policy on renewable energy sources (RESs).

In January 2008 the EU Commission put forward the final text of its proposal for EU law on the contributions member states should make so as to reduce GHG emissions to meet EU GHG reduction commitments up to 2020 (EU Commission 2008a). Simultaneously it put forward its proposal for EU law on the promotion of use of renewable energy sources (EU Commission 2008b). Renewables are to make up 20% of energy sources by 2020 within the EU as a whole, and the burden of this is to be shared among EU member states according to an agreed formula related to the proposed GHG reduction targets, plus known existing renewables potential (See Table 2).

The proposed legislation distinguishes three sectors of renewable energy: electricity, heating and transport. 'The overall approach', says the explanatory memorandum, 'is for Member States to retain discretion as to the mix of these sectors in reaching their national target,' (EU Commission 2008b p.7) apart from a mandatory 10% biofuels – a stipulation many are now regretting.

Meanwhile, within the electricity sector, member states will be free to structure their renewable portfolios how they choose. There is no stipulation as to what proportion of wind, solar, biomass, hydro, etc., each state should aim for.

(1)	(2)	(3)
Targets 2020	Reduction target in sectors not covered by the EU ETS compared to 2005	Share Renewables in the final energy demand by 2020
AT	-16.0%	34%
BE	-15.0%	13%
BG	20.0%	16%
CY	-5.0%	13%
CZ	9.0%	13%
DK	-20.0%	30%
EE	11.0%	25%
FI	-16.0%	38%
FR	-14.0%	23%
DE	-14.0%	18%
EL	-4.0%	18%
HU	10.0%	13%
IE	-20.0%	16%
IT	-13.0%	17%
LV	17.0%	42%
LT	15.0%	23%
LU	-20.0%	11%
MT	5.0%	10%
NL	-16.0%	14%
PL	14.0%	15%
PT	1.0%	31%
RO	19.0%	24%
SK	13.0%	14%
SI	4.0%	25%
ES	-10.0%	20%
SE	-17.0%	49%
UK	-16.0%	15%

Table 2. Legally binding targets for EU states, as proposed by the Commission January 2008.

EU PV policy

PV policy is embedded in renewable energy policy, which is in turn embedded in EU Energy policy and EU climate change policy. Hence, PV policy can be seen as having received a boost from the supply crises of 2006 and 2007 and the general acceptance that energy supply is now a crucial issue for the EU, plus a boost from climate change concerns.

A further strand contributing to PV's promotion within the EU is the desire to benefit from being an international leader in **technology development**. The EU Commission has explored this issue separately and in parallel with those of energy supply and climate change, and now points out, as a matter of course, how the concerns reinforce each other. A typical example is:

> '… [Climate] change offers a stepping stone to modernise the European economy, orientating it towards a future where technology and society will be attuned to new needs and where innovation will create new opportunities to feed growth and jobs.' (EU Commission 2008d, p.2)

The three issues of energy supply, climate change and technology development now form a ubiquitous narrative background to EU statements on RES in general and PV in particular. They appear in the preambles or opening paragraphs of virtually all EU documents that deal with climate change or its proposed solutions. An example is the opening sentence of the EU Commission's Proposal for an EU law on the promotion and use of energy from renewable sources:

> 'The Community has long recognised the need to further promote renewable energy given that its exploitation contributes to climate change mitigation through the reduction of greenhouse gas emissions, sustainable development, security of supply and the development of a knowledge based industry creating jobs, economic growth, competitiveness and regional and rural development.' (EU Commission 2008)

PV has a key place in EU policy as one of a number of RES options. But while the EU Commission supports its development, it does not demand or propose premature deployment of this currently uneconomic technology. This is shown clearly in a key Commission document on RES technology, the Technology Map (EU Commission 2007a). This document looks critically at the research needs and potential of major RESs, including PV. One of its key statements is:

> 'The PV industry is not in competition with other RES-based electricity generation industries. The ultimate goal of the community that supports PV systems is *to make the technology competitive* with all sources of electricity in the medium term and then allow all technologies to compete for their fair share in electricity generation.' (EU Commission 2007a. emphasis added)

Member states are clearly free to ‘make this technology competitive’ by any route they choose. Because Germany has taken on this task with enormous commitment, we will now explore German PV policy in some detail.

German PV policy

Germany is not richly endowed with RESs. Unlike Austria and Latvia it has little potential for hydroelectric power. Compared to sunny Italy, Spain and Greece it is dull and cloudy. It is only about half as windy as the UK and has limited coastline for tidal power potential. Its modest geothermal potential has long been exploited for health spas.

Nevertheless, German RES policy has been steps ahead of EU policy for some years. The Renewable Energy Supply Act *(Stromeinspeisungsgesetz)*, of December 1990, obliged electricity grid operators to buy power generated by RES installations smaller than 4 MW at minimum prices. RES sources were defined as hydroelectric, wind power, solar power, biomass, and power from waste and sewage incineration (UO 1998). PV gained a further boost when the Renewable Energy Feed Law *(Erneubare Energien Gesetz – EEG)* came into force in April 2000 (EEG 2004). This set generous guaranteed ‘feed-in-tariffs’ (FITs – the German form of subsidy) that grid operators had to pay for each kWh of power fed into the grid by RES operators.

The ‘100,000 solar roofs’ programme, introduced in 1999, aimed to boost PV power by 300MW by December 2003. Low interest loans of up to 6.23 euros per kWp were offered. The scheme was oversubscribed and had to be revised upwards (Goetzberger and Hoffmann 2005).

The RES share of German electricity generation grew from 3% in 1990 to almost 9% in 2003, when the 100,000 solar roofs programme ended. The EEG was amended in 2004, obliging grid operators to pay more hefty tariffs to RES operators (see Chart 1).

Consequently the RES share of electricity is likely to surpass Germany's goal of 12.5% by 2010[11].

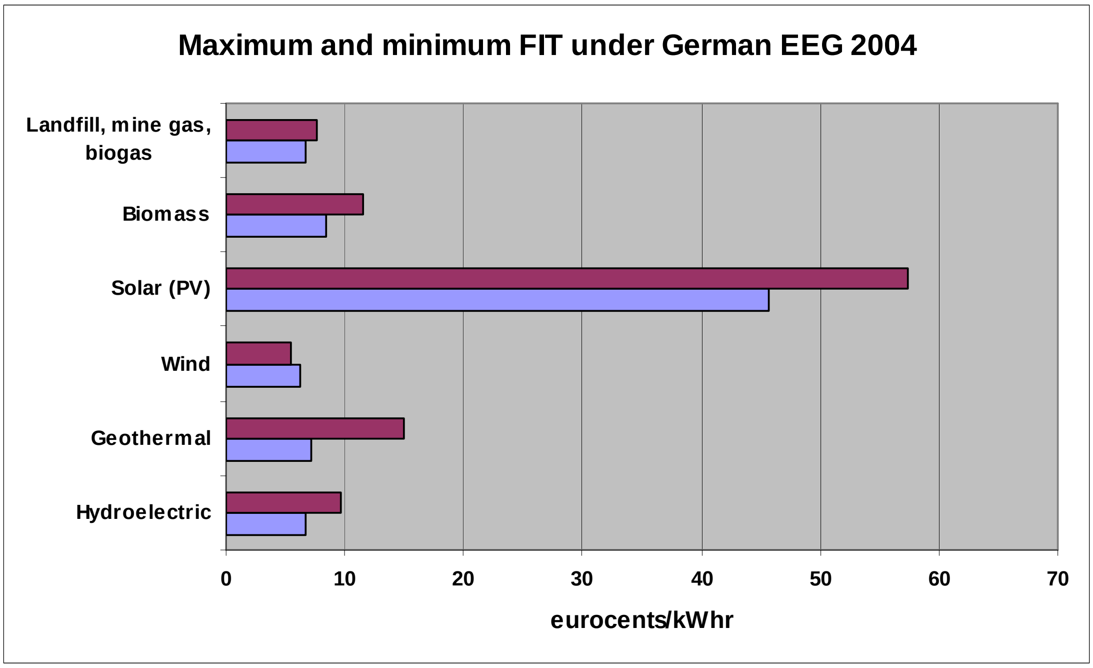


Chart 1. Maximum and minimum feed in tariff under German Renewable Energy Law 2004.

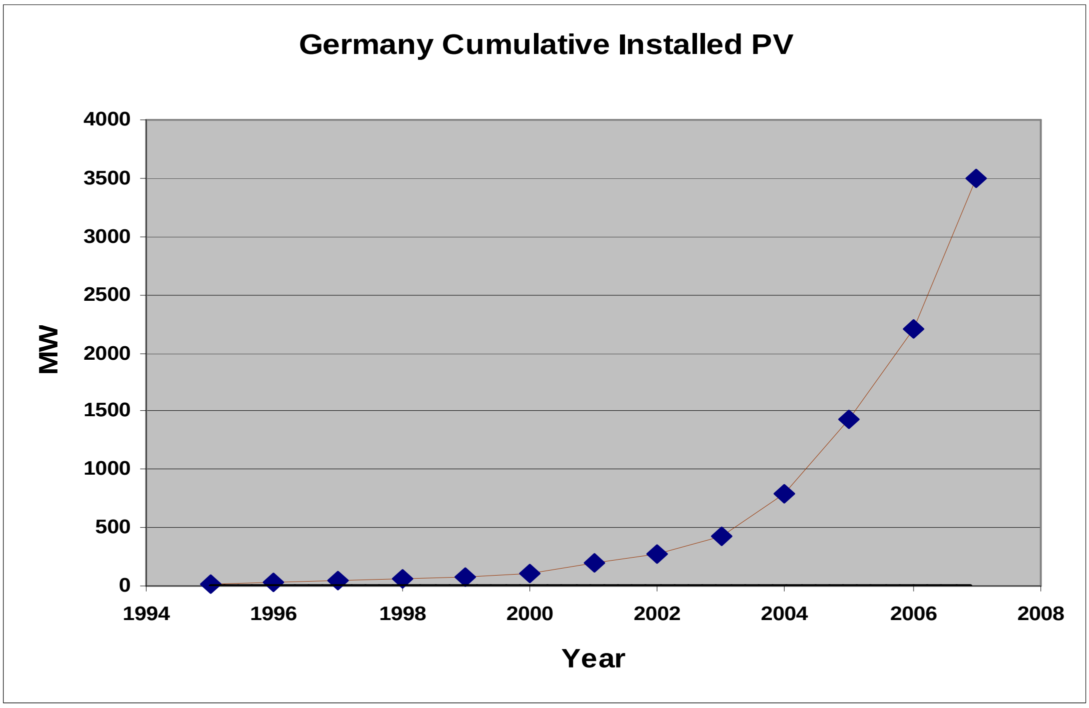
PV has benefited spectacularly from these laws. A specific section deals with it in the EEG, which sets a FIT designed to make it a safe, profitable investment, particularly for small 'rooftop' operators but also for larger installations (EEG 2004 Article 11). The 2004 FIT was set at 45.7 euro cents/kWh for ground-mounted PV systems and 57.4 euro cents/kWh for installations on buildings. It is paid at these rates for 20 years to PV operators who began to generate power in 2004. The starting rate for new operators in subsequent years is tapered, reducing by 5% each year. So, for example, an operator starting in 2005 will receive 95% of 57.4 cents per kWh for 20 years.

As a consequence Germany is now the world's largest producer of PV and accounts for some 35% of the world's PV installed capacity.

How did PV win such generous financial support? The answer lies in large part with extremely successful lobbying by two German Green Party activists, Hans-Josef Fell

[11] Despite a growth in total power consumption by 5% from 1990 to 2003, GHGs from electricity generation declined by 13%. (JGCRI 2004). But this was in large part due to decommissioning of dirty East German power plants after reunification.

and Volker Oschmann, from Hammelburg, a picturesque vineyard town in northern Bavaria. Fell[12], a Federal MP, conceived the FIT in the 1990s, initially setting up a pilot scheme in Hammelburg, which paid a FIT of 2 Deutschmarks per kWhr (Laudatio 2006, Fell 2008). He and Oschmann, a federal bureaucrat, worked very effectively for the100,000 solar roofs programme, the 2000 law and its 2004 amendments (see, e.g. Oschmann et al. 2006) under Gerhard Schroder's Red-Green coalition government.



Graph 1. Cumulative installed PV generating capacity in Germany

The usual justification for massive state-sponsored distribution of PV is a sophisticated argument based on a visionary future: carefully tapered but generous FITs will stimulate the PV industry, drive competition, provoke R&D among manufacturers, develop widespread social acceptance, and lead to early efficiencies in manufacturing, distribution, technical support, maintenance and associated bureaucracy (e.g. Sandén 2003, PV Policy Group 2007).

Without the subsidy, power from a state of the art rooftop PV system connected to the grid costs 4-5 times as much per watt as conventional power - hence the EEG's

[12] It is also claimed that Fell was one of the first in Germany to install a PV system on the roof of his house, which he did in 1991 (Laudatio 2006).

guaranteed tariff of 5 times conventional power price (PV Policy Group 2007, EEG 2004). If PV continues increasing in efficiency at its historic rate, it will be 2081 before it pays its way[13], though possibly much earlier if other power sources become more expensive and there are step-wise breakthroughs in PV efficiency.

But increasing the solar efficiency of PV is not the only way to make it pay. Cost reductions are also being pursued in manufacturing, installation and technical support (Alsema and Nieuwlaar 2000). There is also encouraging research on high-concentration PV (see above), with efficiencies of up to 35%, though this is currently prohibitively expensive (Peharz and Dimroth, 2005). Hence, much current thinking looks forward to an earlier breakeven date. Creuzburg (2005) estimates a future annual 6% increase in overall PV efficiency (i.e. a year-on increment of 6% of the previous years' percentage efficiency), which would bring PV to four times its current efficiency by 2030[14], a date in line with other thinking. But still, all PV systems up to the breakeven time will require a subsidy – money that could have been spent on more focused research and development. Even Sandén, a strong advocate of FIT policy, warns of 'the risk of a premature lock-in of an inferior design' (Sandén 2003).

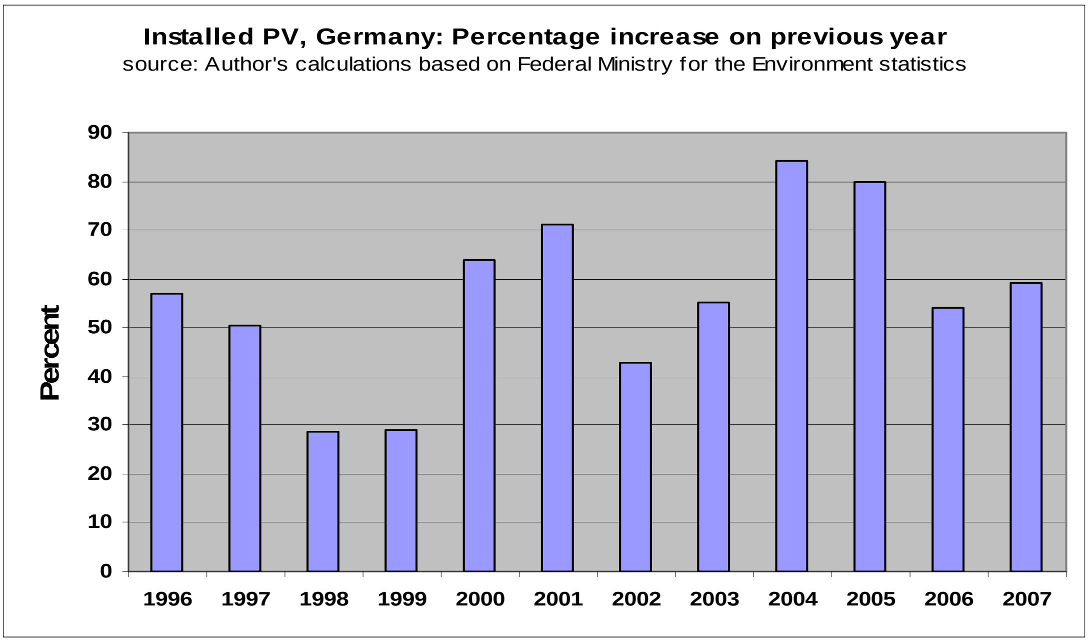


Chart 2. Installed PV, Germany: Percentage increase on previous year
source: Author's calculations based on Federal Ministry for the Environment statistics

[13] Since there are 73 years from now till 2081, efficiency is doubling every 31.64 years, and 2^(73/31.64) = 5
[14] Since 4 = (1/(1-0.06))^22, and there are 22 years from now to 2030.

What it will cost

The author developed a mathematical model to estimate future predictions of total German subsidy (see Appendix 2 and Appendix 3). The model uses parameters for the average annual increase in installed capacity, annual reduction of FIT as set down by the EEG, and the total subsidy for new units paid out in 2004. Under the EEG, units installed in 2004 receive the full FIT for 20 years. Units installed in 2005 receive a FIT of 95% of this rate for 20 years, while those installed in 2006 are subsidised at 95% of *this* rate for 20 years, and so on.

The total subsidy in 2004 was 225 million euros, of which 80 million was for units installed in that year. This payment will continue, for these units, for 20 years, so that the total commitment for units installed in 2004 is 20x80 million = 1.6 billion. Using this as a basis, three scenarios were explored.

Scenario 1. The FIT was set as outlined above. The average annual increase in installed capacity was set at 55%, which has been the average annual increase over the last decade (see Chart 2, and compare BP 2008). In this case, the total subsidy committed by 2020 will be **2.4 trillion euros**, and **116.7 trillion euros** by 2030.

Scenario 2. There is now a government proposal to reduce the FIT more rapidly, by 9.2% in 2008 and 7-9% thereafter (Economist 2008a). Modelling this[15], using the same rate of increase of 55%, shows a total commitment of over **1.7 trillion euros** by 2020 and **61.9 trillion euros** by 2030.

Scenario 3. The government's more modest aim is to increase current PV capacity from 3% of electricity supply to 27% by 2020, a factor of 9 within 12 years, representing an annual increase of about 20%[16]. This would fulfil PV's share of Germany's '20-20 by 2020' goal[17]. Using these parameters, with the reduced FIT in scenario 2, shows a total commitment of over **210 billion euros** by 2020 and **644 billion euros** by 2030.

[15] This model uses a tariff reduction of 8% per year as from 2009, but 5% per year up to 2008.

[16] Since 1.20^12 = 9.

[17] This is the proposal for the EU as a whole to derive 20% of its energy from renewables by 2020, with 20% of transport fuel coming from biofuels.

But the government's figure, of an increase in installed capacity of as little as 20% per year, bears no relation to reality. PV is a safe, lucrative investment under the EEG, and interest is hardly likely to wane overnight.

Further, the PV industry worldwide would be in shock if an annual 20% ceiling were put on German PV expansion. German expansion is a key factor driving the rapid increase in investment in PV worldwide and, ironically, in private R&D. PV is now seen as a lucrative, viable business growth opportunity – not because PV is economic, but because of the artificial but reliable economy the German government has created for it (Chodogam 2008).

But a focused investment in PV R&D of 210 billion euros over 12 years – the absolute minimum subsidy under current policy - could speed the arrival of the breakeven date considerably. Continued subsidies could amount to anything between this figure and hundreds of trillions.

Further, the models show that the present level of financial *commitment* to FIT subsidies is far greater than the (already large) *actual* annual level. For example, the FIT in 2008 will amount to about a billion euros, but the 20-year commitment to *new* PV units installed in 2008 will amount to over 7.5 billion euros. And in 2009, a further 11 billion commitment will be added to this, and so on. The system is unsustainable. Germany's total GDP in 2007 was 3.4 trillion euros. Even our least costly scenario would represent a huge drain on the economy

It could be argued that the government's coffers are safe because the FIT is not a direct government subsidy, as it is paid by grid operators to PV generators. But they pass it on to consumers, so it becomes a cost borne by the public, and functions much like a tax.

PV policy among other EU countries

15 EU countries now have FITs for PV, but most FITs are small and are not boosting the market (Jäger-Waldau 2007, and see Appendix 4). **Slovenia**, for example, has a FIT that is tied to the market electricity price. **Britain** has no FIT but has a RES target

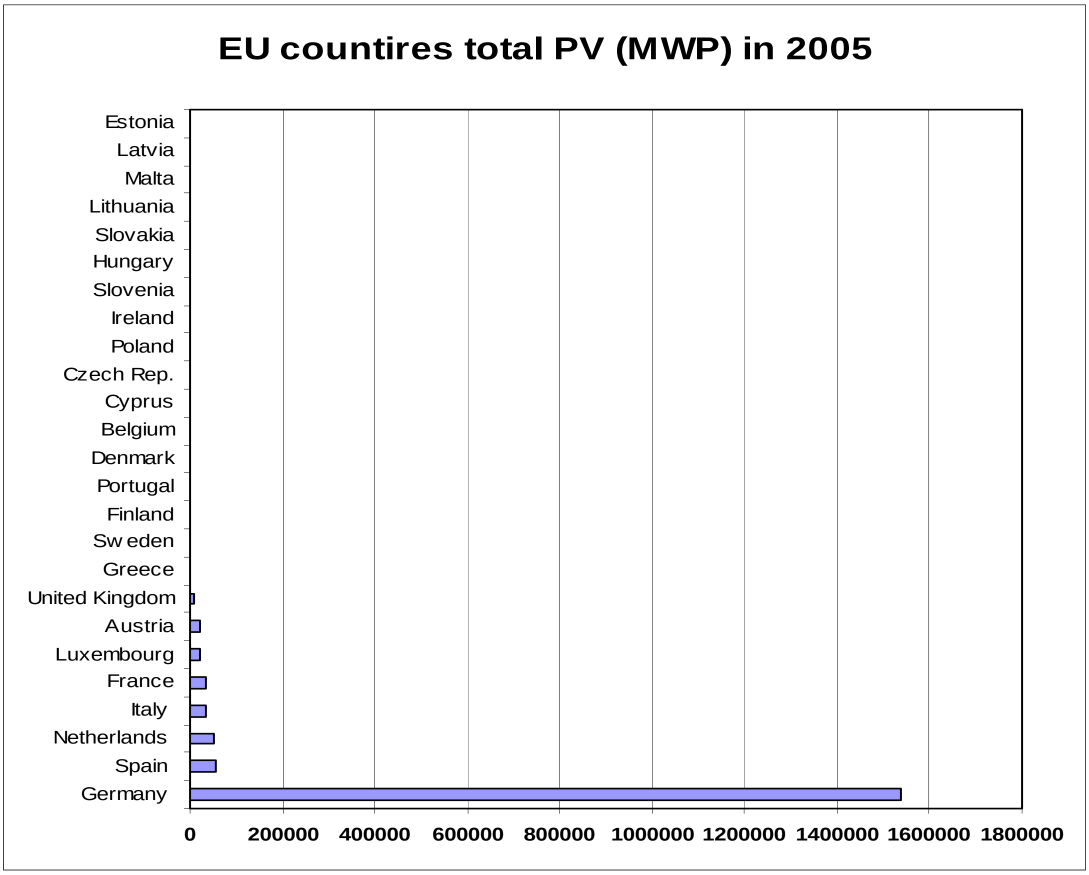


Chart 2. EU countries' total installed PV (MWP) in 2005

of 10% of electricity production by 2010, and 20% by 2020, but no specific PV target. It operates a PV quota system with a subsidy that is hard to get in practice (PV Policy Group 2006, p. 60).

Austria is even more wary of promoting PV. It has no PV strategy, and its current Green Electricity Act limits the maximum total subsidised PV capacity to 15MW, thus 'blocking further market growth.' (PV Policy Group 2006, p. 19)

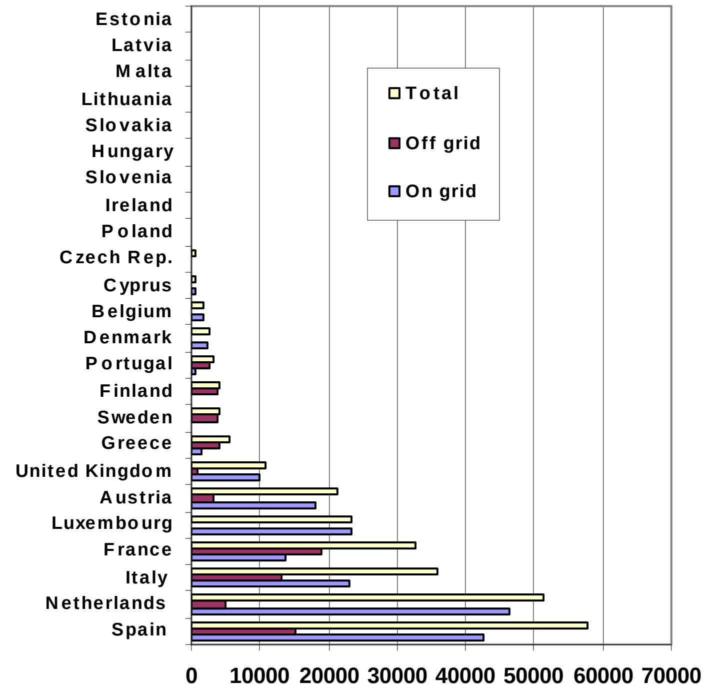
These three are broadly representative of most EU countries. The exceptions, along with Germany, are Greece, Spain, Italy and France (see Chart 2 and Chart 2a).

As of June 2006 **Greece** has a RES law more generous than Germany's. It offers a FIT to PV operators of around 50 eurocents per kWhr, adjusted annually *upwards* for inflation and for increases in the retail electricity price, and guaranteed for 20 years. Like Germany, it has streamlined the permit process for small, grid-connected PV systems. Large commercial systems are eligible for additional grants of up to 60% of their cost. A target of 700MWp minimum has been set for 2020, and installed capacity has shown a steady increase from 1MW in 2000 to 7MW in 2006 (PV Policy Group 2006, Psomos 2007).

Spain has targets for PV of 135MWp capacity by 2010, requiring 122 million euros investment. It offers a FIT of 39-44 eurocents per kWhr, paid directly by the government, plus soft loans, and direct subsidies granted by the Spanish Institute for Energy Diversification and Saving[18] and its regional counterparts. Installed PV is increasing at up to 54% per year and heading towards 100MW.

In **Italy** a FIT is fixed at 50-59 eurocents per kWhr for small (<50MWp) operators, payable for 20 years. There is a competitive tendering scheme for large PV operators, which must bid for payments for power they will offer on the grid. Winners are selected by the Italian Electricity Service[19] (GSN 2008).

Chart 2a. PV (MWP) except Germany 2005



France has a non-binding target of 1-50MWp of installed PV capacity by 2010. PV is seen as a very small niche market, but is supported by a modest FIT of 15.4 eurocent

[18] Instituto para la Diversificación y Ahorro de la Energía - IDAE
[19] Gestori Servizi Electrici –GSN: formerly GRTN

per kWhr, with a 5% abatement and inflation compensation (currently 13.85 eurocents). Investment subsidies are available from the French Environment and Energy Management Agency[20] and regional agencies. Tax credits for PV have recently been increased. These support mechanisms make the average payback time for a small-scale private rooftop PV system 15-30 years, compared with 7 for Germany and about 4 for (sunnier) Greece.

Discussion and conclusions

The EU target of 20% renewable energy by 2020 will be costly because most RES power is more expensive than fossil fuel power. Therefore the target needs to be met in the most economically efficient way. As each country is free to make up its own mix of RESs to meet its allocated portion of the target, countries can pursue efficiency within their own mix of resources, and there is no pressure on any to deploy PV prematurely.

Most EU countries, which are dull and cloudy, have a conservative approach to PV, leaving it to enthusiasts who are prepared to pay its high price. Sunny Mediterranean countries may have less to lose from subsidising it, but even in their climates it comes nowhere near to paying its way.

The handouts for PV in Germany represent a gross misallocation of funds. Spending an extra billion euros per year on PV R&D rather than on operating subsidies would almost certainly hasten the arrival of PV’s commercial viability and therefore lead to much deeper GHG emission cuts sooner, both for the EU and on a worldwide scale as technological advances are shared. Pressure from lobbies such as the PV Policy Group needs to be resisted in other EU countries so that they do not follow Spain, Italy and Greece in taking up the German model.

The world’s largest PV manufacturer, Q-Cells, in Wolfen, near Leipzig, employs 213 people in its R&D department (Q-Cells 2007, cf. Economist 2008a), but the 2007

[20] Association ayant pour la protection de l'environnement et la maitrise de l'énergie: ADEME

subsidy, of 900 million euros, could have paid for 5,000 R&D jobs directly[21]. The additional commitment of a further 7.5 billion euros in 2008, plus a further 11 billion in 2009, would create enough funding for a PV-style Manhattan Project.[22]

A further irony is that the huge German demand for PV keeps the price high and makes it more expensive for sunnier countries which would get up to twice the power per unit. Due to manufacturing bottlenecks, the cost of crystalline silicon has risen from $US25 per kilogram in 2003 to around $US400 today (Economist 2008a).

Is it too late for Germany to pull back from this path? FITs guaranteed for 20 years cannot justly be withdrawn, but there would be no injustice in desisting from starting new contracts. The greater problem would be the social disruption of downsizing the German PV manufacturing and distribution industry, which currently generates some 40,000 jobs (Q-Cells 2007, p. 40) – though each one of these can be accounted for by the size of the year's new subsidy commitment[23].

At the very least, Italy, Spain and Greece should take a warning from this and redirect their funds from FITs to R&D, before a German-style PV juggernaut develops. France's relatively low FIT might be a good compromise position to aim for.

If EU policy makers are serious about GHG abatement they will seek the quickest and most cost-effective way to develop PV to its economic breakeven point. The German government should be challenged to shift public funding from premature deployment of a sub-standard technology to more focused R&D, without any reduction in the annual level of funding.

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[21] This assumes the wages and workplace infrastructure cost 200,000 Euros per year, per worker employed in R&D. Q-Cells does not give a specific figure for cost of R&D in its annual report, but since 213 of its 1,707 employees work in R&D we can roughly estimate that R&D makes up at least 213/1,707 of its annual budget of 190 million euros, i.e. 23.7 million euros. If we assume it actually costs almost twice that much, i.e. 40 million euros, then by the same cost-ratio 900 million euros would provide R&D wages and equipment for 4793 researchers.

[22] The Manhattan project cost $US2 billion, about $US23 billion (18 billion euros) in today's equivalent money (Schwartz 1998).

[23] PV units installed this year will get a guaranteed FIT, spread over 20 years, of about 6 billion euros. This amount would more than pay this year's wages of the 40,000 PV workers in Germany – it would give them an average of 136,000 euros for the year!

Appendix 1: The EU decision making process

'EU policy' has to be carefully defined because the EU is not a sovereign state. Power rests ultimately with the governments of its member states, which alone have the means to implement legislation and enforce it. Nevertheless, to be a member of the EU a country has to enshrine EU rules in its legislation or regulations and undertake to implement and enforce these. Further, EU rules are developing and broadening over time, and there has been a gradual surrender of sovereignty in many areas of policy (Leonard 2005).

In general, EU policy is formed through a process beginning with the **EU Commission.** This body, which sits in Brussels and forms the heart of EU bureaucracy, consists of civil service (non-political) appointees from the 27 member states. It initiates legislation through a lengthy process of consultation, publishing position papers, receiving feedback from the EU Parliament and the European Council, hearing the views of interest groups, and formulating further papers and draft legislation.

To become EU law, the exact wording of a piece of legislation has to be approved by both the **EU Parliament** and the **European Council**. This is not to be confused with the Council of Europe, which is a different body, representing a large number of states in Europe and the Middle East. To add to the confusion the Council of Europe has its headquarters in Strasbourg, which is also one of the two cities where the EU Parliament meets.

Hence an EU 'law' is more properly called 'a Directive of the EU Parliament and the Council' The Parliament is elected by popular vote among EU citizens. The Council consists of a ministerial representative of each member government. While it may have different members for different meetings, according to the policy area under discussion, the European Council is legally only one body. Once every year the heads of government come together for a European Council meeting that has a special kudos, but no more institutional power than any other European Council meeting

Once a document becomes EU law, its member states have two years to enshrine it in legislation or government directives, whichever is appropriate for each law. Governments are also obliged to develop institutions to implement and enforce these laws.

Appendix 2. Spreadsheet results for model of German FIT costs up to 2030 (Scenarios 1 and 2)

German PV Feed in tariff estimates as per EEG Scenario 1					**German PV Feed in tariff estimates as per EEG Scenario 2**		
Year	FIT for newly installed PV (**million** euros)	20 year FIT commitment for each year's new PV (**million** euros)	Total accumulated FIT commitment (**Billion** euros)		FIT for newly installed PV (**million** euros)	20 year FIT commitment for each year's new PV (**million** euros)	Total accumulated FIT commitment (**Billion** euros)
2004	80.0	1600.0	1.600		80.0	1600.0	1.600
2005	117.8	2356.0	3.956		117.8	2356.0	3.956
2006	173.5	3469.2	7.425		173.5	3469.2	7.425
2007	255.4	5108.4	12.534		255.4	5108.4	12.534
2008	376.1	7522.1	20.056		376.1	7522.1	20.056
2009	553.8	11076.3	31.132		536.3	10726.6	30.782
2010	815.5	16309.9	47.442		764.8	15296.1	46.078
2011	1200.8	24016.4	71.458		1090.6	21812.2	67.891
2012	1768.2	35364.1	106.822		1555.2	31104.2	98.995
2013	2603.7	52073.6	158.896		2217.7	44354.6	143.349
2014	3833.9	76678.4	235.574		3162.5	63249.7	206.599
2015	5645.4	112908.9	348.483		4509.7	90194.0	296.793
2016	8312.9	166258.4	514.742		6430.8	128616.7	425.410
2017	12240.8	244815.5	759.557		9170.4	183407.4	608.817
2018	18024.5	360490.8	1120.048		13076.9	261539.0	870.356
2019	26541.1	530822.8	1650.871		18647.7	372954.6	1243.311
2020	39081.8	781636.5	**2432.507**		26591.7	531833.3	**1775.144**
2021	57548.0	1150959.8	3583.467		37919.7	758394.2	2533.538
2022	84739.4	1694788.3	5278.255		54073.5	1081470.2	3615.009
2023	124778.8	2495575.7	7773.831		77108.8	1542176.5	5157.185
2024	183736.8	3674735.2	11448.566		109957.2	2199143.7	7356.329
2025	270552.4	5411047.6	16859.614		156798.9	3135978.9	10492.308
2026	398388.4	7967767.6	24827.382		223595.3	4471905.9	14964.214
2027	586626.9	11732537.8	36559.919		318846.9	6376937.8	21341.151
2028	863808.1	17276161.9	53836.081		454675.7	9093513.3	30434.665
2029	1271957.4	25439148.4	79275.230		648367.5	12967350.0	43402.015
2030	1872957.3	37459146.0	**116734.376**		924572.1	18491441.1	**61893.456**

Appendix 3. Spreadsheet results for model of German FIT costs up to 2030 (scenario 3)

German PV Feed in tariff estimates as per EEG Scenario 3			
Year	FIT for newly installed PV (**million** euros)	20 year FIT commitment for each year's new PV (**million** euros)	Total accumulated FIT commitment (**Billion** euros)
2004	80	1600	1.6
2005	117.8	2356.0	3.956
2006	173.5	3469.2	7.42521
2007	255.4	5108.4	12.53362
2008	376.1	7522.1	20.05576
2009	415.2	8304.4	28.3602
2010	458.4	9168.1	37.5283
2011	506.1	10121.6	47.64988
2012	558.7	11174.2	58.82411
2013	616.8	12336.3	71.16045
2014	681.0	13619.3	84.77978
2015	751.8	15035.7	99.81552
2016	830.0	16599.5	116.415
2017	916.3	18325.8	134.7408
2018	1011.6	20231.7	154.9724
2019	1116.8	22335.8	177.3082
2020	1232.9	24658.7	**201.9669**
2021	1361.2	27223.2	229.1901
2022	1502.7	30054.4	259.2445
2023	1659.0	33180.1	292.4246
2024	1831.5	36630.8	329.0554
2025	2022.0	40440.4	369.4958
2026	2232.3	44646.2	414.142
2027	2464.5	49289.4	463.4314
2028	2720.8	54415.5	517.8469
2029	3003.7	60074.7	577.9216
2030	3316.1	66322.5	**644.2441**

Appendix 4. Support mechanisms for PV in EU and Switzerland.

(Source: Jäger-Waldau 2007)

Support mechanisms for photovoltaic in the European Union and Switzerland (ct = € cent)

Austria	Feed-in tariff paid for 20 years with cap of 15 MWp, but only for systems installed in 2003 and 2004 (cap was reached after only 4 weeks); 0.6 €/kWh < 20 kWp, 0.47 €/kWh > 20 kWp 2005: A new renewable energy law is currently under discussion, but no federal support at the moment. Some of the Federal States have support schemes.
Belgium	Feed-in tariff: 15 ct/kWh; flanders from 1 January 2006: 0.45 ct/kWh (+15 ct/kWh with reverse meter; net feed-in) for 20 years with 16.5 MW cap.
Cyprus	Feed-in tariff: 0.12–0.26 €/kWh and investment subsidies up to 55% for private investors and up to 40% for companies.
Czech Republic	New Law on the Promotion of Production of Electricity from Renewable Energy Sources went into effect on 1 August 2005. Producers of electricity can choose from two support schemes: • Fixed feed-in tariffs • Green Bonus Tariffs are not fixed yet, but the ruling states that the tariffs should be set in such a fashion, that the pay-back time of installations is less than 15 years. In addition, the annual price decrease for new installations should be 5% max.
Denmark	No specific PV programme, but settlement price for green electricity.
Estonia	No specific PV programme but Renewable Portfolio Standard and tax relief. Feed-in tariff for electricity produced out of RES is 5.1 ct/kWh.
Finland	Investment subsidy up to 40%.
France	Feed-in tariff mainland: 15 ct/kWh < 12 MW for 20 years; lower VAT on investments. Feed-in tariff Overseas and Corsica: 30.5 ct/kWh.
Germany	Feed-in tariff for 20 years with built-in annual decrease of 5% from 2005 onward. For plants, neither on buildings nor sound barriers, the decrease will rise to 6.5% from 2006 onward. 2005 tariffs: 43.4 ct/kWh minimum; on buildings and sound barriers 54.5 ct/kWh < 30 kWp, 51.9 ct/kWh > 30 kWp and 51.3 ct/kWh > 100 kWp, for façade integration there is an additional bonus of 5 ct/kWh.
Greece	Feed-in tariff: 0.078 €/kWh on islands and 0.07 €/kWh on the mainland. Grants for 40–50% of total cost. Holds only for commercial applications > 5 kW, no grants for domestic applications. Law 2364/95 introduces a reduction of the taxable income of final users installing renewable energy systems in private buildings (75% of costs for purchase and installation is tax-deductible).
Hungary	Ministerial Decree 56/2002: guaranteed feed-in tariff (on indefinite term), beginning in January 2003, all energy generated from renewable energy resources must be purchased between 6 and 6.8 ct/kWh, not technology-specific. Subsidies for renewable energy projects.
Ireland	Alternative Energy Requirement tender scheme (no targets for PV).
Italy	Feed-in tariff: guaranteed for 20 years. The tariffs for 2005 and 2006 are listed below, after that there is a 2% decrease for new systems each year, but tariffs will be corrected according to inflation (ISTAT): (1) up to 20 kW: 44.5 ct/kWh (1 and 2 together have a cap of 60 MW), (2) between 20 and 50 kW: 46 ct/kWh, (3) between 50 kW and 1 MW: 49 ct/kWh (cap of 40 MW).

(continued overleaf)

Latvia	Feed-in tariff: Licensed before 01.06.2001: double the average sales price (~10.1 ct/kWh) for 8 years, then reduction to normal sales price. Licensed after 01.06.2001: Regulator sets the price. A national investment programme for RES has been running since 2002.
Lithuania	Feed-in tariff: 5.6 ct/kWh.
Luxembourg	Feed-in with quota (1% of total energy consumption). < 50 kWp: municipalities 25 ct/kWh and private investors: 45 ct/kWh (after the revision of the law in January 2004); in addition, investment subsidies up to 40% possible (this was also reduced for systems > 10 kWp).
Malta	No specific PV programme yet, but reduced VAT 5% instead of 15%.
Netherlands	Feed-in tariff: 6.8 ct/kWh.
Poland	Tax incentives: no customs duty on PV and reduced VAT (7%) for complete PV systems, but 22% for modules and components. Some soft loans and subsidies. A new law was passed in April 2004 that tariffs for all renewable energies have to be approved by the regulator (until now only for projects larger than 5 MW).
Portugal	Feed-in tariff: 41 ct/kWh < 5 kWp and 0.224 ct/kWh > 5 kWp. In addition investment subsidies and tax deductions are available.
Slovakia	Feed-in tariff st by regulator each year: 8 SKK/kWh (ca. 26 ct/kWh) for 2006. Tax deduction on income earned. RES feed-in tariff in 2005: ~3 ct/kWh.
Slovenia[a]	Feed-in tariff: either fixed price or electricity price (8 SIT/kWh) + premium. Uniform annual price: 37.4 ct/kWh < 36 kWp and 6.4 ct/kWh > 36 kWp. Uniform annual premium: 34.0 ct/kWh < 36 kWp and 3.1 ct/kWh > 36 kWp.
Spain	Feed-in tariff with cap of 150 MW: 0.396 €/kWh < 100 kWp for 20 years (previously limited to 5 kWp systems), with payment on 80% of rated power output beyond that; > 100 kWp 0.216 €/kWh.
Sweden	70% tax deduction on investment and installation cost for systems on public buildings proposed as from beginning of 2005 and for 36 months onwards. Electricity certificates for wind, solar, biomass, geothermal and small hydro. Energy tax exemption.
Switzerland	Net metering with feed-in tariff of min. 0.15 CHF/kWh (10 ct/kWh); investment subsidies in some cantons; promotion of voluntary measures (solar stock exchanges, green power marketing).
United Kingdom	Investment subsidies in the framework of a PV demonstration programme. Reduced VAT.

[a]1 °€~240 °SIT.

Appendix 5: ABBREVIATIONS:

ECCP: European Climate Change Programme

EEG: *Erneubare Enegien Gesetz* – German Renewable Energy Law

EPE: Energy Plan for Europe, as put forward by the EU Commission

EPBT: Energy payback time

CPBT: Carbon payback time

FIT: Feed in tariff (guaranteed payment to renewable electricity generator for each kWhr of power fed into the grid)

GHG: Greenhouse gas

kWhr: kilowatt hour (of power)

kWp: kilowatts of potential power generation

MWp: megawatts of potential power generation

PV: Photovoltaic(s) – solar power generators based on sunlight causing electric current to flow in a medium

PWC: per Watt of production capacity (e.g. $5 PWC means it costs $5 to make a unit that has a maximum power output of 1 Watt)

R&D: Research and development

RES: Renewable energy source(s)

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