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# Electricity from Renewables in the EU: Feed-in Tariffs and the 2020 Targets

A Master's Thesis submitted for the degree of
"Master of Science"

supervised by
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# Affidavit

I, **Luka Jazbec**, hereby declare

1. that I am the sole author of the present Master's Thesis, "Electricity from Renewables in the EU: Feed-in Tariffs and the 2020 Targets", 102 pages, bound, and that I have not used any source or tool other than those referenced or any other illicit aid or tool, and
2. that I have not prior to this date submitted this Master's Thesis as an examination paper in any form in Austria or abroad.

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## ACKNOWLEDGEMENTS

**I would like to thank my supervisor Prof. Dr. Brauner for his help and advice, and all the people, from A to Z, that make this world what it is – worth saving.**

***For Maja, the environmentalist, and Milan, the diplomat***

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## ABSTRACT

The EU´s climate policy for 2020 consists of a 20% reduction in greenhouse gas emissions, a 20% improvement in energy efficiency, and a 20% share of renewable in energy consumption. The latter share is allocated differently across Member States, and broken down into the sectors of heating and cooling, electricity, and transport. We focus on the electricity sector and on three Member States with similar 2020 targets and similar support measures (i.e. variations on feed-in tariffs) in place to achieve these targets: Germany, Spain, and Slovenia.

First, we attempt to internalize the positive externality of carbon dioxide emissions avoided, using various estimates of the social cost of carbon, to evaluate how the benefits of emissions avoided, due to additional renewable energy deployment, compare to the additional costs imposed on society from use of the feed-in tariffs. Second, we compare and evaluate the progress made by the three Member States towards reaching the indicative targets from their National Renewable Energy Action Plans, in the 2010-2012, and comment on the effectiveness of their feed-in tariff structures. Third, we use the data on progress made so far to comment on the perspectives of each Member State for reaching their 2020 target.

We find that for some technologies and under some estimates of the social cost of carbon, the benefits of carbon dioxide emissions avoided exceed the minimum additional costs imposed on society by the use of feed-in tariffs. This is the case mainly for more established technologies, such as wind and hydro. The maximum additional costs imposed on society exceed the benefits, regardless of the social cost of carbon estimate used. These results, due to the assumptions used, should be taken as illustrative of a theoretical possibility, and not a practical certainty. In any case, it is the costs of feed-in tariffs for solar photovoltaic that are most controversial, and for these the costs outweigh the benefits in terms of emissions avoided, regardless of the estimate of the social cost of carbon used.

With regard to progress made in 2010-2012, we find that Germany and Slovenia have met their targets while Spain has likely not, although due to the data used, we cannot be certain. On the basis of this, we judge that Germany is well on track to meet its 2020 target for electricity produced from renewable energy sources. The situation in Spain looks more pessimistic, particularly as a result of Royal Decree 1/2012, which suspended feed-in tariffs for new installations. Finally, while Slovenia has been meeting its targets, we note that solar photovoltaic is experiencing a boom (much like in Germany and Spain in previous years), which may cause problems for the feed-in tariff system in the future (much like it has in Germany and Spain).

## 1. INTRODUCTION

In the fight against climate change, the European Union has ambitious goals. In the short-term, these are contained in the 2020 strategy, composed of a 20% reduction in greenhouse gas emissions, a 20% share of renewable energy in final energy consumption, and a 20% increase in energy efficiency (COMM, 2007).

Directive 2009/28/EC, also known as the Renewables Directive, sets out the 20% share of renewable energy in final energy consumption target and further sub-divides it amongst different sectors, namely electricity, heating and cooling, and transport (DIR 2009/28/EC). The targets are distributed differently among different member states, according to their respective potential and capabilities. In order to achieve their respective targets, each member state had to submit a National Renewable Energy Action Plan (NREAP) by 2010, outlining an indicative trajectory for development of renewables in the 2010-2020 period and explaining what measures are in place to ensure the achievements of their targets. The member states are also required by article 22 of Directive 2009/28/EC to submit progress reports to the European Commission on the progress made in the previous two years, every two years, starting with 2011 (DIR 2009/28/EC).

In the electricity sector, generation by most renewable energy technologies is uncompetitive and requires the use of support measures (Owen, 2006). While the measures implemented in the member states vary, by far the most common type of support measure is a variation of the feed-in tariff, whereby each producer of electricity from renewable energy sources is paid a certain price for producing electricity (Lesser and Su, 2008). This price may be fixed, or it may be a premium on top of the market price. Additionally, depending on their generation costs and other factors, the feed-in tariffs differ from one type of renewable energy technology to another. While feed-in tariffs are generally acknowledged to be the most effective of support policies (CSWD, 2008), they are not without controversy, particularly with regard to the high additional costs they impose on society. However, they are seen by many as necessary in order to overcome the cost difference between renewable energy sources and conventional energy generation, a cost difference that is, amongst other factors, due to positive externalities of renewables and negative externalities of conventional generation, neither of which is taken into account in the pricing system (Lehmann and Gawel, 2011).

We focus on three EU Member States with similar 2020 targets for electricity generation from renewable energy sources – Germany, Spain, and Slovenia (NREAP DE, 2010; NREAP ES, 2010; NREAP SI, 2010). Each of the three uses a variation of the feed-in tariff as the main support measure for promotion of renewable energy sources for electricity generation. As of 2010, Germany had a fixed feed-in tariff system, Spain had both a fixed tariff and a premium tariff (with price floors and ceilings), and Slovenia had both a fixed tariff and a premium tariff (without price floors and ceilings). Our purpose here is two-fold: we attempt to internalize the positive externality of carbon dioxide emissions avoided by renewable energy deployment and evaluate how this affects the additional costs imposed on society by the use of feed-in tariffs for Germany, Spain, and Slovenia in the 2010-

2020 period, and we analyse and evaluate the actual progress made by Germany, Spain, and Slovenia towards their NREAP targets in the 2010-2012 period. We proceed as follows:

First, we evaluate the costs of the feed-in tariffs by attempting to take into account one of the main positive externalities of electricity generation by renewable energy sources – the emissions of carbon dioxide avoided, and the benefits thereof. Our aim here is to put feed-in tariffs into perspective – they impose additional costs on society, but they also yield benefits that must not be disregarded. We do this for each of the three member states of interest, for each type of technology, for each year in their respective 2010-2020 NREAP indicative trajectories.

Second, we investigate the progress made by each of the member states in the years 2010-2012, both quantitatively by comparing the actual progress in installed capacity of, and electricity produced by, renewable energy sources to the yearly targets as stated in the NREAP indicative trajectories, and qualitatively, by looking at other developments such as changes in legislation and adjustments made to the feed-in tariff structure. We also evaluate the effectiveness of the feed-in tariff structures in each member state in 2011, compare these to their effectiveness in 2010, and attempt to link them to changes in the feed-in tariff structure framework.

Third, we use the evidence on progress (or lack thereof) in the 2010-2012 period, and the changes made in the legislative framework, to evaluate the prospects of reaching the 2020 NREAP targets for each member state of interest, identifying areas of concern and where there is room for improvement.

Essentially, our work will guided by the following research questions:

1. *Is there a point in the NREAP indicative trajectories at which the benefits from emissions avoided due to the feed-in tariffs exceed the additional costs imposed on society by the feed-in tariffs? And, if so, for which technology types and under which assumptions regarding the social cost of carbon?*

2. *How the Member States of interest have progressed in reaching the targets for electricity from renewable energy sources as stated in their respective NREAP indicative trajectories? What other developments are significant?*

3. *What are the implications of the progress made, and the developments that have occurred, in the 2010-2012 period with regard to reaching the NREAP targets for 2020?*

The structure of the thesis is as follows:

Section 2 deals with the background of the various aspects investigated. Thus, we take a brief look at the background behind the EU's 2020 policy, focusing on the electricity sector, and explain the need for support measures for renewable energy in general, and their interactions with the EU ETS, a point of controversy in the literature. We then proceed to look at the theoretical basis behind designing feed-in tariff systems, and at the systems in place in Germany, Spain, and Slovenia as of

2010. Finally, we look at the state of the art research for the two main areas we investigate: the member states' NREAPs, the effectiveness of the support measures, and the issues involving estimates of the social cost of carbon.

Section 3 deals with our methodology, explaining how the cost-benefit comparison of feed-in tariffs was carried out. Additionally, we comment on the data used for evaluating the progress made in 2011 and 2012, and some of the issues with making it comparable to Table 10 of the NREAP, which list the indicative trajectories for the period of 2010-2020.

Section 4 shows our results, section 5 is a discussion of our results where we answer our research questions, and section 6 highlights the main conclusions of our work.

## 2. BACKGROUND

### 2.1. European Union Climate Policy

The European Union "*considers itself as a forerunner in climate protection*" (Böhringer et al., 2009) with a very ambitious climate policy. Despite the absence of a binding international agreement, the EU has set itself the following targets to be achieved by 2020: reducing greenhouse gas emissions by 20%, improving energy efficiency by 20%, and increasing the share of renewable energy to 20% Commission (COMM, 2007).

Promoting the use of renewable energy sources for electricity production as a priority for the European Union was set out in a 1997 White Paper, endorsed by resolutions in both the Council and the European Parliament, and was set out in a 2001 Directive (DIR 2001/77/EC), citing "*reasons of security and diversification of energy supply, of environmental protection and of social and economic cohesion*" (DIR 2001/77/EC). The Directive requires Member States to adopt national indicative targets for electricity production from renewable energy sources until 2010, and to outline the measures implemented or planned to reach them, in order to reach an EU-wide target of a 22.1% share of renewable energy sources in total electricity consumption (DIR 2001/77/EC).

The 2001 Directive was replaced by Directive 2009/28/EC, which further defines and details the 20% share of renewable sources in energy, and translates the overall target to individual Member State targets, "*taking account of Member States' different starting points and potentials, including the existing level of energy from renewable sources and the energy mix*" (DIR 2009/28/EC). More specifically, this is done

> "*by sharing the required total increase in the use of energy from renewable sources between Member States on the basis of an equal increase in each Member State's share weighted by their GDP, modulated to reflect their starting points, and by accounting in terms of gross final consumption of energy, with account taken of Member States' past efforts with regard to the use of energy from renewable sources*" (DIR 2009/28/EC).

In addition, a separate target of minimum 10% renewable energy in transport is set, "*at the same level for each Member State in order to ensure consistency in transport fuel specifications and availability*" (DIR 2009/28/EC).

Each Member State is required by the Renewables Directive to adopt, by 2010, a national plan on how it intends to achieve its 2020 targets, including the policy measures that are or will be implemented, and submit it to the European Commission; this is the National Renewable Energy Action Plan (NREAP) for the 2010-2020 period (DIR 2009/28/EC). The Directive also requires Member States to report on their progress made every two years, starting in 2011 (DIR 2009/28/EC).

In the NREAP, a Member State's overall target is sub-divided into the share of renewable energy sources in total consumption in three sectors: electricity, heating and cooling, and transport (DIR 2009/28/EC). Member States may of course set their own targets higher than those required by the Renewables Directive, and they may divide the overall target across the three sectors depending on their situation. We limit ourselves to investigating renewable energy sources in the electricity sector, and in three Member States – Germany, Spain, and Slovenia – which have similar targets in that sector. The overall 2020 targets and the sectoral targets of these three member states are as follows:

| | 2020 Target (Directive 2009/28/EC) (%) | 2020 Target (NREAP) (%) | Heating & Cooling (%) | Electricity (%) | Transport (%) |
|---|---|---|---|---|---|
| Germany | 18 | 19.6 | 15.5 | 38.6 | 13.2 |
| Spain | 20 | 22.7 | 18.9 | 40.0 | 13.6 |
| Slovenia | 25 | 25.3 | 30.8 | 39.3 | 10.5 |

**Table 1 - 2020 Targets (adapted from DIR 2009/28/EC, NREAP DE 2010, NREAP ES 2010, NREAP SI 2010)**

These three member states have set their NREAP 2020 targets higher than those required by the Renewables Directive, with Spain having the highest difference and Slovenia only a slight increase in their NREAP 2020 target.

The Directive also defines support measures, as

> "*any instrument, scheme or mechanism […] that promotes the use of energy from renewable sources by reducing the cost of that energy, increasing the price at which it can be sold, or increasing, by means of a renewable energy obligation or otherwise, the volume of such energy purchased. This includes, but is not restricted to, investment aid, tax exemptions or reductions, tax refunds, renewable energy obligation support schemes including those using green certificates, and direct price support schemes including feed-in tariffs and premium payments*" (DIR 2009/28/EC).

We turn to the need for these support schemes next.

## 2.2. The Need for Support Schemes

Electricity and other forms of energy produced using renewable energy sources are generally not competitive on price with conventional, i.e. fossil-fuel based, generation methods (Owen, 2006). However, a number of obstacles prevent a true comparison; for example, the non-internalization of externalities, "*where certain environmental costs of production are not reflected in the market cost of the commodity*" (Owen, 2006), favors fossil-fuel based power generation over renewable energy sources, and their cost advantage is further increased by the existence of both direct and indirect subsidies for fossil-fuel based power generation in many countries (Owen, 2006). Externalities are a type of market failure, and market failures lead to outcomes deviate from the economically efficient outcomes that perfectly functioning markets would provide (Gillingham and Sweeney, 2010). According to economic theory, "*policy measures to mitigate these deviations can improve net social welfare, as long as the cost of implementing the policy is less than the gains if the deviations can be successfully mitigated*" (Gillingham and Sweeney, 2010).

The types of market failures associated with renewable energy sources are many. Certainly, environmental externalities are the first, as they provide "*the underlying motivation for much of the interest in renewable energy*" (Gillingham and Sweeney, 2010). These consist of the damages from $CO_2$ emissions, as well as non-$CO_2$ emissions; for example, the ExternE study estimated that non-greenhouse gas pollution damages, such as acid rain and health impacts, of the coal fuel cycle are in the range of 0.2 to 4 Euro cents per kWh (Owen, 2006). Damages from $CO_2$ emissions are harder to estimate, due to the uncertainty surrounding climate change, and we take a look at these a bit later, but what is certain is that $CO_2$ emissions do cause damage and that the costs thereof are not taken into account in the price of energy generated from fossil fuels.

The security of supply of fossil fuels also presents an important externality not considered in the pricing system, particularly for oil, "*with the bulk of the oil reserves in the hands of national oil companies in unstable regions or countries of the world*" (Gillingham and Sweeney, 2010). For Europe, natural gas is subject to supply risks (Gillingham and Sweeney, 2010). Although the externalities associated with security of supply are more difficult to quantify than environmental externalities, they may be substantial (Gillingham and Sweeney, 2010).

Another type of market failure involves economies of scale, "*a situation where the average cost of producing a unit decreases as the rate of output at any given time increases*" (Gillingham and Sweeney, 2010). This is a result of learning-by-doing, and the learning curves for renewable energy sources, particularly solar photovoltaic, are quite steep, i.e. an increase in output leads to high price reductions (Owen, 2006). Increased investment in research and development is also a contributing factor to the learning effect, but is characterized by spillovers; new knowledge can be transmitted, so that the results of successful research & development by one firm can yield benefits to other firms (Gillingham and Sweeney, 2010). As the firm doing the investing is unable to capture all of the benefits of its investment, this "*typically results in significant underinvestment in R&D and suboptimally low levels of technology adoption*" (Lehmann and Gawel, 2011). Both learning by doing and research & development spillovers are market failures involving "*imperfect capture of future payoffs from current actions*" (Gillingham and Sweeney, 2010).

The deployment of renewable energy sources is also influenced by market power (Gillingham and Sweeney, 2010). The liberalization of the electricity market in EU Member States was done with the aim of increasing competition, but generally has led to mergers and acquisitions that increased market concentration instead of competition, and has led to higher electricity prices (Brandt, 2006). In all three member states of interest, the electricity market can be considered an oligopoly (see Brandt 2006; Crampes and Fabra, 2004; EA RS, 2010). On an EU-wide level, the electricity market structure "*is likely to be conducive to anticompetitive behavior*" (London Economics, 2006). The market power of large electricity generation firms, particularly if they own the distribution companies as well, can lead to favoring fossil-fuel based generation (Gillingham and Sweeney, 2010), although it must be noted that "*the existence of market power is not necessarily evidence of its abuse*" (London Economics, 2006).

All market failures are market barriers in the sense that they prevent the market from producing efficient outcomes, but there are additional market barriers that are not market failures yet prevent or limit the development of a market for a good, i.e. act as disincentives (Gillingham and Sweeney, 2010). A good overview of the various market barriers, including market failures, and these, as well as mitigation measures that can be taken, are found in table 2 below.

Types of market barriers and measures that can alleviate them

| Barrier | Key characteristics | Typical measures |
|---|---|---|
| Uncompetitive market price | Scale economies and learning benefits have not yet been realised | • Learning investments<br>• Additional technical development |
| Price distortion | Costs associated with incumbent technologies may not be included in their prices; incumbent technologies may be subsidised | • Regulation to internalise 'externalities' or remove subsidies<br>• Special offsetting taxes or levies<br>• Removal of subsidies |
| Information | Availability and nature of a product must be understood at the time of investment | • Standardisation<br>• Labelling |
| Transactions costs | Costs of administering a decision to purchase and use equipment(overlaps with "Information" above) | • Reliable independent information sources<br>• Convenient & transparent calculation methods for decision making |
| Buyer's risk | • Perception of risk may differ from actual risk (e.g. 'pay-back gap')<br>• Difficulty in forecasting over an appropriate time period | • Demonstration<br>• Routines to make life-cycle cost calculations easy |
| Finance | • Initial cost may be high threshold<br>• Imperfections in market access to funds | • Third party financing options<br>• Special funding<br>• Adjust financial structure |
| Inefficient market organisation in relation to new technologies | • Incentives inappropriately split—owner/designer/user not the same<br>• Traditional business boundaries may be inappropriate<br>• Established companies may have market power to guard their positions | • Restructure markets<br>• Market liberalisation could force market participants to find new solutions |
| Excessive/inefficient regulation | Regulation based on industry tradition laid down in standards and codes not in pace with developments | • Regulatory reform<br>• Performance based regulation |
| Capital stock turnover rates | Sunk costs, tax rules that require long depreciation & inertia | • Adjust tax rules<br>• Capital subsidies |
| Technology-specific barriers | Often related to existing infrastructures in regard to hardware and the institutional skill to handle it | • Focus on system aspects in use of technology<br>• Connect measures to other important business issues (productivity, environment) |

**Table 2 - Market Barriers and Mitigation Measures (Owen, 2006)**

As we have seen, the majority of the market barriers above can be related to the market for renewable energy sources, from learning benefits that have not yet been realized to financing (e.g. high initial costs, but low running costs), and thus some policy measures to promote renewable energy sources both necessary and justified (Owen, 2006). A variety of measures can be taken to mitigate these market barriers; while table 2 above lists general measures, more specific measures relating to renewable energy sources can be found in table 3 (Gillingham and Sweeney, 2010) below.

| Some Potential Policy Instruments | |
|---|---|
| Direct Regulation | command and control methods (e.g., requiring firms to generate electricity from renewable energy resources) |
| Direct Government-Sponsored R&D | government funding for scientists and engineers working on improving different renewable energy technologies, support for national laboratories, funding research prizes such as "X prizes" |
| R&D Tax Incentives | subsidies for private renewable energy technology R&D |
| Instruments to Correct Market Prices<br>- excise taxes<br>- cap-and-trade<br>- subsidies | "get prices right" by adding to the cost of goods (e.g., through a tax or a permit price) or reducing the cost of goods (e.g., through a subsidy) |
| Feed-In Tariffs | require electric utilities to purchase electricity from other generators (often small renewable energy generators) at a specified price |
| Information Programs | education campaigns and required labels |
| Product Standards | require firms to improve their product characteristics to meet a specified goal (e.g., efficiency of solar PV cell or energy efficiency of lighting) |
| Marketable Market-Wide Standards<br>- renewable portfolio standards<br>- low carbon fuel standards<br>- corporate average fuel economy standards | require firms (e.g., utilities) to meet a specified standard (e.g., produce a specified amount of electricity from renewables) or purchase permits or certificates from other firms who over-comply with the standard |
| Transparency Rules | require firms to provide more information about their current conditions to investors |
| Macroeconomic Policy | fiscal or monetary policies to stabilize the economy and provide liquidity to markets to reduce credit constraints |
| Corporate Taxation Reform | adjusting the corporate income tax to improve corporate incentives |
| Competition Policy/Laws | reduce the exercise of market power through anti-trust action |
| Restructured Regulation | reduce regulatory failures and loopholes in regulations that allow for market power |
| Intellectual Property Law | laws to encourage innovation by allowing innovators to appropriate the benefits of their work |

**Table 3 - Policy Instruments to Overcome Market Failures (Gillingham and Sweeney, 2010)**

In the EU, different Member States use different policy measures, but the ones most frequently applied are feed-in tariffs and quota obligations (Steinhilber et al., 2011). However, they are accompanied by other measures, such as the EU Emissions Trading Scheme, and before we tackle feed-in tariffs themselves, it will be useful to take a quick look at how support measures for renewable energy and the EU ETS interact.

## 2.3. Policy Interactions

The combination of the EU-wide ETS with support measures for renewable energy at the member state level has been criticized, with "*oftentimes observed disqualification of RES-E support schemes in academic literature*" (Lehmann and Gawel, 2011). The criticism is based on the Tinbergen rule in economics, which states that "*in order to reach one policy target only one policy instrument should be used*" (Böhringer et al., 2009). Thus, the use of multiple policy instruments (the ETS and support measures for electricity from renewable energy sources) to achieve one policy goal (prevent climate change via a reduction in greenhouse gases) is generally seen as inefficient (Böhringer et al., 2009).

More specifically, some authors go as far as recommending the abolishment of support measures (Lehmann and Gawel, 2011), with the argument that support measures for electricity from renewable energy sources "*do not contribute anything to $CO_2$ emissions reduction in the presence of the EU ETS*" (Lehmann and Gawel, 2011) and in fact increase the costs of the ETS (Lehmann and Gawel, 2011). The mechanism through which this occurs is as follows: electricity from fossil fuels is replaced by electricity from renewable energy sources, leading to lower demand for emissions allowances by the electricity sector, resulting in a lower price of emissions allowances which are purchased by emitters in other sectors who now have a lower incentive to abate emissions (Lehmann and Gawel, 2011). Thus, instead of emissions being reduced, they are only shifted from one sector to another (Lehmann and Gawel, 2011).

This view depends on one crucial assumption, that competition for electricity generation technologies would be efficient with only the ETS in place, which itself assumes that optimal levels of technology development and adoption happen through the market, existing policy instruments do not distort technological choice, and that optimal technology mixes can be continuously composed based on marginal generation costs (Lehmann and Gawel, 2011). A second assumption is that promotion of renewable energy sources has the same goal, and only the same goal, as the EU ETS, namely the reduction of greenhouse gas emissions (Lehmann and Gawel, 2011). However, as we have seen, these assumptions do not accurately reflect reality; there are a number of other market barriers and failures involved that necessitate support measures, and increased deployment of renewable energy sources is aimed not only at tackling climate change but also to improve energy security.

Furthermore, the EU ETS itself is far from perfect. Emission allowances are allocated in phases; phase 1, lasting from 2005 to 2007, was criticized for reasons of over-allocation, distortion of allocation among member states, and windfall profits as initial emissions allowances were given out for free, while phase 2, lasting from 2008 to 2012, saw some improvements, in particular the elimination of over-allocation (Egenhofer et al., 2011). The power sector in particular saw windfall profits, although this will change in phase 3, covering the period from 2013-2020, as power companies will have to buy initial allowances through auctions (Egenhofer et al., 2011). Furthermore, the ETS covers only energy-intensive installations, accounting for less than 50% of total EU greenhouse gas emissions, and according to (Böhringer et al., 2009) the excess costs of this segmentation are higher than the excess costs of overlapping regulation.

Thus, despite the criticisms raised, when one considers "*real-world conditions (…) a policy mix of the EU ETS and complementary RES-E support schemes may be justified for a variety of reasons*" (Lehmann and Gawel, 2011). We now turn to examine feed-in tariffs in more detail.

## 2.4. Feed-in Tariffs: Theoretical Approaches

As of 2010, 21 of the 27 EU Member States used a variation of the feed-in tariff to support electricity production from renewable energy sources (Canton and Linden, 2010). This is no surprise, as a 2008 European Commission document accompanying the proposal that became the Renewables Directive notes that "*well-adapted feed in tariff regimes are generally the most efficient and effective support schemes for promoting renewable electricity*" (CSWD 2008). The attribute that all have in common is "*a guarantee of a long-term minimum price for generated electricity*" (Lesser and Su, 2008), which provides financial stability for investors and encourages increase in installed capacity (Lesser and Su, 2008). Feed-in tariff policies "*can significantly reduce the risks of investing in renewable energy technologies and thus create conditions conducive to rapid market growth*" (Couture and Gagnon, 2010).

The design of a feed-in tariff policy involves defining three attributes – the level of remuneration (and whether this is differentiated by technology and/or installation size), the structure of remuneration (fixed, or declining with time), and the duration of remuneration (limited to a certain number of years, or indefinite) (Lesser and Su, 2008). These "*require significant "guess-work" on the part of policymakers*" (Lesser and Su, 2008) and "*once specific price paths (i.e. level, structure, and duration) are specified, changing those paths is both difficult and costly, as it creates excessive regulatory uncertainty that, in turn, increases investment costs*" (Lesser and Su, 2008). Thus, a fixed long-term price improves financial stability for investors, but leads to welfare loss over time as the fixed long-term price "*will almost certainly deviate from realized market prices by greater amounts over time*" (Lesser and Su, 2008).

The literature contains a number of recommendations on designing an economically efficient feed-in tariff policy and theoretically, it is very straightforward. Thus, Lesser and Su emphasize the need for an appropriate balance in the remuneration levels (high enough to stimulate investment but low enough not to create excess costs), linking payment to the amount of energy produced rather than the capacity installed (as supporting idle capacity is besides the point), setting remuneration levels for each technology which maximize the rate of technological progress for that technology (i.e. too high feed-in tariffs may reduce the rate of technological progress by taking lowering the incentives for improvements), and minimizing reliance on administrative information (Lesser and Su, 2008). However, achieving this in practice is much more difficult. On the basis of their analysis, Lesser and Su evaluate the feed-in tariff policies in place in the EU, noting that they are "*inefficient,* *in that they needlessly pay too much for renewables, raise overall electric costs, and reduce economic competitiveness. The danger is that, if FITs are set too high, there is likely to be a political backlash that could abruptly halt the entire FIT approach*" (Lesser and Su, 2008).

In any case, there are "*many different ways to structure the remuneration of a feed-in tariff policy*" (Couture and Gagnon, 2010). A feed-in tariff may thus be independent or dependent on the market; it is a fixed tariff in the former case, and a premium tariff in the latter (Couture and Gagnon, 2010). The fixed tariff is a guaranteed payment per kWh produced, while a premium is paid on top of the market price for electricity (Couture and Gagnon, 2010). In some feed-in tariff systems, both a fixed and a premium tariff are available, with the choice between them up to the producer (Couture and Gagnon, 2010).

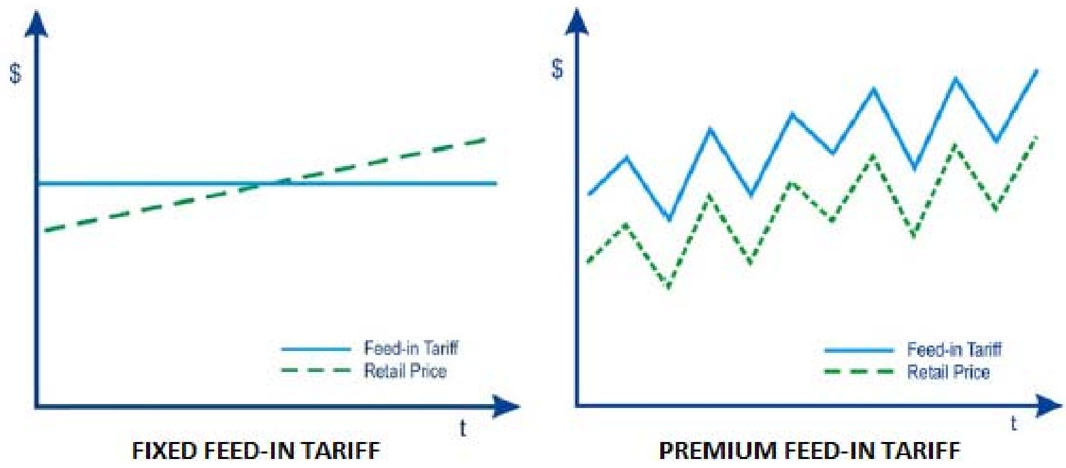


**Figure 1 - Fixed and Premium Feed-in Tariffs (Couture and Gagnon, 2010)**

Fixed tariffs are usually set for a certain duration, e.g. for the first 20 years of operation, and this price is independent of other variables, such as the electricity price, inflation, fossil fuel prices (Couture and Gagnon, 2010). Particularly with regard to inflation, "*the actual value of the revenues obtained will tend to decrease over time*" (Couture and Gagnon, 2010), but the fixed tariff still provides "*a reliable formula to calculate future project revenues*" (Couture and Gagnon, 2010) and thereby provides investment stability. Variations on the fixed tariff include the inflation-adjusted fixed tariff model, the front-end loaded tariff model (where the tariff level is higher in the first years of operation and lower in later years), and the spot market gap model (where the tariff is fixed, but only the difference between the retail price and the tariff is subsidized) (Couture and Gagnon, 2010).

A premium tariff involves greater risk and lower investment stability, but it is more suitable for deregulated electricity markets and allows better market integration of renewable energy sources (Couture and Gagnon, 2010). Although the main point is that premium prices should lead to lower additional costs for society, some studies find that "*on average, premium price policies have been found to be more costly per kWh than fixed-price policies*" (Couture and Gagnon, 2010). A variation on the premium tariff is a variable premium model that includes a ceiling and a floor price; if the market price falls below the floor price, the 'premium' paid to producers is equal to this floor price, while if the market price exceeds the ceiling, the 'premium' paid is zero as the market price obtained offers more than sufficient remuneration (Couture and Gagnon, 2010). A variable premium model can reduce windfall profits (in the case of high electricity prices) and improve investment stability (in the case of low electricity prices), and thereby "*can help keep actual remuneration more closely aligned with project costs*" (Couture and Gagnon, 2010). It is therefore seen by Couture and Gagnon as offering advantages over both the constant premium tariff and the fixed tariff. Another variation of the premium tariff is the percentage of retail price model, but it is no longer in use and is "*unlikely to be used again in a comprehensive manner*" (Couture and Gagnon, 2010).

Both the fixed and the premium tariff systems have advantages and disadvantages. The fixed tariff system is seen as a distortion of electricity prices (Lesser and Su, 2008), and it ignores demand as it offers "*the same prices regardless of the time of day at which electricity is supplied*" (Couture and Gagnon, 2010); at the same time, it offers greater investment stability and its decoupling from market volatilities "*can confer a significant risk-hedging advantage*" (Couture and Gagnon, 2010). The premium tariff, as mentioned, can result in actually higher costs per kWh, and has higher uncertainty which is problematic for renewable energy sources that have high initial investment costs and particularly problematic for "*smaller investors or community-owned projects, both of which require more stable and predictable revenue streams to obtain project financing*" (Couture and Gagnon, 2010). However, as premium tariffs are based on market forces, they lead to better integration of renewable energy sources and "*can create a more efficient electricity market, by encouraging supply in times when electricity is needed most*" (Couture and Gagnon, 2010). Another advantage of premium systems is that they require less administrative intervention (Couture and Gagnon, 2010). Overall, Couture and Gagnon note that fixed feed-in tariffs "*are proving a stronger and more cost-efficient policy option in the near-term*" (Couture and Gagnon, 2010). However, as has been mentioned, a feed-in tariff system may incorporate both a fixed tariff and a premium tariff; as of 2010, this was the case in Spain and Slovenia, while Germany had a fixed tariff only. We now examine their tariff systems in more detail.

## 2.5. The Tariff Systems of Germany, Spain, and Slovenia

We take a look at the feed-in tariff systems implemented in Germany, Spain, and Slovenia, as of 2010 (since later developments are dealt with in later sections), that is, as described in their NREAPs. Of course, the relevant legal frameworks in each country have been in place earlier than 2010 and have undergone several changes. Thus, the support of renewables through feed-in tariffs has been in place in Germany since 1991's 'Electricity Feed-in Act' (Held et al., 2010); in Spain, tariffs have been in place since 1997's 'Electric Power Act' (Held et al., 2010); in Slovenia, although support measures for renewable energy were already mentioned in the 'Energy Law' of 1999, a proper feed-in tariff structure was only implemented in 2009 after a delay due the need for approval from the European Commission (Held et al., 2010) . Due to the later adoption of feed-in tariffs in Slovenia, as well as its smaller size and economic importance, much more attention has been given in the literature to the feed-in tariff systems of Germany and Spain.

On a general level, the three Member States of interest used different approaches to feed-in tariffs as of 2010. Germany's system was based on fixed feed-in tariffs with annual degressions (i.e. reductions in the remuneration level for new installations), although the level of remuneration available in the first year of operation is guaranteed for a period of 20 years (NREAP DE, 2010). Spain's system contained both a fixed feed-in tariff and a premium feed-in tariff with a cap and a floor price (e.g. a variable premium model); producers with installations of up to 50MW capacity could choose on an annual basis whether to opt for the fixed or the premium tariff (NREAP ES, 2010). Support was guaranteed for the lifetime of a plant, although the level of support would decrease in later years (NREAP ES, 2010). Additionally, an annual capacity quota for solar photovoltaic installations exists, where additional capacity installed after the quota has been reached is not eligible for support (NREAP ES, 2010). Slovenia's system also contained both a fixed and a premium feed-in tariff (without a cap and floor price); producers with installations of up to 5MW capacity could choose between the fixed and the premium tariff, while producers with installations larger than 5MW capacity are eligible for the premium tariff only (NREAP SI, 2010). Additionally, installations with capacities of 125MW or more are not eligible for any support (NREAP SI, 2010). The level of support is guaranteed for 15 years (NREAP SI, 2010). All three member states differentiate their tariffs according to technology type, and the tariff structures are of different complexity depending on the technology, with hydropower generally having the most straightforward tariff and biomass the most complex tariff structure, in each of the three member states of interest. The funding of the feed-in tariff in Germany and Slovenia is done entirely by consumers, by including a renewables contribution in the electricity price, while in Spain, it is funded both by consumers as well as from tax revenue (Couture and Gagnon, 2010).

In order to keep remuneration levels in line with cost decreases that result from technological progress, the feed-in tariff structures and levels of remuneration in each country are reviewed on a regular basis. Germany's next revision of the 'Renewable Energy Act' was expected in January 2012 (NREAP DE, 2010), Spain's system is to be reviewed every four years according to Royal Decree 661/2007 (NREAP ES, 2010), and Slovenia's is reviewed every five years, with the next scheduled for 2014, although reference costs for calculating premium tariffs are reviewed on a yearly basis (NREAP SI, 2010). However, there have also been unscheduled revisions in Germany in 2010 dealing with feed-in tariffs for solar photovoltaic, with the tariffs cut quite severely (NREAP DE, 2010); if the feed-in tariff system is meant to guarantee stability, dramatic and above all unforeseen reductions are counter-productive. Spain's changes in 2008 – again, with regard to feed-in tariffs for solar photovoltaic – also undermine the stability the system was meant to provide (NREAP ES, 2010). Similarly, Slovenia has provided degressions in solar photovoltaic tariffs (NREAP SI, 2010), but these are fixed at the same level for the next five years; of course, this does not preclude unscheduled revisions. However, it must be noted that these unscheduled reviews have focused only on feed-in tariffs for solar photovoltaic and were in Germany "*a result of the unforeseen developments in the prices of photovoltaic systems*" (NREAP DE, 2010), in Spain a result of 85% of the 2005-2010 target having been achieved already by 2007 (NREAP ES, 2010), and in Slovenia, like Germany, due to rapidly changing prices (NREAP SI 2010).

The systems in place as of 2010 in the three member states of interest thus represent different approaches to the three essential elements of a feed-in tariff system noted in the previous section. The level of remuneration is generally differentiated by both technology and installation size in each of the three member states of interest; the structure of remuneration differs, from fixed tariffs in Germany to both fixed and premium in Spain and Slovenia; the duration of remuneration differs as well, from 15 years in Slovenia to 20 years in Germany and indefinitely in Spain (though with lower remuneration in later years). At the same time, unscheduled revisions to the tariffs for solar photovoltaic have been observed in each of the three member states.

The NREAPs and support measures implemented to achieve the 2020 targets have also been compared elsewhere in the literature, and we turn to these next.

## 2.6. Evaluation of the National Renewable Energy Action Plans

Assessments of the NREAPS have been carried out within the REPAP project; the relevant documents are the NREAP Assessment Report (Ragwitz et al., 2011) and the EU Industry Roadmap (EREC, 2011). A more detailed comparison of the support policies in place in all EU member states was conducted in the framework of the RE-Shaping project, and the latest version of this is the D-17 Report (Steinhilber et al., 2011).

### *2.6.1. REPAP Evaluations*

The NREAP Assessment Report, by the Vienna University of Technology Energy Economics Group and the Fraunhofer Institute Systems and Innovation Research, evaluates each member state's NREAP according to a number of assessment criteria. These fall into five main categories; with regard to the member states of interest, the results are as follows:

| Topic / Country | Administrative procedures and spatial planning | Infrastructure development and electricity network operations | RES electricity support measures | RES heating and cooling support measures | RES transport support measures |
|---|---|---|---|---|---|
| Germany | ☺ | 😐 | ☺ | 😐 | 😐 |
| Slovenia | ☹ | 😐 | ☺ | 😐 | 😐 |
| Spain | 😐 | 😐 | 😐 | 😐 | 😐 |

**Table 4 - REPAP Evaluation (adapted from Ragwitz et al., 2011)**

With regard to support measures for electricity from renewable energy sources, the NREAPs of both Germany and Slovenia were deemed good, while that of Spain was found to require "*further stabilization and strengthening*" (Ragwitz et al., 2011). The report goes into more detail, and we examine that for the member states of interest below.

The 'EU Industry Roadmap' report, compiled by the European Renewable Energy Council, compares the projections of each member state as stated in the NREAP with the projections by the renewable energy industry, and includes key recommendations from the renewable energy industry (EREC, 2011). With regard to support measures for electricity from renewable energy sources, the report notes, on a general level, that "*certain NREAPs create instabilities in their support mechanisms by announcing cuts or changes without giving details as to the future shape or duration of the mechanism*" (EREC, 2011).

The report also describes the role of the European Commission, which is to ensure that member states "*stay on track and in line with their indicative trajectories and with their 2020 binding targets*" (EREC, 2011). In addition, the report notes that from 2010 on, infringement procedures can be put before the European Court of Justice for, amongst others, "*significant deviation from plan or trajectory*" (EREC, 2011).

The NREAPs are then evaluated from the industry's point of view, for each member state. Evaluations of the electricity sector, and the support measures associated with it, for the three member states of interest follow in the next section.

*Germany*

The NREAP Assessment Report states that "*the support measures for renewable electricity currently implemented in Germany can be considered best practice*" (Ragwitz et al., 2011), but it also notes that in the future, "*more incentives for RES producers to sell their production on the market to achieve a higher degree of market integration*" (Ragwitz et al., 2011) will be necessary.

By contrast, the EU Industry Roadmap Report is critical of the amendments made to the Renewable Energy Act, noting the deep cuts for PV tariffs and "*proposals to phase out technology specific support by 2020*" (Ragwitz et al., 2011) are leading to increasing concerns with regard to stability and reliability (EREC, 2011). Comparing the NREAP projections for 2020 with the projections by the renewable energy industry, the NREAP projections are lower for all renewable energy technologies except for solar photovoltaic, biomass, and biogas (EREC, 2011). Finally, recommendations for the feed-in tariff structure are focused mainly on maintaining the basic elements thereof (EREC, 2011).

*Spain*

The NREAP Assessment Report notes that while some support levels are sufficient (onshore wind, solar, and small hydro), it recommends that others be reviewed (marine, biogas, biomass, small wind) (Ragwitz et al., 2011). Additionally, it notes "*major concerns*" (Ragwitz et al., 2011) with regard to overall support levels in the future and in particular for solar photovoltaic.

Similarly, the EU Industry Roadmap Report is highly critical of the 2010 tariff cuts for Spain for wind power as well as solar photovoltaic, which "*have worsened the already difficult situation for the Spanish RES sector in general and the image of missing long-term stability and reliability of RES support policies*" (EREC, 2011). Comparing the NREAP projections for 2020 with the projections by the renewable energy industry, the NREAP projections are lower for all renewable energy technologies except for large hydro (EREC, 2011). Finally, recommendations for the feed-in tariff structure include improvements in revisions of the tariff levels, with the right of annual revisions but without retroactivity, and the introduction of tariffs for self-consumption (EREC, 2011).

*Slovenia*
The NREAP Assessment Report assesses Slovenia's support measures as "*mostly adequate*" (Ragwitz et al., 2011), with a recommendation to adjust support for solar photovoltaic (Ragwitz et al., 2011).

Similarly, the EU Industry Roadmap Report assesses the feed-in structure of Slovenia as "*appropriate and efficient*" (EREC, 2011). However, it also notes that "*in the past six years, the support system changed far too often and hopefully the current one will, as is planned, remain valid for a longer period of time*" (EREC, 2011). Comparing the NREAP projections for 2020 with the projections by the renewable energy industry[1], the NREAP projections are lower for wind power and biogas, while they are higher or the same for all others. The difference in wind power projections is substantial, with nearly 1,000GWh of additional production compared to the NREAP projections (EREC, 2011). Finally, recommendations on the feed-in tariff structure deal mainly with the shortening and simplification of some procedures (e.g. calculating the reference premium), as well as incentive levels for the refurbishment of old power plants (EREC, 2011).

### *2.6.2. The RE-Shaping Report*

The D-17 Report within the RE-Shaping framework deals specifically with the support measures in place to promote electricity from renewable energy sources. The support measures are analysed with various indicators, to evaluate policy effectiveness, deployment status, economic incentives, and electricity market preparedness (Steinhilber et al., 2011). The data used for computing the different indicators varies; some is as recent of 2011 (e.g. economic incentives) while other data is from 2009.

The report defines the effectiveness of a support policy for RES electricity as "*the ratio of the change in the normalized final energy generation during a given period of time and the additional realizable mid-term potential until 2020 for a specific technology*" (Steinhilber et al., 2011), which allows for unbiased cross-country comparisons as Member States should develop their renewable energy sources in proportion to their specific potential (Steinhilber et al., 2011).

[1] For Slovenia, these projections were prepared by the Vienna University of Technology Energy Economics Group and the Fraunhofer Institute Systems and Innovation Research.

The deployment status quantifies the advancement of the market for specific renewable energy technologies, based on market surveys, and distinguishes between immature, intermediate, and advanced markets (Steinhilber et al., 2011). It is composed of sub-indicators on the share of total production in the sector (e.g. electricity), production as a share of 2030 potential, and installed capacity (Steinhilber et al., 2011).

Economic incentives – i.e. support measures – are aggregated by technology type and evaluated by comparing the net present value of overall support payments discounted to the electricity generation costs levelised over the whole lifetime of the plant (Steinhilber et al., 2011). Feed-in tariffs are compared as ranges, and the complexity of some support schemes means that the comparison in the report "*serves as an indication*" (Steinhilber et al., 2011). Potential profit for investors is also taken into account, with the maximum profit defined as the "difference between the maximum support level and minimum generation costs" (Steinhilber et al., 2011). A comparison is made between effectiveness of the policy with the level of financial support "*to clarify whether the success of a specific policy depends predominantly on the economic incentives or whether additional aspects influence the market development of RET*" (Steinhilber et al., 2011).

With regard to electricity market preparedness, the indicator deals with "*the maturity or preparedness of the electricity market for RES-E market integration*" (Steinhilber et al., 2011); it is composed of sub-indicators dealing with TSO unbundling, number of companies with more than 5% shares of generation capacity, the wholesale market, and the retail market, the share of electricity traded at exchanges, and the gate closure time (Steinhilber et al., 2011). The electricity market preparedness indicator is used in combination with the deployment status indicator to derive differentiated policy recommendations, such as whether to move from fixed feed-in tariffs to premium tariff systems (Steinhilber et al., 2011).

For the Member States of interest, the indicators are as follows:

| Technology | Germany | | Spain | | Slovenia | |
|---|---|---|---|---|---|---|
| | Policy Effectiveness | Deployment Status | Policy Effectiveness | Deployment Status | Policy Effectiveness | Deployment Status |
| Wind Onshore (2010) | 6% | Advanced | 10% | Advanced | 0% | Immature |
| Wind Offshore (2010) | 0.5% | Immature | 0% | Immature | 0% | Immature |
| Solar Photovoltaic (2010) | 36% | Intermediate | 2% | Intermediate | 3% | Immature |
| Solid &Liquid Biomass (2009) | 9% | Intermediate (solid only) | 1.5% | Immature (solid only) | 0% | Immature (solid only) |
| Biogas (2009) | 45% | Advanced | 0% | Immature | 2% | Immature |
| Small-scale Hydropower (2009) | 34% | Intermediate | 2% | Intermediate | 7.5% | Advanced |

**Table 5 – Policy Effectiveness and Deployment Status Indicators (adapted from Steinhilber et al., 2011)**

We can here relate the policy effectiveness to the structure of the feed-in tariff systems applied in each member state of interest. Thus, the fixed tariff approach used in Germany is more effective than the fixed and premium tariff mixes of both Spain and Slovenia, although the effects of perceived stability must be considered as well, with uncertainty regarding future developments in Spain likely lowering its policy effectiveness, while Slovenia's relatively late implementation of a proper feed-in tariff system may have contributed to the rather low policy effectiveness indicated above.

The economic incentives are evaluated by comparing the average to maximum tariff offered per technology to the long-term marginal generation cost range (from minimum to average costs) (Steinhilber et al., 2011). Thus, economic incentives can be considered "*sufficiently high*" (Steinhilber et al., 2011) even if the average tariff is below the minimum long-term marginal generation cost, as long as the maximum tariff is within the range or above the average long-term marginal generation cost. For the Member States of interest, we observe the following:

| Technology | Germany | | Spain | | Slovenia | |
|---|---|---|---|---|---|---|
| | Average Tariff | Maximum Tariff | Average Tariff | Maximum Tariff | Average Tariff | Maximum Tariff |
| Wind Onshore (2011) | in range | in range | in range | in range | above range | above range |
| Wind Offshore (2011) | in range | in range | below range | above range | N/A | N/A |
| Solar Photovoltaic (2011) | below range | in range | above range | above range | within range | within range |
| Solid &Liquid Biomass (2009) | above range | above range | above range | above range | above range | above range |
| Biogas (2009) | above range | above range | below range | within range | within range | within range |
| Small-scale Hydropower (2009) | within range | within range | above range | above range | above range | above range |

**Table 6 - Economic Incentives (adapted from Steinhilber et al., 2011)**

We can here relate the level of the tariff as compared to minimum to average generation costs to the balancing need of feed-in tariff design mentioned earlier, namely, that support levels should be "*sufficient to stimulate capacity growth (…) but should also avoid windfall profits*" (Steinhilber et al., 2011). We can expect that the balancing is achieved if the average and maximum tariffs fall within the range of minimum to average generation costs. We see that despite the cuts made to feed-in tariffs for solar photovoltaic in Spain before 2010, the average and maximum tariffs remain above the minimum to average generation costs. Additionally, all three member states also have tariffs above the minimum to average generation cost range for biomass. With regard to other tariffs that exceed the minimum to average generation cost range, Spain and Slovenia have tariffs for small-scale hydropower that are higher than the minimum to average generation costs; Slovenia has higher tariffs for onshore wind; and Germany has higher tariffs for biomass.

The indicator on electricity market preparedness is a percentage score from 0% (low preparedness) to 100% (high preparedness) (Steinhilber et al., 2011). The member states of interest scored as follows:

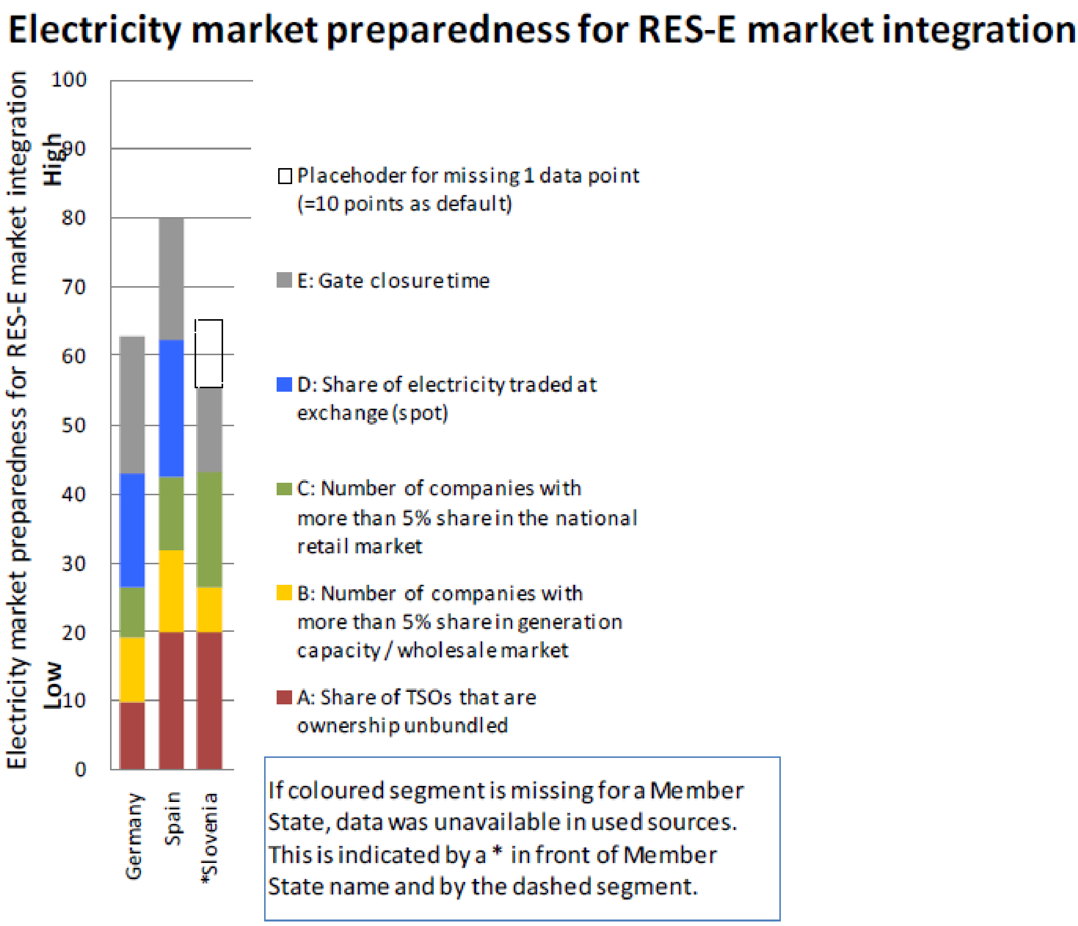


**Figure 2 - Electricity Market Preparedness (adapted from Steinhilber et al., 2011)**

All three member states of interest score reasonably well on the electricity market preparedness indicator. For Slovenia, data on the share of electricity traded at the exchange was missing. In other literature, the role of the electricity exchange in Slovenia is "*given rather low importance*" (Bojnec and Papler, 2010), as retail distribution companies prefer to purchase electricity directly from HES (Bojnec and Papler, 2010), which, with a 68.4% share of electricity production, is by far the largest producer (EA RS, 2010). Thus, in figure 2 above, Slovenia likely scores the lowest of the three.

## 2.7. The Social Cost of Carbon

A big reason behind the need for support measures to promote renewable energy stems from the fact that many negative externalities of conventional energy generation are not taken into account in the pricing of the energy produced them, while many positive externalities of renewable energy generation are likewise not taken into account in the pricing of the energy produced by, as explained above. One such externality, highly relevant to climate policy, is the social cost of carbon; emissions from conventional energy generation and the damage they cause are not taken into account in the pricing system, while emissions avoided by deploying renewable energy sources and the benefit thereof are also not taken into account.

As Tol puts it, “*estimates of the social cost of carbon (dioxide) emissions), or the marginal cost of climate change are an essential ingredient to any assessment of climate policy*” (Tol, 2008). Numerous estimates from various studies have been put forward, with the total number of estimates above 200 (Tol, 2008).

Estimating the social cost of carbon is an attempt to put a number on “*the cost of climate change damages – the net effects of impacts on economies and societies of long term trends in climate conditions, including extreme events, related to anthropogenic emission of greenhouse gases*” (Downing et al., 2005). However, given the uncertainties surrounding climate change projections and their impacts, estimates of the social cost of carbon are subject to high uncertainty; “*experts disagree regarding the appropriateness of cost benefit aggregations, the nature of quantifiable damages and the range of resulting estimates*” (Downing et al., 2005). The uncertainty cascade inherent in estimating impacts of climate change leads to uncertainties in the social cost of carbon (Downing et al., 2005).

A study commissioned by the UK Department for Environment, Food and Rural Affairs evaluates the social cost of carbon within a risk assessment framework (Downing et al., 2005). More specifically, they employ the following risk matrix:

| | | Uncertainty in valuation | | |
|---|---|---|---|---|
| | | A. Market | B. Non-market | C. Socially contingent |
| Uncertainty in Climate Change | 1. Projection | | | |
| | 2. Bounded risks | | | |
| | 3. System change and surprise | | | |

**Figure 3 - Risk Matrix for the Social Cost of Carbon (Downing et al., 2005)**

Going from top to bottom represents increasing uncertainty, as, for example, the uncertainty surrounding large-scale system changes (and their timing) is higher than the uncertainty surrounding the projections of future carbon dioxide emissions (though there is uncertainty here as well); similarly, going from left to right also represents increasing uncertainty, as valuation measures for market-related impacts yield more explicitly quantified results compared to valuation measures for non-market impacts (e.g. loss of species) or socially contingent impacts (e.g. increasing droughts leading to regional migration) (Downing et al., 2005). Furthermore, the report notes that “*the coverage of existing studies is almost exclusively in the upper left quadrant of our risk matrix*” (Downing et al., 2005).

Within the report, the definition of the social cost of carbon employed is the following: "*the net present value of the impact over the next 100 years (or longer) of one additional ton of carbon emitted to the atmosphere today*" (Downing et al., 2005). The range of estimates varies by at least three orders of magnitude; thus "*the range of estimates currently offered as the state-of-the-art is incomplete*" (Downing et al., 2005). The estimates of the social cost of carbon are, aside from the uncertainties involved in climate change impacts, also sensitive to the choice of discount rate as well as equity weighting. The latter involves taking into account "*that a pound is worth more to the rich than to the poor*" (Downing et al., 2005), and this has "*a significant impact on the social cost of carbon*" (Downing et al., 2005). Tol carries out a meta-analysis of 211 estimates of the social cost of carbon found in the literature, again finding a wide range (Tol, 2008).

The report by Downing et al. does arrive at a figure of £35 per ton of carbon as a reasonable lower benchmark for "*a global decision context that has already agreed to the UNFCCC commitment*" (Downing et al., 2005). An upper benchmark is not presented, but it is noted that "*the risk of higher values for the social cost of carbon is significant*" (Downing et al., 2005). In addition, it estimates a social cost of carbon equity-weighted for EU income levels, as "*only values calibrated at EU incomes are useful policy making in Europe*" (Downing et al., 2005); this estimate is markedly higher, at £120 per ton of carbon (Downing et al., 2005).

Other values for the social cost of carbon have been suggested by the Stern Review on the Economics of Climate Change, with a value of $85 per ton of carbon dioxide (Stern, 2006). One may also refer to the price of carbon allowances in the EU ETS, which have been much lower than most estimates in the literature and close to the lower benchmark identified by (Downing et al., 2005); the highest price based on the EU ETS was reached in April 2006, and was €31.59 (Point Carbon, 2007). However, care must be taken when looking at prices from the EU ETS, particularly during the first phase where allowances were given out for free and may not reflect true cost (see 2.3).

With regard to actually applying estimates of the social cost of carbon to evaluations of climate policy, there is some controversy. For example, Ekins suggests that "*there is no scientifically valid way of assigning monetary numbers*" (Ekins, 2005) to outcomes characterized by high uncertainty, ignorance and indeterminacy (Ekins, 2005). Furthermore, given the discontinuity of the temporal damage profile of carbon emissions (e.g. sudden changes leading to runaway climate change), Ekins argues that using a marginal damage approach "*is simply inappropriate*" (Ekins, 2005).

However, the fact is that estimates of the social cost of carbon, riddled with uncertainties as they may be, have been used to evaluate policies in the past, and this will continue in the future. For example, UK government recommended an illustrative value (£70/tC) and an illustrative range (£35-£140/tC) for use in policy appraisal; furthermore, the values, based for the year 2000, were to increase each year (by £1/tC) (Watkiss and Downing, 2008). Since the recommendation was made in 2002, the illustrative values "*have been used widely in regulatory impact appraisal* *and in the consideration of environmental taxes and charges*" (Watkiss and Downing, 2008). It must be pointed out that for analyzing long-term climate policy, the social cost of carbon has "*limited use*" but its use in analyzing short-term policy is less controversial. As the EU climate policy up to 2020 falls into the short-term (Watkiss and Downing, 2008), we may take estimates of the social cost of carbon into account in our analysis.

## 2.8. Discussion

We may now make some comments on the implications of the theoretical basis behind feed-in tariff design and the costs associated with them, as well as the structure of the feed-in tariffs in practice in the three member states of interest as of 2010, on our first two research questions[2].

Our first research question is as follows: *Is there a point in the NREAP indicative trajectories at which the benefits from emissions avoided due to the feed-in tariffs exceed the additional costs imposed on society by the feed-in tariffs? And, if so, for which technology types and under which assumptions regarding the social cost of carbon?*

Germany, which has annual degressions of remuneration levels for new installations, will provide an illustration of what we are suggesting. Remuneration levels are fixed for a number of years at the level they were when an installation becomes operational, while later installations receive a lower tariff; thus, with time, the overall costs of the feed-in tariff first increase as the number of installations increases and 'old' installations continue to receive the higher tariffs, but then level off and decrease as 'old' installations' remuneration expires and as new installations receive even smaller tariffs (or, eventually, none at all). At the same time, the benefits in terms of carbon dioxide emissions avoided, increase linearly as capacity increases. Thus, the picture may look as follows:

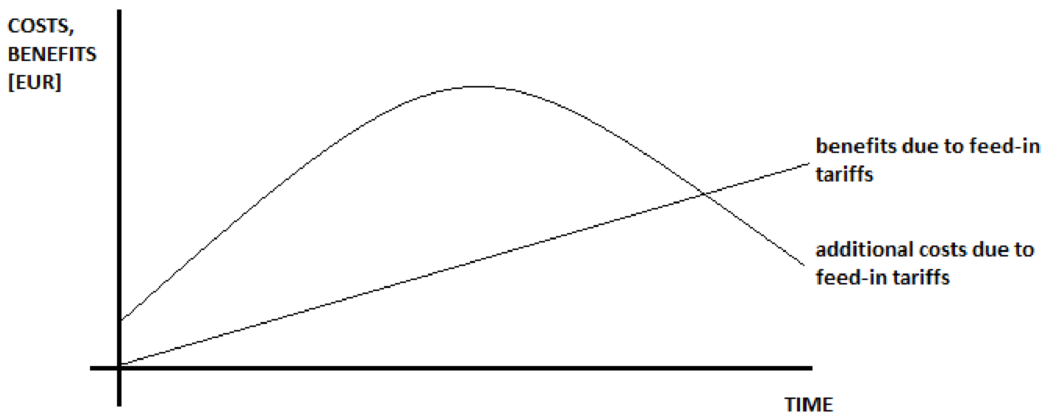


**Figure 4 - Cost and Benefit Trajectory (own elaboration)**

[2] We do not attempt to comment on our third research question, as its nature is speculative and itself depends on the answers to the first two research questions.

Thus, in attempting to answer research question 1, we are looking for whether the development of feed-in tariff costs and benefits in the 2010-2020 period in the three member states of interest approximates such a situation or not. While from a theoretical point of view, it is possible for Germany (depending on the estimate of the social cost of carbon used), the general absence of planned degressions in Spain and Slovenia complicates the matter as it is unlikely that the costs due to feed-in tariffs to follow a trajectory of the sort shown in Figure 4 above without them. However, both Spain and Slovenia have planned degressions for the tariff for solar photovoltaic, so it might be possible in this case.

Our second research question is as follows: *How have the member states of interest progressed in reaching the targets for electricity from renewable energy sources as stated in their respective NREAP indicative trajectories? What other developments are significant?*

We can only comment on the implications for each Member State based on the theoretical analysis of their individual feed-in tariff design choices. As mentioned, fixed feed-in tariffs provide more stability and result in more deployment. Given that as of 2010, Germany used fixed tariffs exclusively, Spain used both fixed and premium tariffs with the choice up to the producer (provided the capacity of the installation is less than 50MW), and Slovenia used both fixed and premium tariffs with the choice up to the producer (provided the capacity of the installation is less than 5MW), it would seem logical that Germany would make the most progress and Slovenia the least, with Spain inbetween, given the relative reliance on fixed or premium tariffs. However, this assumes that no other factors play a part, which is not realistic; the perceived stability and remuneration levels are also important. For example, Spain's system is perceived as less stable, especially with regard to solar photovoltaic, but its remuneration levels for the same technology are higher than in Germany and Slovenia (relative to the minimum to average generation cost ranges); one would expect that the lack of stability acts as a disincentive, and that the high remuneration levels acts as an incentive. The relative influence and magnitude of these two factors, and the resulting effects, are difficult to evaluate *a priori*. Additionally, any hypothesis made with regard to our second research question would be made with the assumption that the legal framework and the feed-in tariff structure as of 2010 would not have changed since, an assumption that is clearly false. Thus, we end this section by noting that although we cannot link the feed-in tariff structure, its remuneration levels and the perceived stability of the system with an *a priori* judgment on the success of the policy, we may be able to link the two in hindsight by looking at the actual progress made.

## 3. METHODOLOGY

We use different approaches in different sections. The methodological notes for each section are as follows:

### 3.1. Cost-Benefit Analysis of the NREAP Targets

#### *3.1.1. Potential Cost Ranges*

This section has the most complex methodology involving a number of assumptions. Our starting point are the indicative trajectories for installed capacity of, and electricity production from, renewable energy sources in the member states of interest, as found in their respective NREAPs in Table 10.

We then use the data in the NREAP indicative trajectories to derive potential cost ranges. These costs reflect the *additional* cost imposed on society (i.e. consumers) by the use of feed-in tariffs. The feed-in tariffs are often differentiated according to installation size, and can be either fixed feed-in tariffs or a premium feed-in tariff. As the figures on installed capacity and electricity produced contained within Table 10 of the NREAPs are mainly aggregated, and that no data is available detailing which producers opt for the fixed or the premium tariffs (where the choice is available), the cost ranges have been computed by using the lowest possible tariff and the highest possible tariff. An example, using the German feed-in tariff levels for hydropower as stated in the NREAP, and the 2010 NREAP target for electricity production from hydropower, is as follows:

Minimum tariff: 3.50 cent/kWh
Maximum tariff: 12.67 cent/kWh

2010 NREAP production target: 18,000 GWh

Potential cost range
= (min. tariff x electricity production) – (max. tariff x electricity production)

= 630,000,000 – 2,280,600,000 EUR

When producers have a choice between a fixed tariff or a premium tariff, the same approach is used, only that the value used for the minimum tariff is whichever is lower – the lowest fixed tariff or the premium tariff (the maximum tariff is in all cases a fixed tariff; even if the electricity price is very high and the producer profits more under a premium tariff, the *additional* costs imposed on society by the use of feed-in tariffs is still only the premium on top of the electricity price, and not the entire amount). An example, using the Slovenian feed-in tariff levels for hydropower as stated in the NREAP, and the 2010 NREAP target for electricity production from hydropower, is as follows:

Minimum tariff: 1.807 cent/kWh (lowest premium tariff)
Maximum tariff: 10.547 cent/kWh (highest fixed tariff)

2010 NREAP production target: 4,099 GWh

Potential cost range
= (min. tariff x electricity production) – (max. tariff x electricity production)

= 7,4068,930 – 432,321,530 EUR

When producers have a choice between a fixed tariff or a premium tariff, and the premium tariff system includes a ceiling and a floor price, where if the electricity price exceeds the ceiling, the premium is zero and if the electricity price falls below the floor, the premium is equal to the floor price, the situation is a bit more complicated. Under such a system, when the ceiling has been reached, the *additional* cost imposed on society by the use of feed-in tariffs is zero (as the premium paid is zero). Thus, theoretically, if all producers opt for the feed-in premium and if the electricity price is always above the ceiling, then the minimum of the potential cost range should be zero. However, in practice, not all producers opt for the feed-in premium, nor is the electricity price always above the ceiling. Of the member states of interest, only Spain has implemented a premium tariff with price ceilings and price floors; for a situation where the electricity price is between the ceiling and floor, the producer receives a reference premium. Thus, in computing our potential cost ranges, we assume that on average, the reference premium is the minimum tariff paid. An example, using the Spanish feed-in tariff levels for hydropower as stated in the NREAP, and the 2010 NREAP target for electricity production from hydropower, is as follows:

Minimum tariff: 2.2263 cent/kWh (reference premium)
Maximum tariff: 8.2519 cent/kWh

2010 NREAP production target: 34,617 GWh

Potential cost range
= (min. tariff x electricity production) – (max. tariff x electricity production)

= 783,382,710 – 2,856,560,223 EUR

### *3.1.2. Feed-in Tariff Levels*

Computing the potential cost ranges is dependent on the feed-in tariff levels used, and these may vary in the 2010-2020 period. For example, Germany's 2009 Renewable Energy Act includes yearly degressions on all feed-in tariffs, from 1% for hydropower to up to 10% for solar photovoltaic (NREAP DE, 2010). Additional cuts are mentioned in Germany's NREAP for solar photovoltaic, for example a 13% cut for roof installations in July 2010 (NREAP DE, 2010). Spain does not mention yearly degressions in its NREAP, but imposes an installed capacity quota for solar photovoltaic, whereby feed-in tariffs are reduced if the quota is exceeded, with adjustments occurring in each quarter (NREAP ES, 2010). Slovenia includes yearly degressions for solar photovoltaic remuneration of 7% and no degressions on tariffs for other technologies, although the premium tariff is re-calculated every year to take into account changing costs (NREAP SI, 2010).

The purpose of feed-in tariffs is to promote electricity from renewable energy sources that are not competitive without support; as their costs decrease, so should the support. They should also provide investment stability; thus support should not decrease suddenly or without warning. Generally, support levels should be "*sufficient to stimulate capacity growth (…) but should also avoid windfall profits*" (Steinhilber et al., 2011). In this respect, Germany's yearly degressions are appropriate (though its rapid and unannounced cuts in solar photovoltaic tariffs are not). In order for the potential cost range to more accurately reflect the actual situation, the feed-in tariffs used for calculating the potential cost range are thus adjusted from year to year, according to legislation as of 2011 and the most recent data available. However, given the different feed-in tariff structures of the member states of interest, this is done differently depending on the member state concerned:

*Germany*: As mentioned, yearly degressions are provided for in the Renewable Energy Act. At the time of writing, these have been adjusted from those stated in the NREAP (PR DE, 2011). For computing potential cost ranges, we use the NREAP tariffs for 2010 (adjusted for degressions in solar photovoltaic tariffs), adjusted NREAP tariffs for 2011 (Held et al., 2010), amended Renewable Energy Act tariffs for 2012 (PR DE, 2011), and use the yearly degressions provided for in the 2012 tariffs to calculate the tariffs expected in each successive year.

*Spain*: The only degressions provided for in Spain are those for solar photovoltaic, and these differ depending on quota fulfillment. According to Spain's NREAP, solar photovoltaic "tariffs fall at an approximate annual rate of 10% depending on the way the assigned quotas are covered" (NREAP ES, 2010). As Spain did not submit a Progress Report, we use a 10% yearly degression for solar photovoltaic tariffs and no degression at all for tariffs for other technology types. While Royal Decree 1/2012 suspends feed-in tariffs for new installations (see 5.4.2.2.), we do not take it into account as we are interested in the additional costs imposed by the feed-in tariffs, and without feed-in tariffs, these do not exist.

*Slovenia*: The only degressions provided for in the NREAP are for solar photovoltaic, with a yearly value of 7% (NREAP SI, 2010). However, an amendment to the Energy Law in 2011 changes this to 8% yearly, depending on the fulfillment of a yearly new installed capacity quota of 55MW. Additionally, one-time cuts of 40% and 30% are scheduled for 2012. Data for 2010, 2011, and 2012 tariff levels are taken from the respective yearly reports by Borzen, the Slovenian electricity exchange (Borzen, 2009; 2011-a; 2011-b). For successive years, an 8% degression is applied for solar photovoltaic tariffs while all other tariffs are kept at 2012 levels. Although premium tariffs are recalculated annually, in the absence of data on expected developments in the reference price of electricity (on which premium tariff calculations are based), we use 2012 levels also for successive years.

Two final assumptions were used in the calculations. *First*, with regard to the feed-in tariff levels used in calculating the potential cost ranges, we start with the year 2010; for easier comparison, it is assumed that all installed capacity in the year 2010 receives their respective tariffs at 2010 levels. This is done to facilitate calculations but underestimates the maximum of the potential cost range, as in reality, capacity installed before 2010 receives the feed-in tariff from that year for a guaranteed period (which generally lasts past 2020, depending on the age of the installation); these earlier tariff levels were generally higher than those in 2010. *Second*, we assume that *all* installed capacity participates in the feed-in tariff system. While this is a reasonable assumption for some technologies (e.g. solar photovoltaic), it does not fully reflect reality for others, especially hydropower; for example, in Spain only hydropower with a capacity below 50MW is eligible to receive feed-in tariffs (NREAP ES, 2010). However, the latter assumption poses less of a problem. We are here concerned with comparing the *additional* costs imposed on society by the use of feed-in tariffs with the benefits gained by the use of feed-in tariffs; the latter assumption overestimates both in the same direction and with the same magnitude, so that the difference between the additional costs and the benefits is unchanged.

### *3.1.3. Electricity Production and Applicable Tariffs*

In the section above, we explained that we use different feed-in tariff levels for different technology types in different years, depending on actual/expected tariff cuts and degressions. More specifically, we use different tariff levels in Germany for each technology type in each year from 2010 to 2020; in Spain, for solar photovoltaic in each year from 2010 to 2020; and in Slovenia, for each technology type in 2010, 2011, and 2012, and solar photovoltaic in each successive year up to 2020. This has implications on the quantity of electricity produced that the different tariff levels are applied to.

We therefore assume that the difference between electricity produced in year N and electricity produced in year N-1 is solely due to the additional capacity installed in year N. For analysis of the NREAP indicative trajectories, this is a reasonable assumption; electricity production from technologies with variable production (e.g. hydro, wind) has been normalized to take into account of said variation.

For computing the potential cost ranges of a particular renewable energy technology on a year-by-year basis, we therefore use the minimum and maximum tariffs for that technology for year n and the electricity produced by that technology in year n. Where tariffs change on a yearly basis (e.g. Germany), the potential cost range for year n is calculated as:

Potential cost range $_{\text{YEAR N}}$
= potential cost range $_{\text{YEAR N-1}}$ + potential additional cost range $_{\text{YEAR N}}$
= ((min. tariff $_{\text{YEAR N-1}}$ x electricity production $_{\text{YEAR N-1}}$) – (max. tariff $_{\text{YEAR N-1}}$ x electricity production $_{\text{YEAR N-1}}$))
+ ((min. tariff $_{\text{YEAR N}}$ x *additional electricity production* $_{\textit{YEAR N}}$) – (max tariff $_{\text{YEAR N}}$ x *additional electricity production* $_{\textit{YEAR N}}$))

where *additional electricity production* $_{\textit{YEAR N}}$ is simply electricity production in year N minus electricity production in year N-1. An example, using solar photovoltaic in Germany in the years 2010 and 2011, looks as follows:

min. tariff $_{2010}$ = 27 cent/kWh

max. tariff $_{2010}$ = 47.3 cent/kWh

min. tariff $_{2011}$ = 22.06 cent/kWh

max tariff $_{2011}$ = 30.06 cent/kWh

electricity production $_{2010}$= 9,499 GWh

electricity production $_{2011}$= 13,967 GWh

additional electricity production $_{2011}$ = 4,468 GWh

Potential cost range$_{2011}$
= ((27 cent/kWh x 9,499 GWh) – (47.3 cent/kWh x 9,499 GWh)) + ((22.06 cent/kWh x 4,468 GWh) – (30.06 cent/kWh x 4,468 GWh))
= 3,550,370,800 – 5,836,107,800 EUR

In some cases where yearly degressions are not applicable (e.g. Spain for all technology types except solar photovoltaic), the potential cost range in year N is calculated according to 3.1.1.

### *3.1.4. Emissions Avoided*

For each kWh of electricity generated by renewable energy sources, a certain quantity of emissions of carbon dioxide is avoided. The precise quantity depends on the avoidance factor for the specific renewable energy technology. These are available in the annual reports on renewable energy, published by Germany's Federal Ministry for the Environment, Nature Conservation, and Nuclear Safety (BMU, 2009; 2010).

The reports note that "*calculation of the emissions avoided by the use of renewable energy sources is derived from the volume of renewable electricity generation as well as substitution and emission factors*" (BMU, 2009), and the substitution and emission factors used in the reports are themselves derived from different databases and research projects (BMU, 2009).

The precise avoidance factor depends on what kind of conventional electricity generation technology is substituted; thus, the factor varies from year to year and country to country. Thus, in the 2009 report, the following avoidance factors are used (BMU, 2009):

| Technology | Avoidance Factor (gCO2/kWh) |
|---|---|
| Hydropower | 851 |
| Wind | 753 |
| Solar Photovoltaic | 591 |
| Biogenic solid fuels | 819 |
| Biogenic liquid fuels | 570 |
| Biogas | 688 |
| Sewage gas | 780 |
| Landfill gas | 784 |
| Biogenic share of waste | 829 |
| Geothermal energy | 835 |

**Table 7 – Avoidance Factors for Germany in 2009 (BMU, 2009)**

The 2011 report uses avoidance factors based on newer research. Due to a changed generation mixed and a revised method (BMU, 2011), the resulting avoidance factors are different:

| Technology | Avoidance Factor (gCO2/kWh) |
|---|---|
| Hydropower | 794 |
| Wind | 736 |
| Solar Photovoltaic | 679 |
| Biogenic solid fuels | 778 |
| Biogenic liquid fuels | 602 |
| Biogas | 565 |
| Sewage gas | 748 |
| Landfill gas | 748 |
| Biogenic share of waste | 773 |
| Geothermal energy | 488 |

**Table 8 - Avoidance Factors for Germany in 2010 (BMU, 2010)**

These avoidance factors are based on a simulation of the German electricity market; the values are likely different for Spain and Slovenia. However, in the absence of data on avoidance factors specific to those countries, we use the latest avoidance factors for Germany from Table 8 above for calculating avoided emissions, keeping in mind that the figures may not be accurate for Spain and Slovenia.

Our basis for the amount of electricity generated from each particular technology type will be the Table 10 projections of the NREAP, and the actual progress made, which has the same aggregate categorization. However, the data on avoidance factors is categorized differently; thus, there is no differentiation between onshore and offshore wind, while the various types of biomass are disaggregated to a deeper extent than they are in Table 10 of the NREAP. We thus combine electricity production from onshore and offshore wind, and use a range for emissions avoided by biomass, where there range is 565g $CO_2$/kWh – 778g $CO_2$/kWh. In addition, there is no listed avoidance factor for tidal energy – since the factors are derived for the German situation, where no tidal energy is expected in the 2010-2020 period – so we cannot include it in our analysis. For the same reason, there is no avoidance factor for concentrated solar, and again, this precludes cost-benefit analysis of concentrated solar deployment in Spain.

The estimate for emissions avoided is calculated simply as follows:

Emissions avoided (t$CO_2$) = Avoidance factor (g $CO_2$/kWh) x Electricity Production (GWh)

### *3.1.5. The Benefit of Avoided Emissions*

In order to calculate the benefits of the feed-in tariff scheme, we must choose some value for the damage caused by emissions $CO_2$; the benefits are then the value of the damage avoided by reducing $CO_2$ emissions. While estimating the marginal cost of carbon is riddled with uncertainties (see 2.7), the literature does provide different estimates based on different assumptions. For our analysis, four estimates reflecting different assumptions have been chosen, found in table 9 below :

| Social Cost of Carbon Estimate (EUR2010/tCO2) |
|---|
| 14.51 (lower benchmark) |
| 34.14 (maximum ETS price) |
| 50.09 (EU-income weighted) |
| 89.86 (Stern Review) |

**Table 9 – Social Cost of Carbon Estimates in 2010 (own elaboration)**

These are based on the following four estimates in the literature:

- \$85/$tCO_2$ (or €89.86/$tCO_2$); the social cost of carbon estimate used in the Stern Review (Stern, 2006)
- £35/tC (or €53.44/$tCO_2$); the social cost of carbon estimate recommended as a lower benchmark (Downing et al., 2005)
- £120/tC (or €183.25/$tCO_2$); the social cost of carbon estimate weighted for EU-income levels (Downing et al., 2005)
- €31.58/$tCO_2$ (or €34.14/$tCO_2$ in 2010 levels); the maximum price of carbon allowances reached in the EU ETS (Point Carbon, 2007)

These estimates are expressed in USD1995, GBP2000, and EUR2006, respectively, and have been updated in table 9 to EUR2010 values, first by inflating them to 2010 values and then converting them to EUR (where applicable) using annualized bilateral exchange rates. These figures are found in Table 10 below. Additionally, conversion from tons of carbon to tons of carbon dioxide is necessary to calculate the value of avoided emissions which are expressed in tons of carbon dioxide, where one ton of carbon equals 3.664 tons of carbon dioxide (Downing et al., 2005).

| Original Value | Inflation (Original Year to 2010) | Annualized Bilateral Exchange Rate in 2010 (EUR/currency) |
|---|---|---|
| USD1995 | 43% | 0.73926 |
| GBP2000 | 31% | 1.1657 |
| EUR2006 | 8.1% | N/A |

**Table 10 – Inflation and Exchange Rates (U.S. Bureau of Labour Statistics, 2012; Bank of England, 2012; Eurostat, 2012; ECB Statistical Data Warehouse, 2012)**

Thus, for each technology type in each year, we calculate the benefit from avoided emissions by multiplying the emissions avoided with the different estimates of the social cost of carbon in Table 10 above.

Finally, the different values for the social cost of carbon are also expressed for emissions in different years; for example, the estimates in Downing et al. refer to emissions starting in the year 2000. Generally, the estimates are "*the net present value of the impact over the next 100 years (or longer) of one additional ton of carbon emitted to the atmosphere today*" (Downing et al., 2005). But today in 2000 is not today in 2010. For this reason, a caveat must be added here regarding the temporal dynamics of the social cost of carbon; while the chosen estimates from the literature have been updated to EUR2010 values, they still reflect the damage over the next 100 years of additional emissions in the year 2000. The damages from emissions in the year 2010, and the years leading up to and including 2020, are not the same. For example, the approach of the UK government is having the social cost of carbon increase by a certain amount for each year after 2000 (Watkiss and Downing, 2008). But the additional increases used in that approach are small - £1/tC, or £0.273/tCO2, each year (Watkiss and Downing, 2008). Given that there are already substantial uncertainties regarding the estimates of the social cost of carbon, and that the time horizon considered in this thesis is short, we do not incorporate such an approach, and assume static values for the social cost of carbon.

### *3.1.6. Cost-Benefit Analysis*

Having calculated the potential cost ranges for each technology type for year for each member state under their NREAP indicative trajectories, and the benefit from emissions avoided under different assumptions as to what the social cost of carbon could be, we compare these. Given the various assumptions made in our calculations, as explained above, the analysis should be taken mainly as a theoretical illustration to see just how much of the additional costs of feed-in tariffs are offset by the benefits they create.

## 3.2. Comparison of Progress Made

Comparing the actual progress made in 2010-2012 with the indicative trajectories of the NREAPs of the Member States of interest will be done slightly differently for each year, as different data sources were used due to availability reasons.

Generally, we compare both the actual installed capacity and electricity production in year N with the indicative trajectory of the member state's NREAP for year N, and do so for the overall targets (e.g. total installed capacity) as well as the technology-specific targets (e.g. total solar photovoltaic capacity).

### *3.2.1. Progress in 2010*

Article 22 of Directive 2009/28/EC requires Member States to submit progress reports every two years; the first of these was due at the end of 2011 and focused on progress made in 2010 (DIR 2009/28/EC). Of the Member States of interest, Germany and Slovenia submitted their progress reports, but Spain did not.

Thus, comparisons for Germany and Slovenia will be based on actual progress as indicated in their respective progress reports; for Germany, more recent data from the Working Group on Renewable Energy Statistics (BMU, 2012) will also be used. For Spain, data was found in two different sources; statistical data from the National Commission for Energy dealing with Special Regime installations only (NCE, 2012), which uses different categories than Table 10 of the NREAP, and a 2010 report on energy in Spain (MITT, 2010).

### *3.2.2. Progress in 2011*

For actual progress made in 2011, different data sources were used. For Germany, the latest data available was taken from the Working Group on Renewable Energy Statistics (BMU, 2012). For Spain, we again rely on statistical data from the National Commission for Energy (NCE, 2012). For Slovenia, no aggregate data was available, but the requirement for all producers of electricity from renewable energy sources to register before receiving remuneration through the feed-in tariff scheme means that producer-level data is available through the online Register of Declarations (EA RS, 2012). Alongside a technology-specific breakdown of individual installations with their respective capacities, the Register also contains information on the date of registration, providing us with useful information; thus, for purposes of our analysis, we assume that an installation registered in year N counts towards the installed capacity in year N, giving us an aggregate number of total new installations for year N. With regard to electricity production in 2011 in Slovenia, we assume that solar photovoltaic production was possible for 1,000 hours, and that biomass and hydropower production can be extrapolated from installed capacity using the same factors used in calculating Table 10 figures in the NREAP.

Note that the datasets used for Spain and Slovenia deal only with renewable energy sources that participate in the feed-in tariff system; as mentioned earlier, this is a reasonable assumption for some renewable energy types (e.g. solar photovoltaic) but not for others (e.g. large hydropower).

### *3.2.3. Progress in 2012*

Progress made in 2012 can only be evaluated for Spain and Slovenia, as no data was available for Germany.

For Spain, we again rely on statistical data from the National Commission for Energy. The dataset was last updated in March 2012, so we can comment on progress made until that point (NCE, 2012).

For Slovenia, we again rely on newly registered installations in the Register of Declarations, counting all new installations registered until the end of April 2012 (EA RS, 2012).

# 4. RESULTS

## 4.1. The Costs and Benefits of the NREAP Trajectories

In this section, we examine each member state's respective NREAP indicative trajectory using the cost-benefit analysis described in 4.1., where costs are expressed in terms of the additional costs imposed on society by use of feed-in tariffs and benefits are expressed in terms of the costs of damages avoided through avoided carbon dioxide emissions. This is done for each member state of interest and by technology type, although some technologies are aggregated (e.g. wind) and others are excluded (e.g. tidal or concentrated solar, where avoidance factors were missing).

### *4.1.1. Germany*

The cost-benefit analysis of the NREAP trajectory of Germany is the most accurate, given that both the potential cost ranges were calculated using the foreseen tariff degressions for each technology type, and that the benefits are based on avoidance factors calculated for the German situation.

Combining the evolution of costs with the evolution of benefits, we see the following:

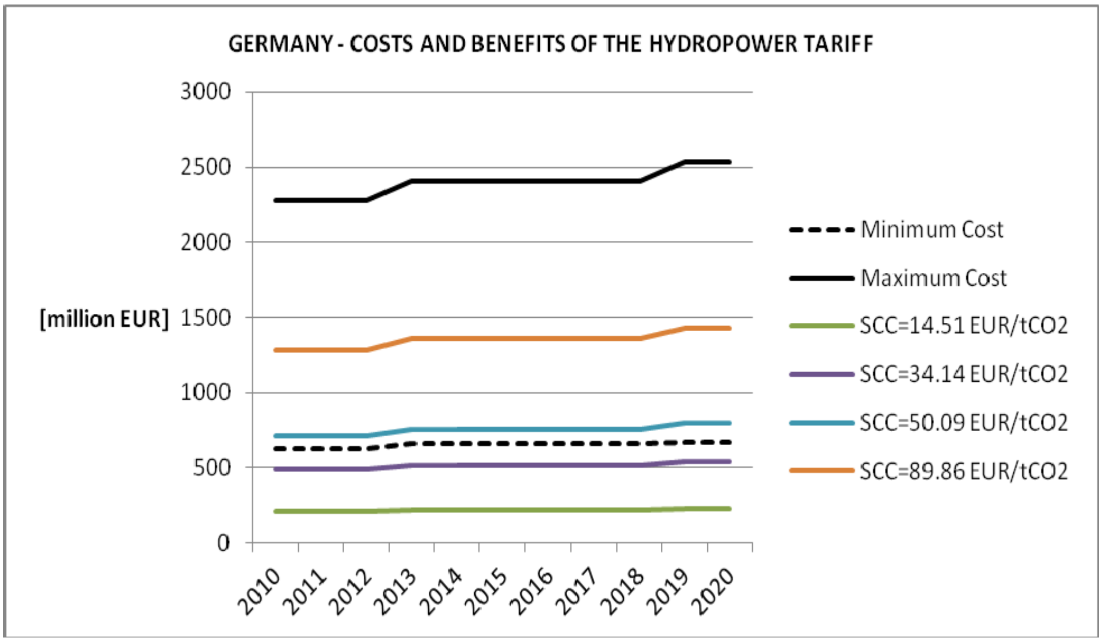


**Figure 5 – Germany, Costs and Benefits of the Hydropower Tariff (own elaboration)**

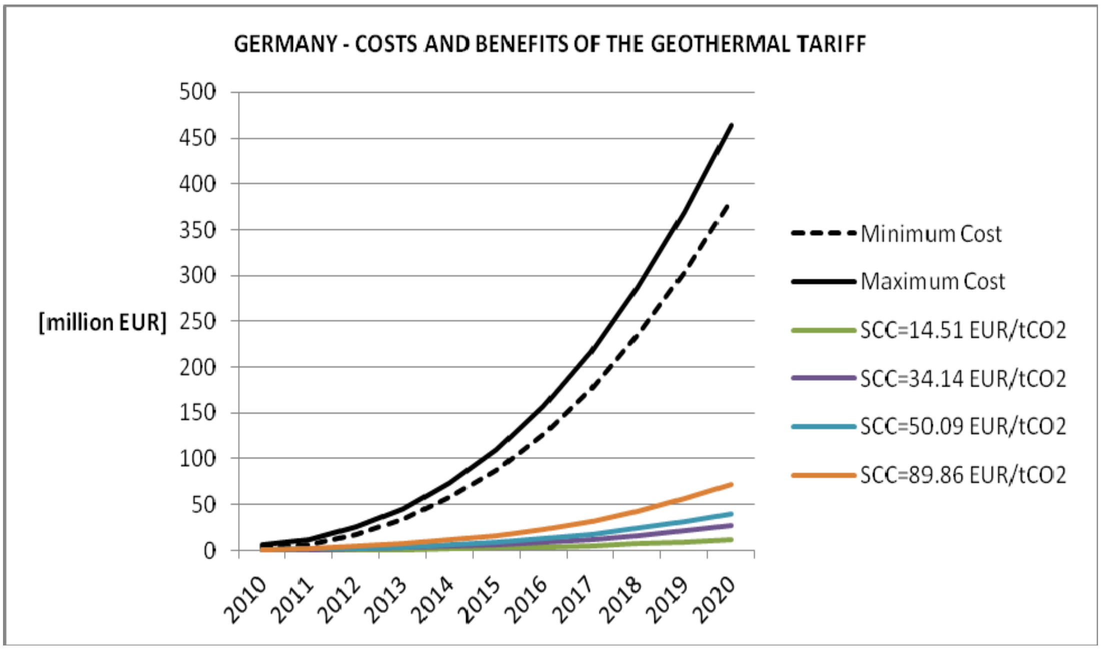


**Figure 6 - Germany, Costs and Benefits of the Geothermal Tariff (own elaboration)**

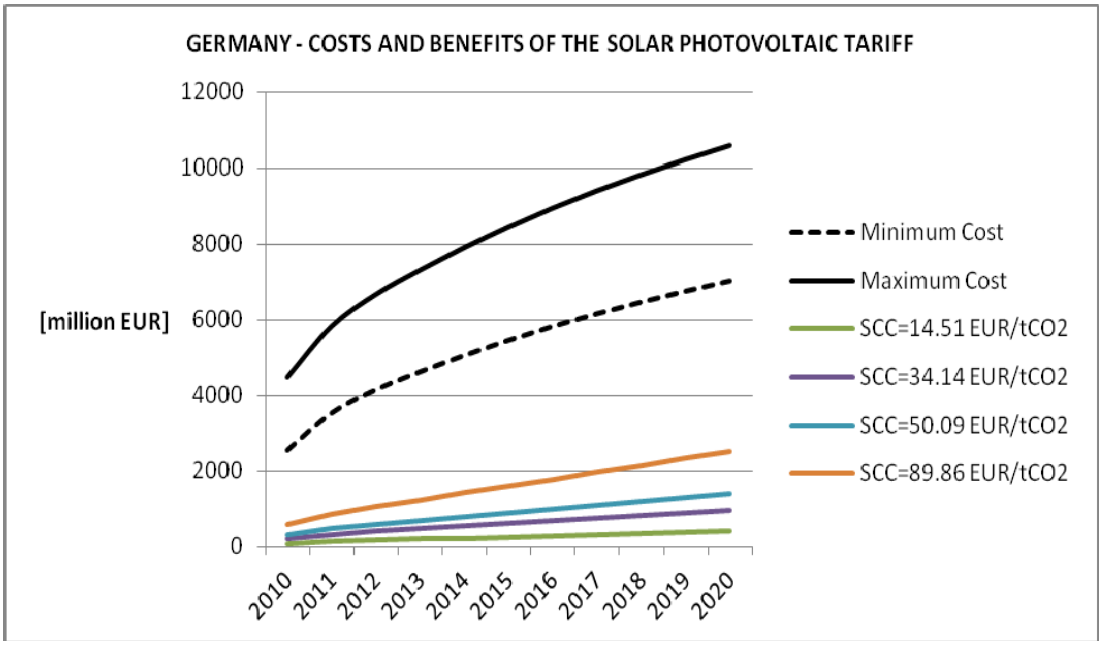


**Figure 7 - Germany, Costs and Benefits of the Solar Photovoltaic Tariff (own elaboration)**

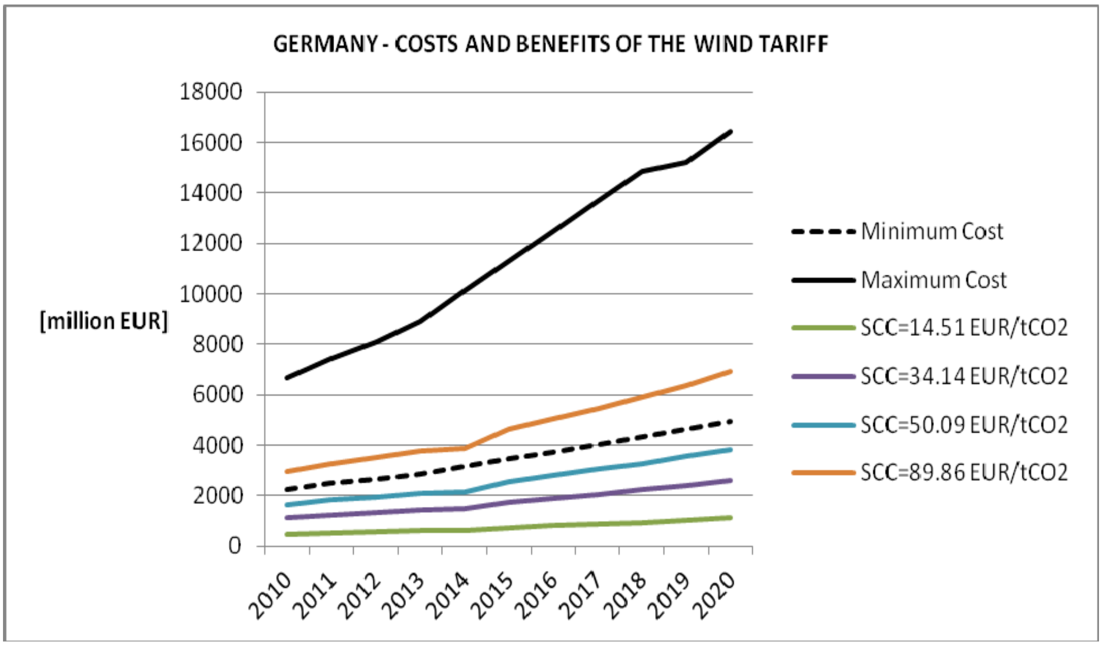


**Figure 8 - Germany, Costs and Benefits of the Wind Tariff (own elaboration)**

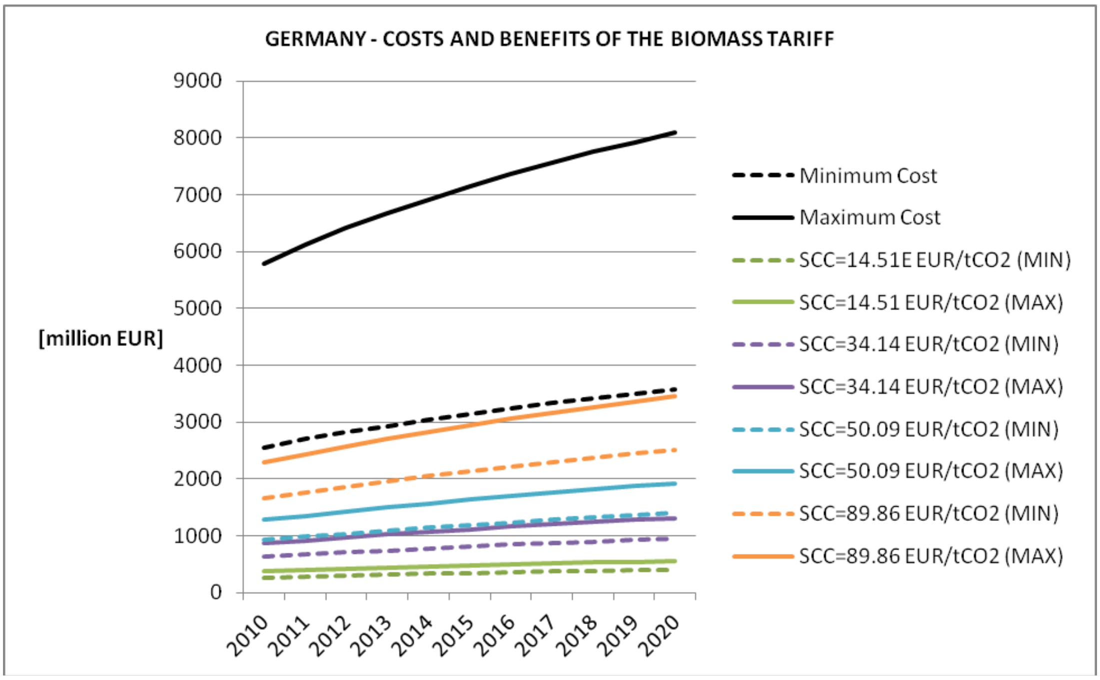


**Figure 9 - Germany, Costs and Benefits of the Biomass Tariff (own elaboration)**

We can see that for solar photovoltaic, geothermal energy, and biomass, the benefits from avoided emissions are much lower than the additional costs imposed on society by the feed-in tariffs, regardless of the estimate of the social cost of carbon used. At the same time, the evolution of costs and benefits for solar photovoltaic approximates our suggestion in 2.8, but given the relatively high costs and low benefits, a break-even point seems to be far in the future.

For hydropower and for wind, however, the benefits from avoided emissions do exceed at least the minimum of the cost range under certain estimates of the social cost of carbon. For wind, the minimum of the cost range is exceeded only by the highest estimate of the social cost of carbon, that which is used in the Stern Review. It must be noted, however, that the maximum of the cost range is likely an overestimate, as wind was aggregated (given that the avoidance factor used to calculate benefits did not distinguish between on- and offshore wind), so that the maximum refers to the feed-in tariff for offshore wind, which is approximately twice than that for onshore wind and is not subject to degressions until 2018. For hydropower, the minimum of the cost range is exceeded by both the estimate of the social cost of carbon used in the Stern Review as well as the estimate of the social cost of carbon adjusted for EU-income levels.

*4.1.2. Spain*

The cost-benefit analysis for Spain is somewhat different, as the feed-in tariffs do not have yearly degressions (aside from solar photovoltaic). Additionally, as the avoidance factors used may not be accurate for Spain, caution must be taken before drawing too strong conclusions.

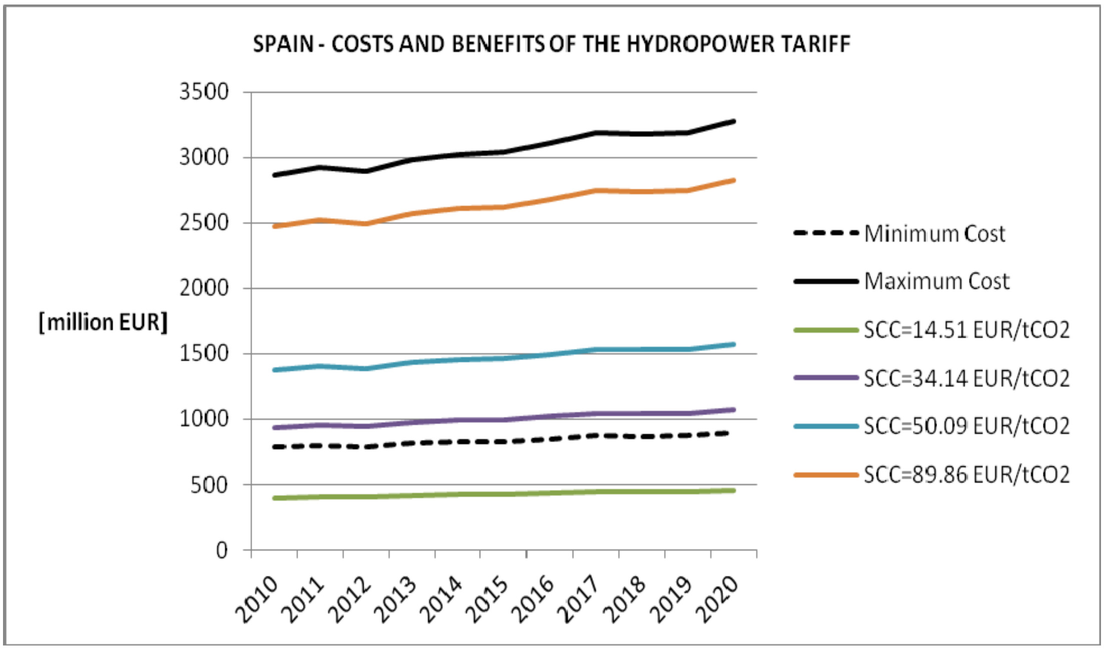


**Figure 10 – Spain, Costs and Benefits of the Hydropower Tariff (own elaboration)**

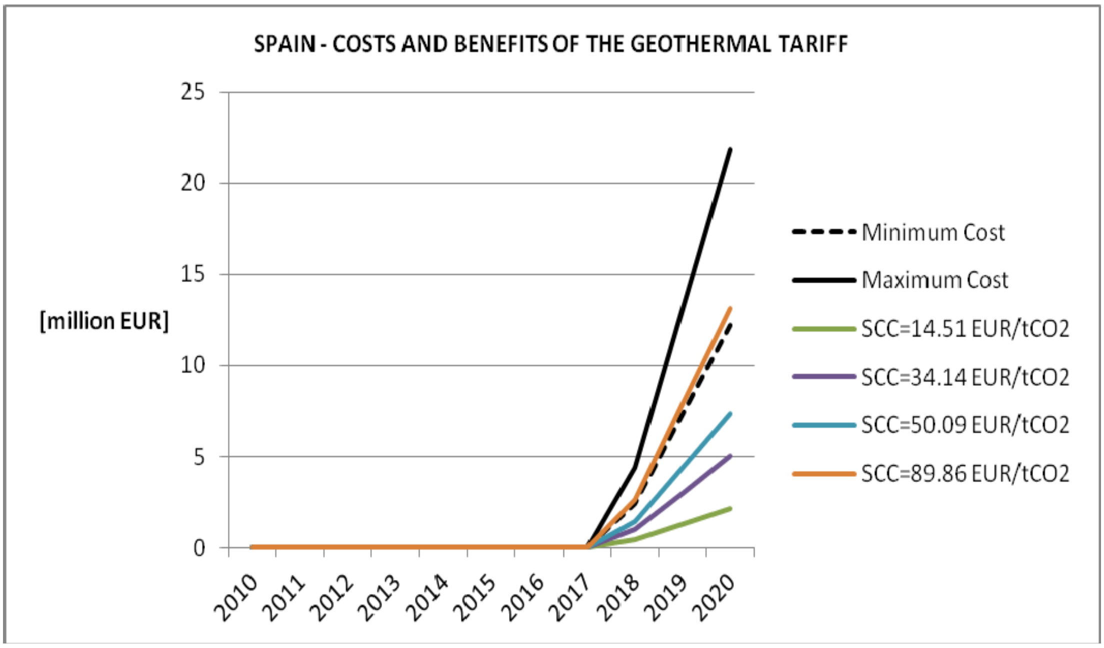


**Figure 11 – Spain, Costs and Benefits of the Geothermal Tariff (own elaboration)**

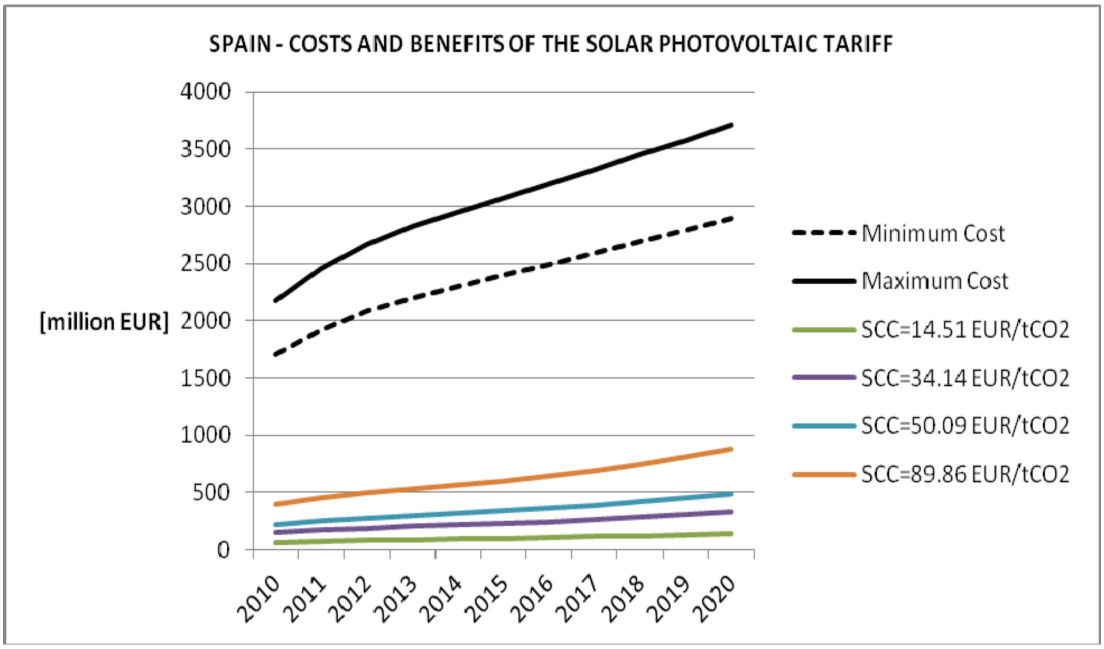


**Figure 12 – Spain, Costs and Benefits of the Solar Photovoltaic Tariff (own elaboration)**

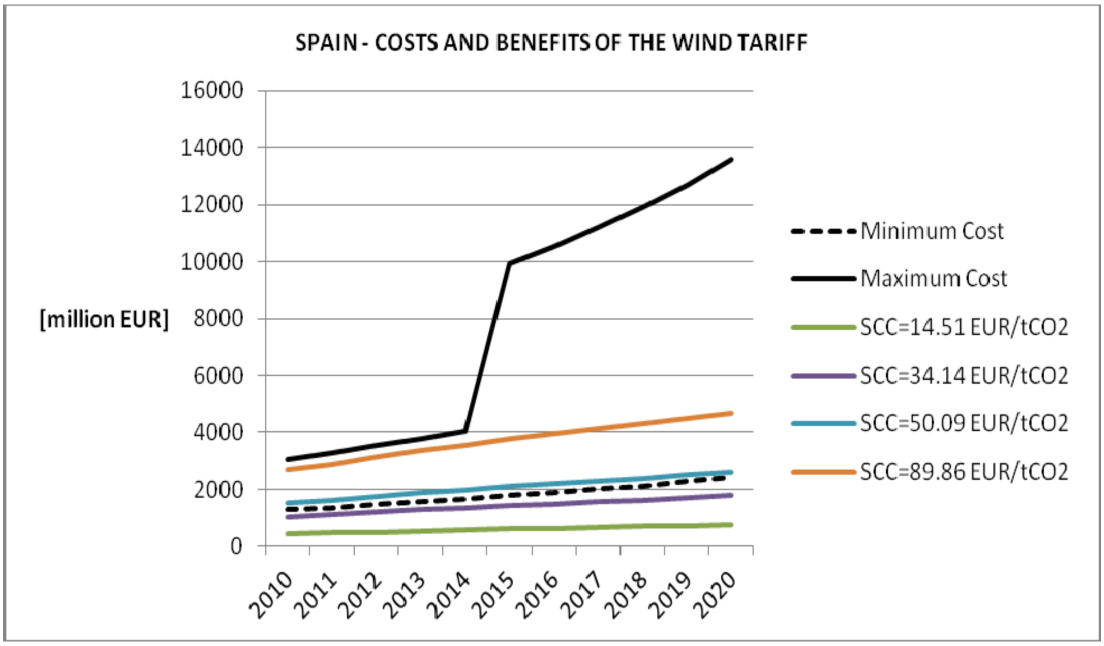


**Figure 13 – Spain, Costs and Benefits of the Wind Tariff (own elaboration)**

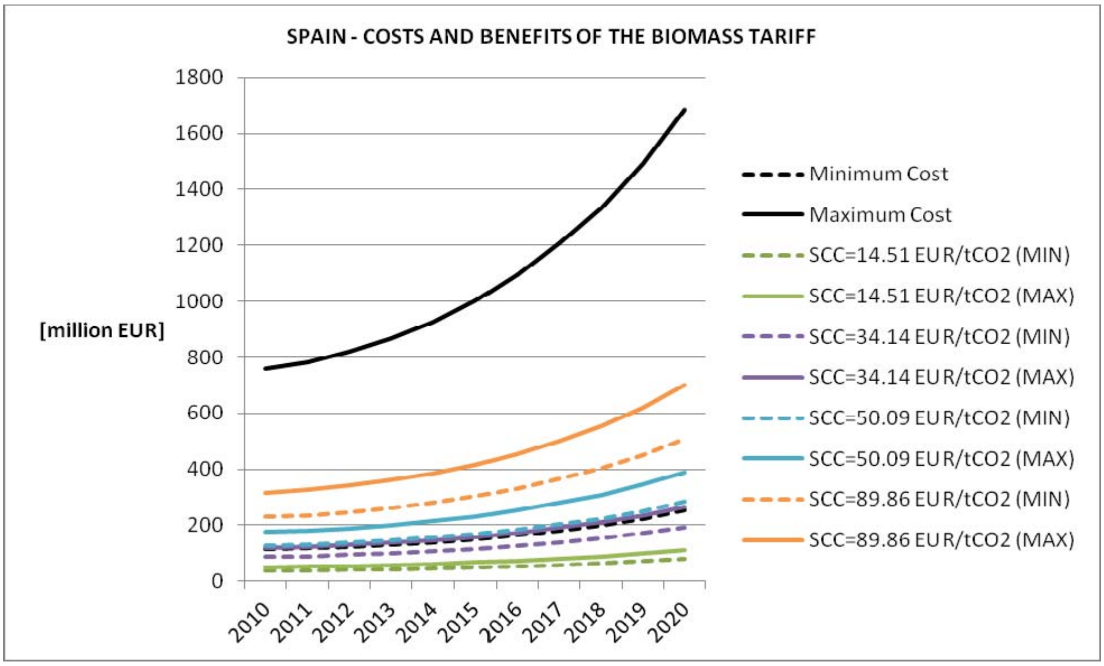


**Figure 14 - Spain, Costs and Benefits of the Biomass Tariff (own elaboration)**

For solar photovoltaic, the additional costs imposed on society by the feed-in tariffs exceed the benefits from emissions avoided by far, regardless of the estimate of the social cost of carbon used. However, for other renewable energy technology types, the picture is different.

For hydropower, the benefits from emissions avoided exceed the minimum of the cost range under three estimates of the social cost of carbon; the Stern Review estimate, the EU-income weighted estimate, and the EU ETS maximum price. Only benefits using the lower benchmark estimate fall below the cost range.

For geothermal energy, the minimum of the cost range is exceeded (although only slightly) by the benefits under the social cost of carbon estimate according to the Stern Review, while other the benefits using other estimates are below the cost range.

For wind power, benefits according to the Stern Review estimate and the EU-income weighted estimate of the social cost of carbon exceed the minimum of the cost range and, up until 2014, the benefits following the Stern Review estimate are close to the maximum of the cost range. The reason for the high jump after 2014 is, that the first offshore wind installations are expected and, like in Germany, the feed-in tariffs for offshore wind are markedly higher than for onshore (but the single avoidance factor for wind necessitated aggregation).

For biomass, the benefits of emissions avoided exceed the minimum of the cost range for the Stern Review estimate and the EU-income weighted estimate of the social cost of carbon, as well as the upper estimate of benefits (i.e. using the higher avoidance factor) using the EU ETS maximum price.

*4.1.3. Slovenia*

The results of the cost-benefit analysis for Slovenia are again different.

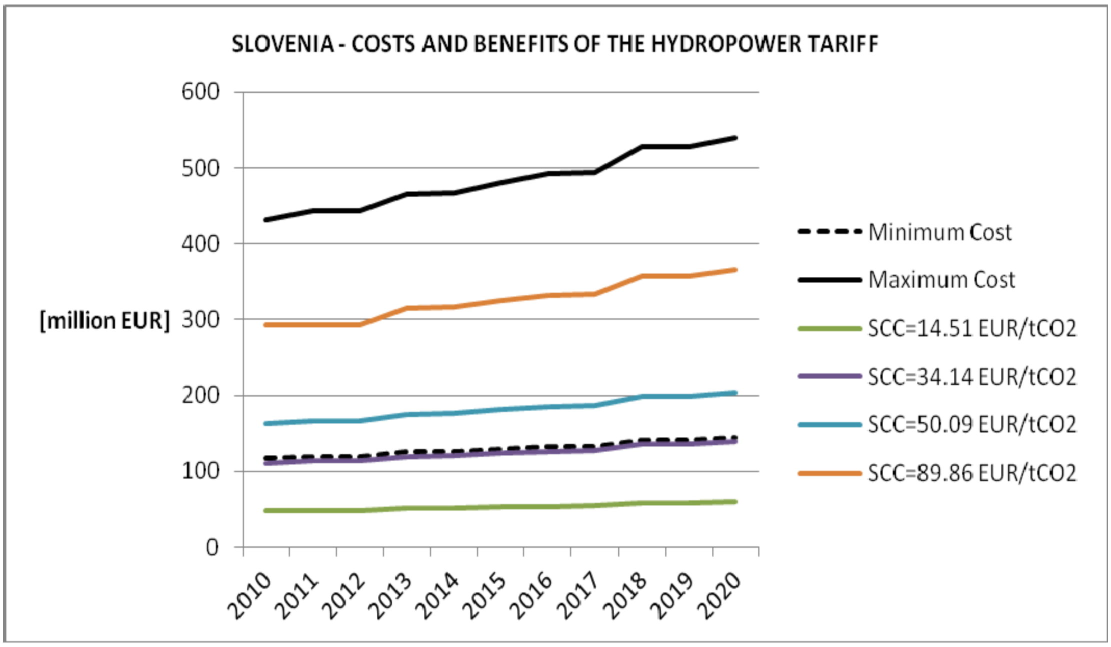


**Figure 15 – Slovenia, Costs and Benefits of the Hydropower Tariff (own elaboration)**

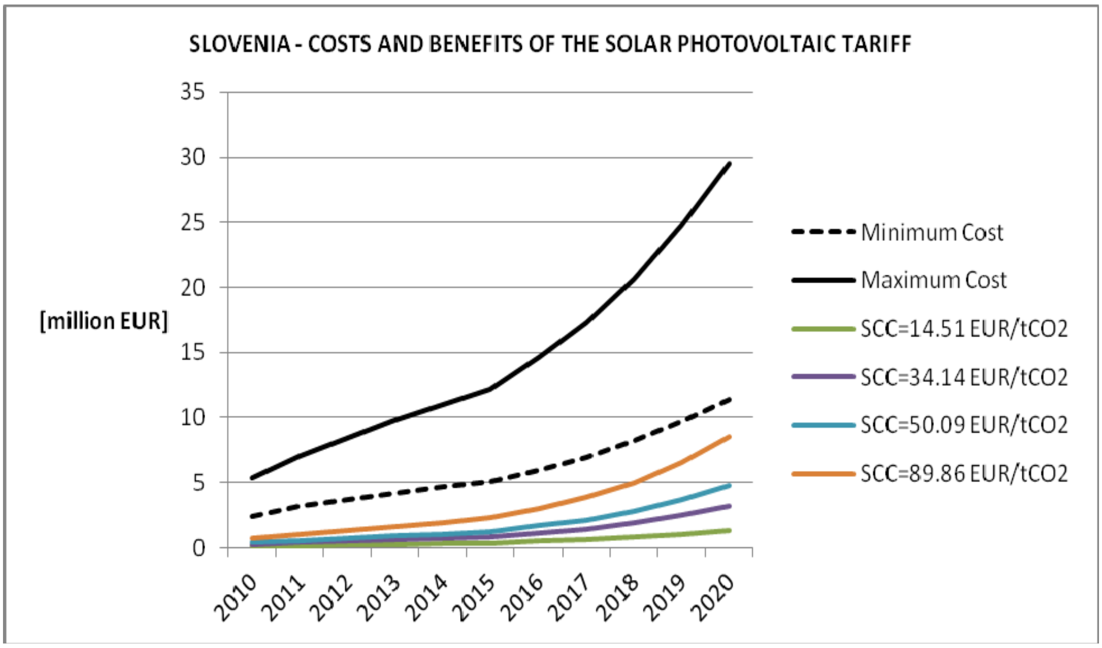


**Figure 16 - Slovenia, Costs and Benefits of the Solar Photovoltaic Tariff (own elaboration)**

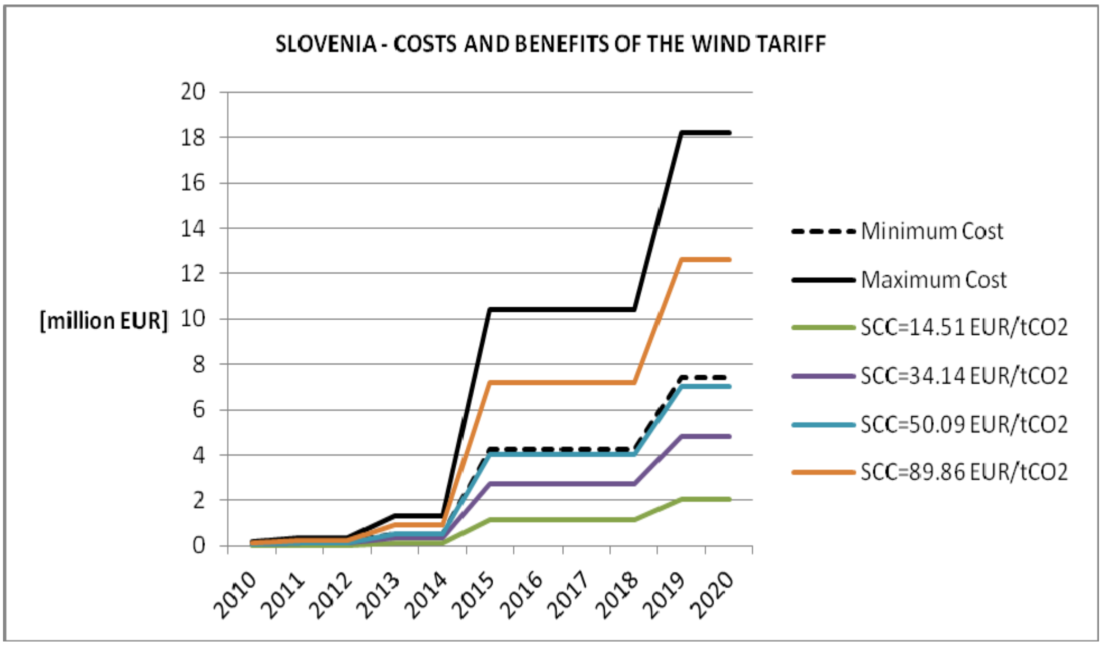


**Figure 17 - Slovenia, Costs and Benefits of the Wind Tariff (own elaboration)**

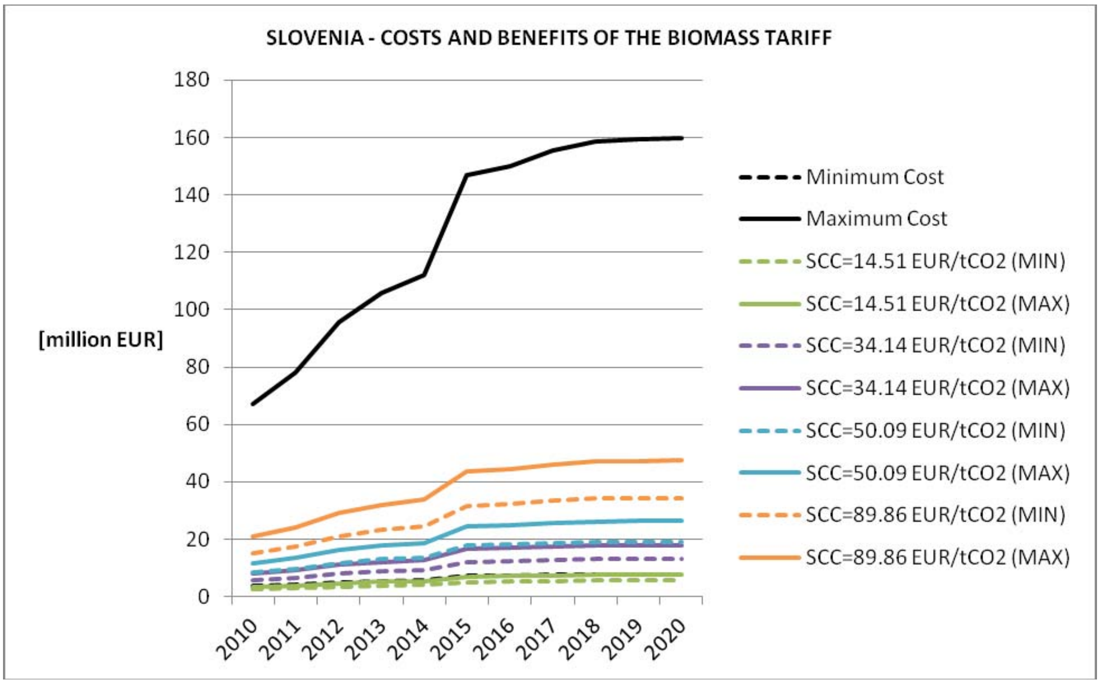


**Figure 18 - Slovenia, Costs and Benefits of the Biomass Tariff (own elaboration)**

Thus, the benefits of avoided emissions for solar photovoltaic are far below the potential cost range, regardless of the social cost of carbon estimate used. Additionally, despite annual degressions, the cost curve is exponential, as the foreseen increases in later years are high enough that they outweigh the lower costs expected from degressions.

For hydropower, the benefits of avoided emissions exceed the minimum of the potential cost range using both the Stern Review estimate and the EU-income weighted estimate. The estimate according to the EU ETS maximum price is not far below the minimum cost, either.

The graphs for the cost of wind reflect the high jumps made in the NREAP indicative trajectory, e.g. an increase in installed capacity from 8MW to 60MW between 2014 and 2015. In any case, the minimum of the potential cost range is exceeded only by benefits from avoided emissions according to the Stern Review estimate, although the EU-income weighted estimate comes close.

## 4.2. Progress Made in 2010

In this section, we compare the actual progress made by the three member states of interest in 2010 to the targets indicated in their respective NREAP trajectories. First, we look at their overall progress in both installed capacity of, and energy production from, renewable energy sources. We then look at the installed capacity targets for each technology type for each country, to compare the progress made in a more detailed way.

### *4.2.1. Overall Progress*

All three member states of interest exceeded their overall 2010 NREAP targets for both installed capacity of, and electricity produced from, renewable energy sources. This can be seen in the figures below:

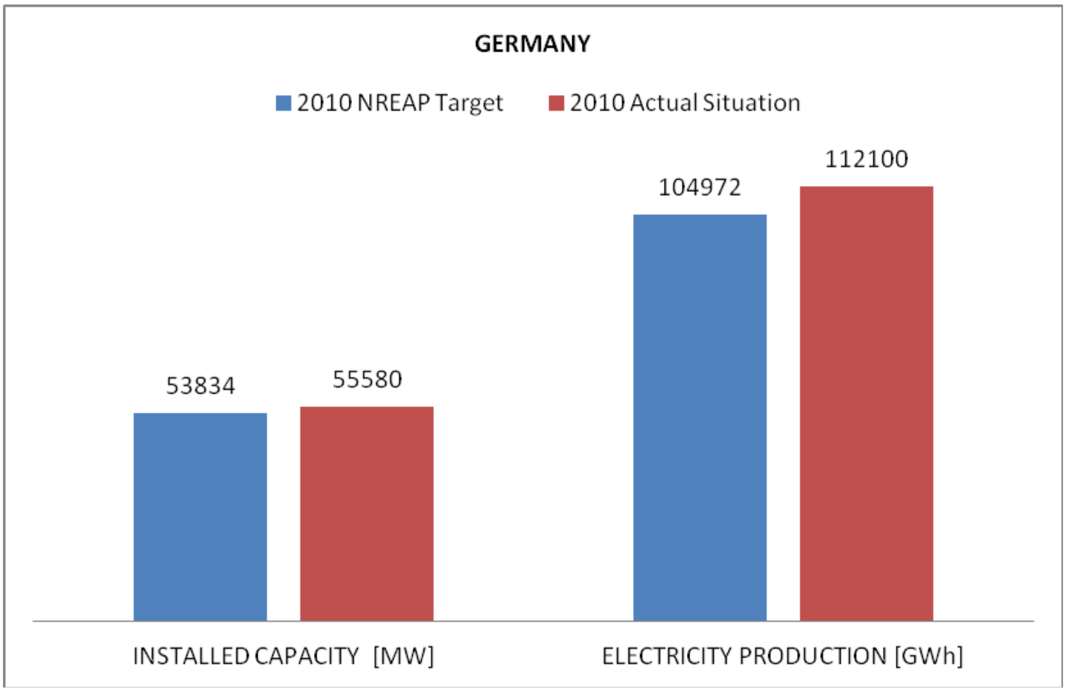


**Figure 19 - Germany, 2010 Progress (NREAP DE, 2010; PR DE, 2011; BMU, 2012)**

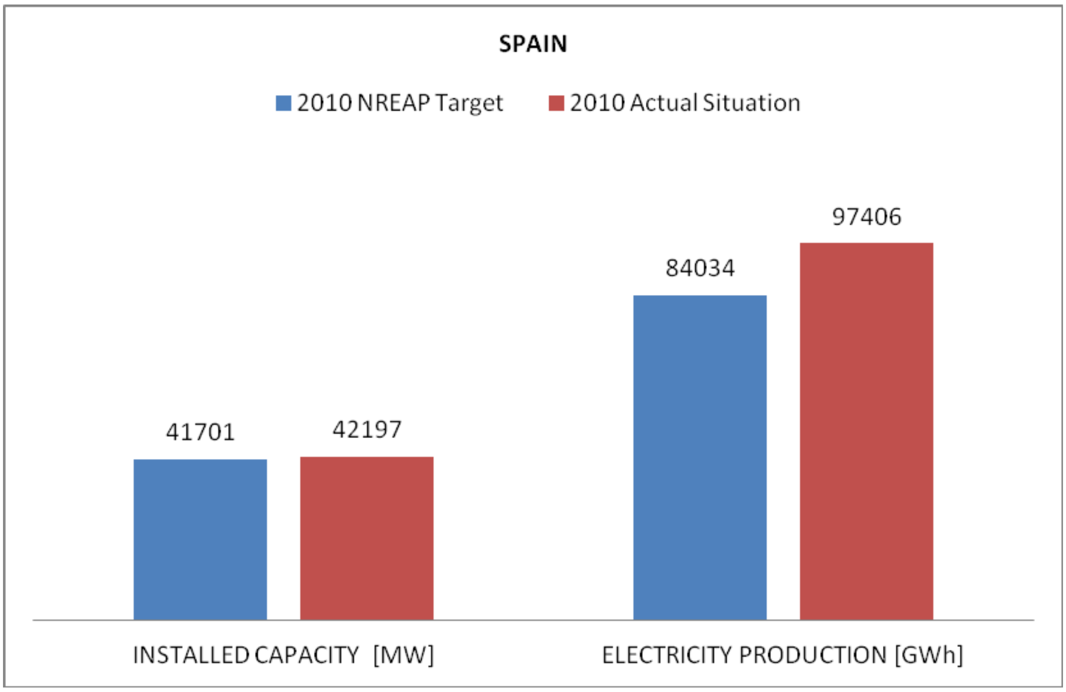


**Figure 20 - Spain, 2010 Progress (NREAP ES, 2010; MITT, 2010; NCE, 2012)**

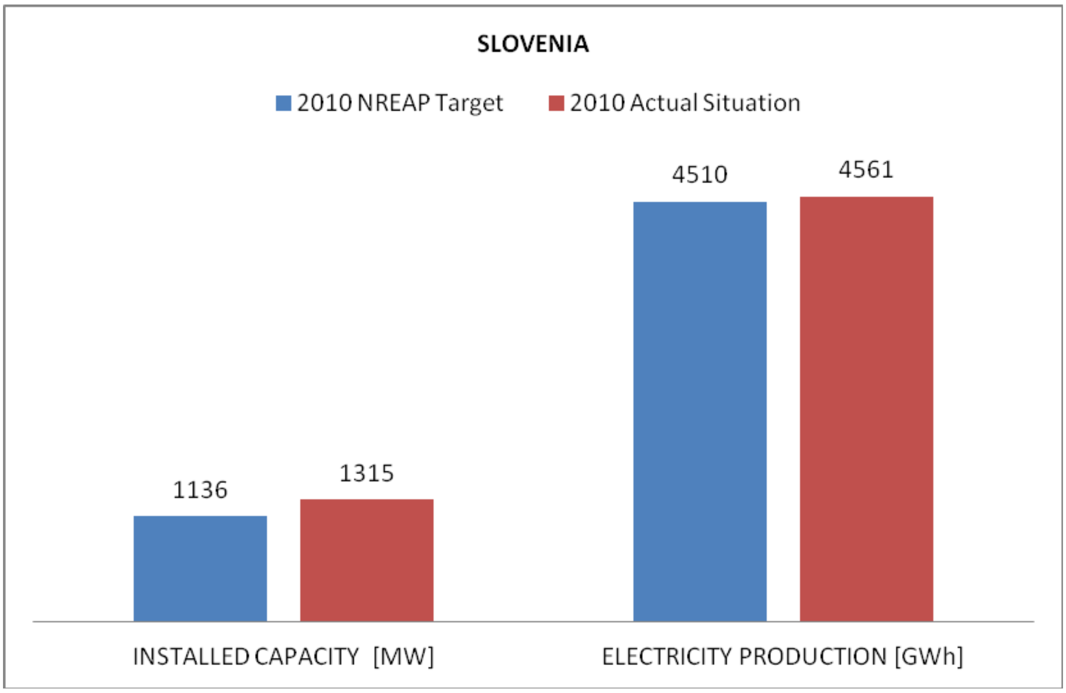


**Figure 21 - Slovenia, 2010 Progress (NREAP SI, 2010; PR SI, 2011)**

The degree to which the 2010 NREAP targets were exceeded differ among the member states. Thus, with regard to installed capacity, Germany exceeded its target by 3.2%; Spain by 1.2%; and Slovenia by 15.8%. With regard to electricity production, Germany exceeded its targets by 6.8%; Spain by 15.9%[3]; and Slovenia by 1.1%.

*4.2.2. Germany*

In this section we compare the actual progress made with the 2010 NREAP targets for the installed capacity of renewable energy sources in Germany, broken down by technology type.

[3] Note that as data for Spain was not obtained through a NREAP Progress Report, the figures for hydropower and wind power production are not normalized according to NREAP rules, and thus actual production may be over- or under-estimated (compared to NREAP-normalized projections).

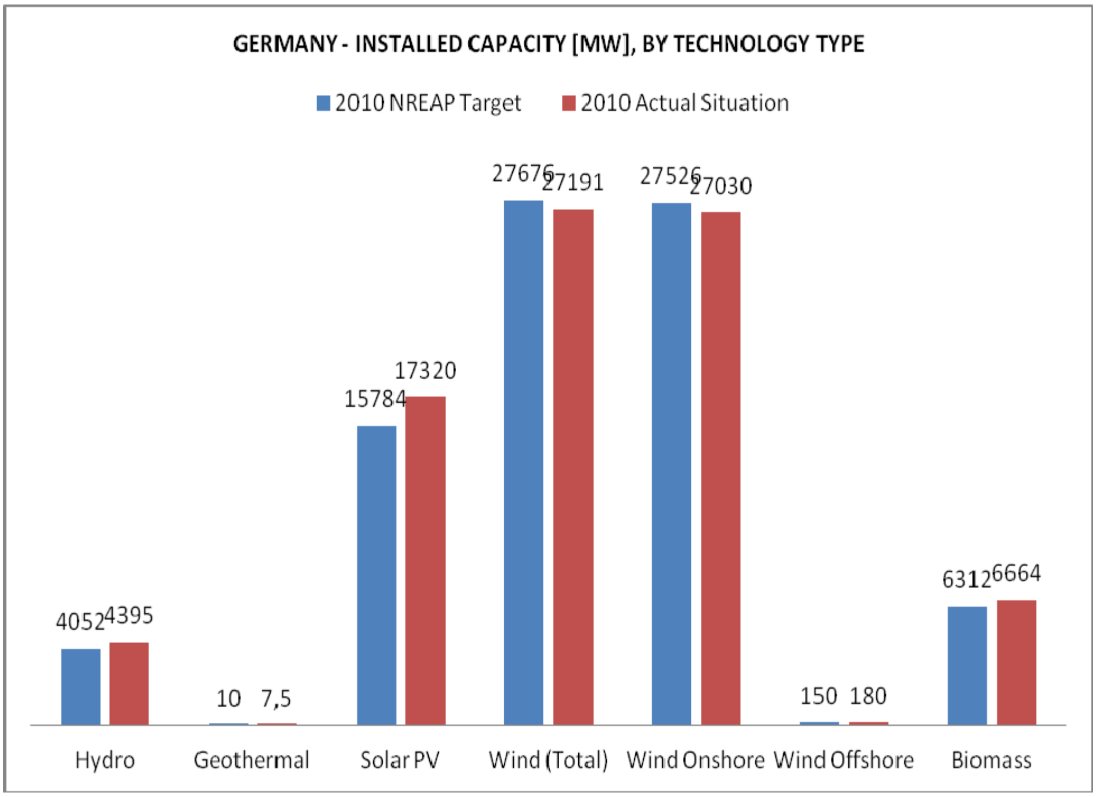


**Figure 22 - Germany, 2010 Progress by Technology (NREAP DE, 2010; PR DE, 2011; BMU, 2012)**

As we can see, although on an overall level, Germany has exceeded its 2010 targets for installed capacity, a closer look shows that some types of technology have exceeded their targets – for example, solar photovoltaic exceeded its target by 9.7% - others have not.

Thus, the targets for installed capacity of hydro, solar photovoltaic, offshore wind, and biomass energy were exceeded, while those for geothermal and onshore wind energy were not reached.

### *4.2.3. Spain*

In this section we compare the actual progress made with the 2010 NREAP targets for the installed capacity of renewable energy sources in Spain, broken down by technology type.

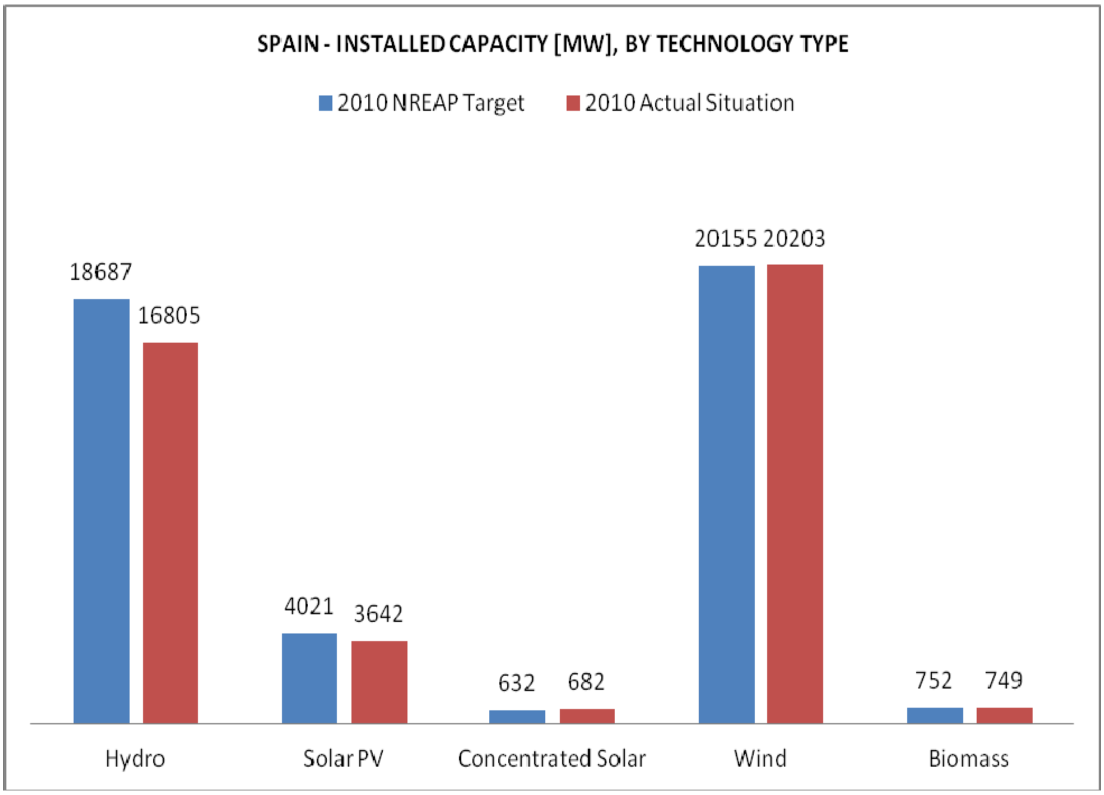


**Figure 23 - Spain, 2010 Progress by Technology (NREAP ES, 2010; MITT, 2010; NCE, 2012)**

As we can see, while the overall installed capacity target for 2010 has been met, a technology type breakdown shows that the targets have only been exceeded for concentrated solar power and for wind. The targets for hydropower, solar photovoltaic, and biomass have, however, not been met[4].

### *4.2.4. Slovenia*

In this section we compare the actual progress made with the 2010 NREAP targets for the installed capacity of renewable energy sources in Slovenia, broken down by technology type.

[4] Note that the total of capacity in figure 23 is less than the total installed capacity in figure 20 as municipal solid waste is not a separate category in Table 10 but counts towards the total.

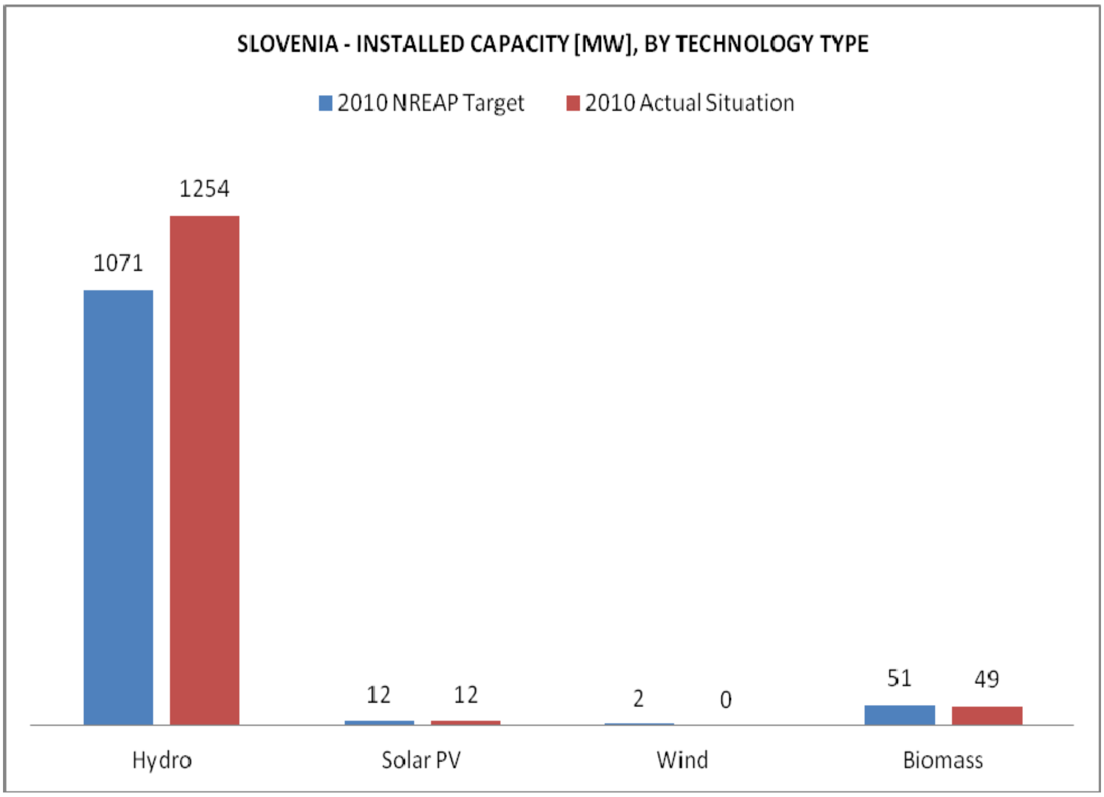


**Figure 24 - Slovenia, 2010 Progress by Technology (NREAP SI, 2010; PR SI, 2011)**

The picture for Slovenia is the most straightforward – the overall target was exceeded only due to the increase in installed capacity of hydropower. The installed capacity target for solar photovoltaic was met, while that for biomass was not. Notably, the target for wind – even though small – was not met and there was no wind power capacity installed in Slovenia as of 2010.

## 4.3. Progress Made in 2011

In this section, we compare the actual progress made in the three member states of interest in 2011 with their respective NREAP trajectories. As in the previous section, we begin by taking a look at the overall situation, for both installed capacity and electricity production. We then look in more detail at the progress made in installed capacity for each technology type in each country.

### *4.3.1. Overall Progress*

The situation in 2011 was a bit different than in 2010. While Germany and Slovenia exceeded their 2011 NREAP targets for both overall installed capacity of, and electricity production from, renewable energy sources, Spain did not meet either target, as we can see in the figures below.

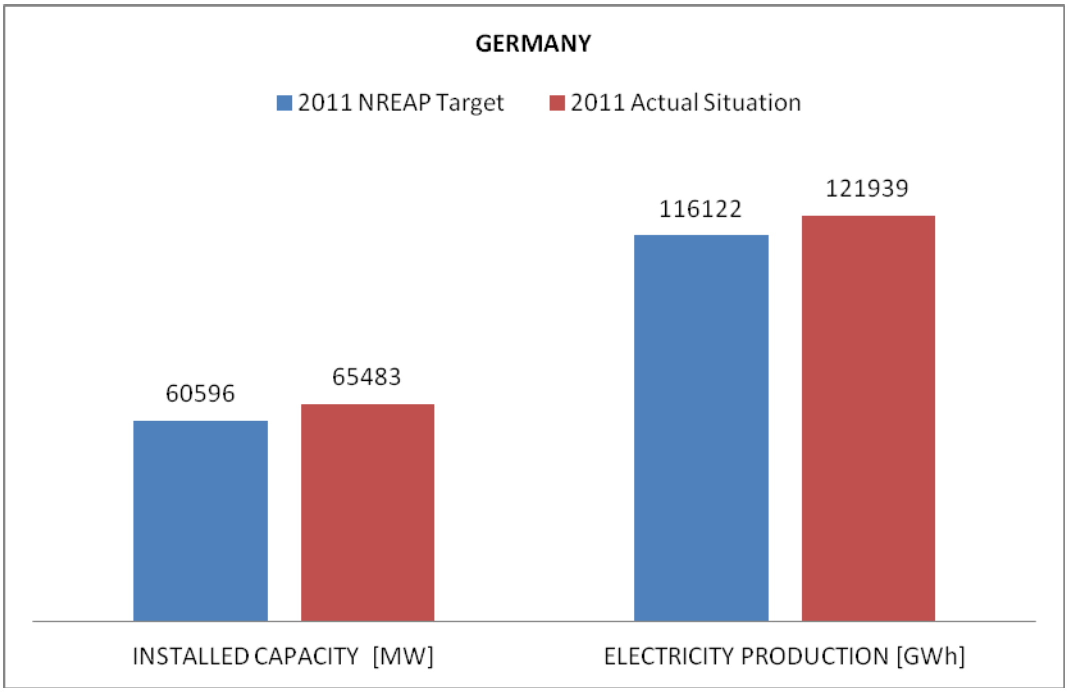


**Figure 25 - Germany, 2011 Progress (NREAP DE, 2010; PR DE, 2011; BMU, 2012)**

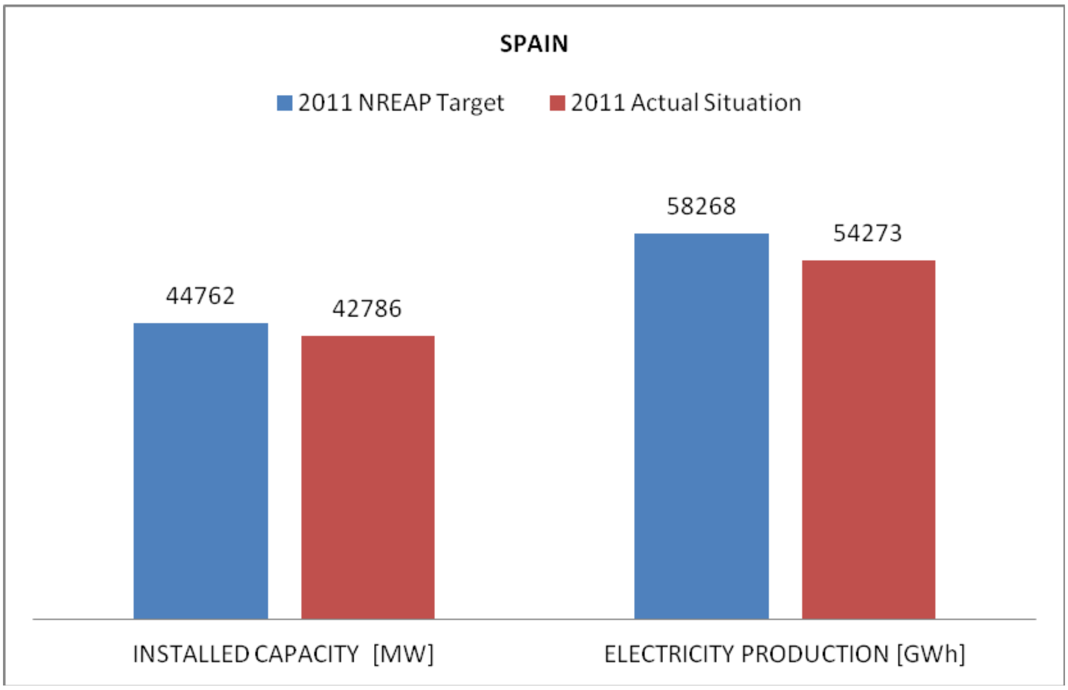


**Figure 26 - Spain, 2011 Progress[5] (NREAP ES, 2010; NCE, 2012)**

[5] Data was missing for hydropower (both capacity and production). We assume installed capacity for hydropower was (at least) the same as in 2010. As 2010 production data was not normalized according to NREAP methodology, we cannot do the same, and omit hydropower from overall electricity production (NREAP and actual situation).

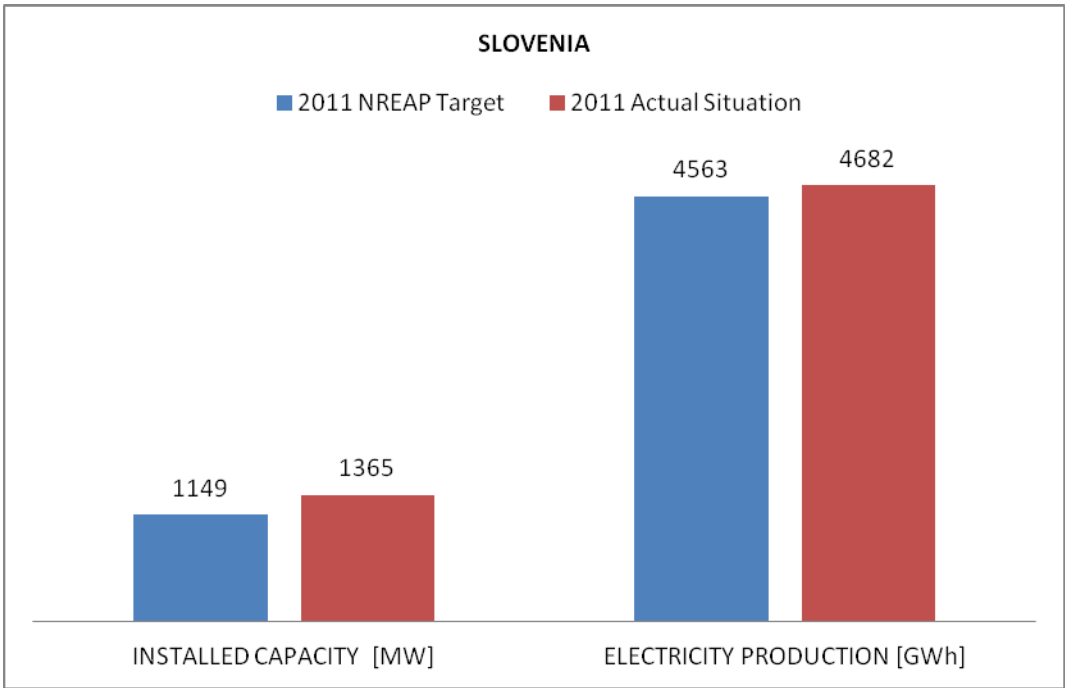


**Figure 27 – Slovenia, 2011 Progress[6] (NREAP SI, 2010; EA RS, 2012)**

When comparing Spain's actual situation with that of the NREAP, it must be taken into account that data was unavailable for hydropower; it is entirely possible that installed capacity in 2011 increased enough to meet the overall target and, in turn, that the overall target for electricity production was also met. However, given that Spain did not reach its 2010 installed capacity target for hydropower, this is not very likely.

We may note the degree to which the 2011 targets were exceeded by Germany and Slovenia. With regard to installed capacity, Germany exceeded its 2011 NREAP target by 8.1%, and Slovenia exceeded its 2011 target by 18.8%. Looking at electricity production from renewable energy sources, Germany has exceeded its 2011 target by 5%[7], while Slovenia exceeded its 2011 target by 2.6%[8].

[6] Data was unavailable for hydropower production. However, as 2010 production was normalized according to NREAP methodology, we assume electricity production from hydropower was (at least) the same as in 2010.

[7] Note that as the data used was not normalized according to NREAP methodology, a direct comparison between actual and target production is not possible.

[8] Note that as data on hydropower production was missing and we assumed that it was (at least) equal to the 2010 figure (which was normalized according to NREAP methodology), this may be an underestimate.

*4.3.2. Germany*

In this section we compare the actual progress made with the 2010 NREAP targets for the installed capacity of renewable energy sources in Germany, broken down by technology type.

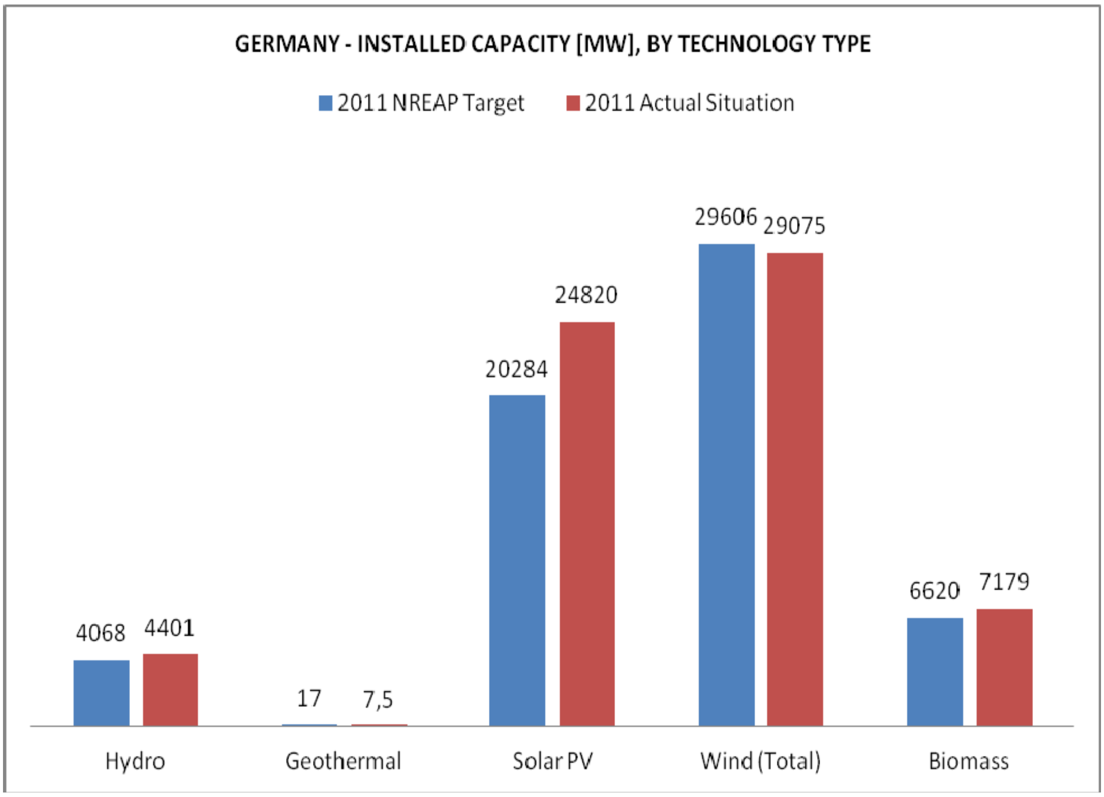


**Figure 28 - Germany, 2011 Progress by Technology[9] (NREAP DE, 2010; PR DE, 2011; BMU, 2012)**

We see from the above that while some technology types exceeded their 2011 NREAP targets for installed capacity, others did not. Thus, installed capacity of hydropower, solar photovoltaic, and biomass energy exceeded the targets, while installed capacity of geothermal and wind energy fell short. What has been observed in 2010 has continued in 2011.

*4.3.3. Spain*

In this section we compare the actual progress made with the 2010 NREAP targets for the installed capacity of renewable energy sources in Germany, broken down by technology type.

[9] Note that available data for wind was not separated into on- and off-shore, so only an aggregate comparison is possible.

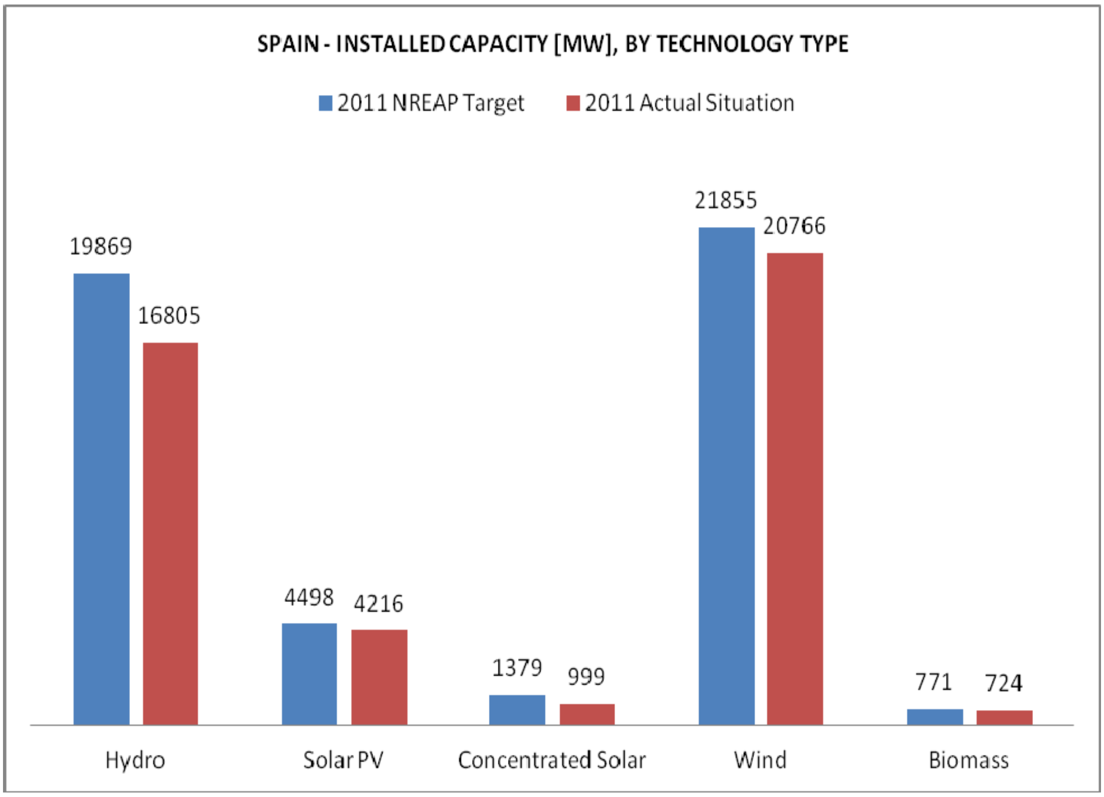


**Figure 29 - Spain, 2011 Progress by Technology[10] (NREAP ES, 2010; NCE, 2012)**

For Spain, we see that the (likely) failure to have reached its overall 2011 targets was due to not a single type of renewable energy technology having reached its 2011 installed capacity targets. As the data is from the NCE dataset, which covers 'Special Regime' installations only, it is entirely possible that the actual installed capacity is higher than what is noted in the figure above. However, this seems unlikely[11] given that the entire purpose of implementing a feed-in tariff system is to promote renewable energy sources which would otherwise be uncompetitive.

### *4.3.4. Slovenia*

In this section we compare the actual progress made with the 2010 NREAP targets for the installed capacity of renewable energy sources in Slovenia, broken down by technology type.

[10] The hydropower figure is from 2010, as no accurate data was available for 2011.

[11] Except in the case of large hydropower, which is not covered by the 'Special Regime'.

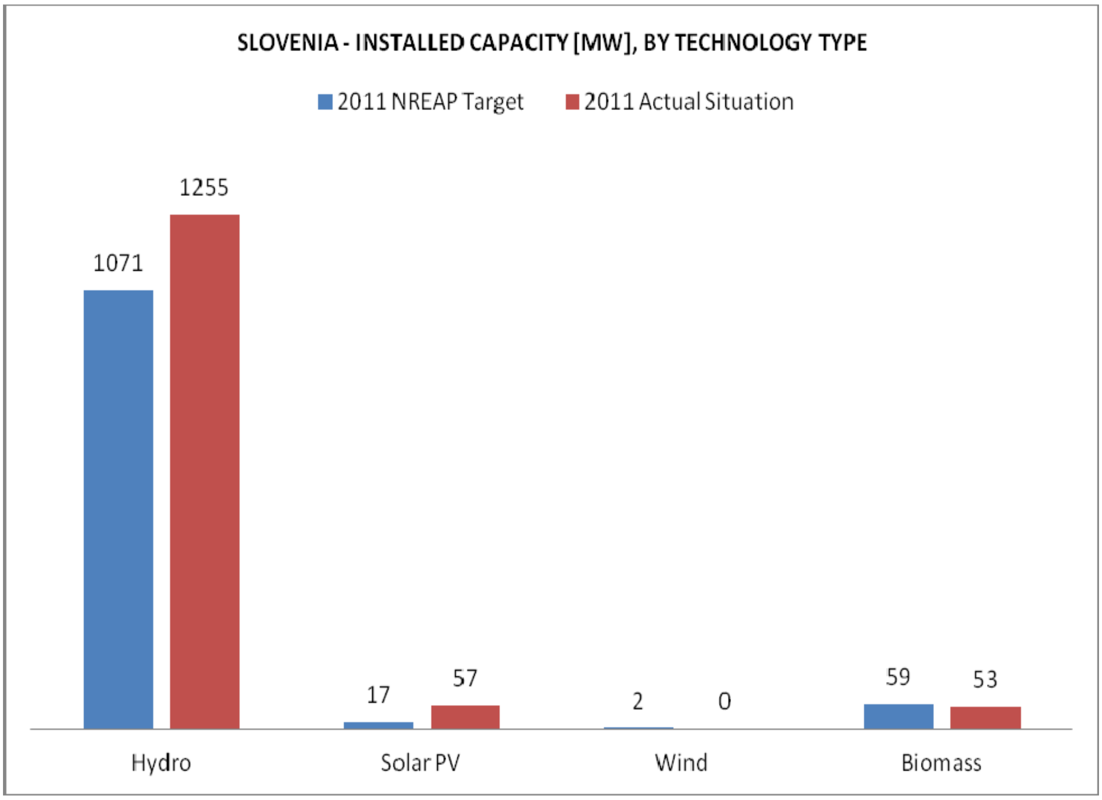


**Figure 30 - Slovenia, 2011 Progress by Technology (NREAP SI, 2010; EA RS, 2012)**

As in 2010, installed capacity for hydropower exceeded the NREAP target in 2011, while installed capacity for biomass energy did not reach the target. More important, however, are the installed capacities of wind energy and solar photovoltaic. Thus, Slovenia in 2011 still had no wind power capacity installed, despite the relatively low target set in the NREAP. The increase in installed capacity of solar photovoltaic, however, is striking – capacity more than tripled in 2011.

## 4.4. Developments in 2012

In this section, we take a look at the more recent developments in the three Member States of interest. We do so quantitatively, by looking at new installed capacity in 2012 so far[12], as well as qualitatively, by noting developments in the legal frameworks and/or the levels of the feed-in tariffs available.

### *4.4.1. Progress in Installed Capacity*

We compare the additional installed capacity in 2012 so far with the additional capacity in 2012 according to the NREAP indicative trajectory. Preliminary data on 2012 was available only for Spain and Slovenia, so Germany will not be considered in this section.

[12] At the time of writing; this would be until April 2012.

*Spain*

Provisional data for Spain was available in the NCE data set, for the 1st quarter of 2012. The additional installed capacity in 2012 so far, and how it compares to the increase in the NREAP, is given in table 11 below.

| Technology | 2012 Total Capacity Increase (NREAP) | 2012 Capacity Increase (Actual) | % of Projected Increase Achieved |
|---|---|---|---|
| Solar Photovoltaic | 423 MW | 7 MW | 1.6 |
| Concentrated Solar | 649 MW | 150 MW | 23.1 |
| Wind (Onshore) | 1700 MW | 278 MW | 16.4 |

**Table 11 – Spain, 2012 Progress (NREAP ES, 2010; NCE, 2012)**

Progress in the 1st quarter of 2012 in Spain has been quite good for concentrated solar. Wind, while progressing slower, is not too bad either. The capacity increase in solar photovoltaic has been however very low. Again, the figures may be underestimated, given that the NCE dataset covers only 'Special Regime' installations, but this is unlikely. However, the figures in table 2 are disappointing, especially when one considers that Spain likely did not reach its 2011 NREAP targets. In order to catch up with its NREAP indicative trajectory targets, Spain would require higher increases in installed capacity than those mentioned above – the progress, therefore, is correspondingly lower.

At the same time, the results must be interpreted with the suspension of feed-in tariff eligibility for new installations that occurred in early 2012 (see 4.4.2.2.); thus, any capacity installed after the suspension of the feed-in tariff system are excluded from the data.

*Slovenia*

Data for Slovenia was obtained from the Register of Declarations, up to the 30th April 2012 (EA RS, 2012). The additional installed capacity in 2012 so far, and how it compares to the increase in the NREAP, is given in table 12 below.

| Technology | 2012 Total Capacity Increase (NREAP) | 2012 Capacity Increase (Actual) | % of Projected Increase Achieved |
|---|---|---|---|
| Hydropower | 0 MW | 52 MW | N/A |
| Solar Photovoltaic | 5 MW | 47 MW | 840% |
| Wind (Onshore) | 0 MW | 0 MW | N/A |

**Table 12 - Slovenia, 2012 Progress (NREAP SI, 2010; EA RS, 2012)**

Progress in Slovenia up to April 2012 has been interesting and deserves a bit more comment. Thus, the NREAP indicative trajectory did not include any increase in hydropower capacity, while in reality, there was a big increase. However, as the data in the Register of Declarations deals only with installed capacity participating in the feed-in tariff system, it is possible that this was not new hydropower capacity (as in newly built) but that some existing hydropower capacity began to participate in the feed-in tariff system. The NREAP indicative trajectory also did not include any increase in wind capacity in 2012, but it must be noted that there has still not been any progress to reaching the target of 2MW installed capacity, set for 2010 in the NREAP. Finally, the increase in solar photovoltaic capacity is striking, as by April 2012, the additional installed capacity was already higher than the additional installed capacity in all of 2011, and of course, much higher than the overall 2012 capacity increases according to the NREAP.

### *4.4.2. Other Developments*

In this section we note other recent developments in 2012 related to the feed-in tariff systems in the member states of interest.

*Germany*

A February 2012 report announced another revision of the Renewable Energy Act (BMU/BMWi, 2012-a). The planned revisions include one-time tariff cuts for solar photovoltaic, depending on installation size, and increases in the frequency of degressions to a monthly basis (BMU/BMWi, 2012-b). Additionally, a yearly cap is to be placed on new installed capacities for solar photovoltaic, decreasing each year from 2014 onwards (BMU/BMWi, 2012-b). However, in May 2012, the proposed revisions were rejected by the Bundesrat, citing, amongst other reasons, that the revisions would undermine national renewable energy goals and undermine investment security (Bundesrat, 2012).

*Spain*

The situation in Spain in 2012, from the point of view of reaching the NREAP targets for electricity from renewable energy sources, has developed in a very negative direction. The main reason for this is Royal Decree 1/2012 from January 2012 (RD, 2012). The Decree notes that the combination of a significant drop in demand in 2010 as well as favorable weather conditions that lead to more production by renewables than expected has led to higher-than-expected costs through the feed-in tariff system (RD, 2012). Additionally, it states that current installed capacity is enough to cover demand in the upcoming years (RD, 2012). Citing austerity measures and the need to resolve the threat (via feed-in tariffs) to the economic sustainability of the electric system, the Decree suspends feed-in tariffs and economic incentives for all new installations (RD, 2012). A report by the National Commission on Energy from March recommends that the suspension last until 2017 (ENDS Europe, 2012).

*Slovenia*

Unlike Germany and Spain, there were no major developments (or near-developments) in the legal framework behind the feed-in tariff system in the beginning of 2012. There were however developments regarding wind energy; construction of the first wind turbine began and is expected to be completed by the middle of the year, with 24 others to follow in what should become Slovenia's first wind park, and with other wind parks in the planning stages (Ozebek, 2012).

## 4.5. The Effectiveness of Feed-in Tariffs

In this section, we evaluate the feed-in tariffs of the member states of interest. We do so on the basis of the 'Policy Effectiveness Indicator' developed in the framework of the RE-Shaping project (see 2.6.2.), where the effectiveness of a policy in year N is defined as the increase in capacity for that technology in year N relative to the remaining potential to be achieved in 2020. We then compare them to their 2010 values as found in the RE-Shaping Report (Steinhilber et al., 2011); however, due to data availability, the analysis is limited to feed-in tariffs for solar energy.

*Germany*

For Germany, we evaluate only the effectiveness of the feed-in tariffs for geothermal energy and solar photovoltaic. The effectiveness of feed-in tariffs for hydropower cannot be evaluated, as effectiveness is measured relative to 2020, and Germany exceeded its 2020 target in 2010 already. Feed-in tariffs are different for on- and off-shore wind, but available wind energy data was aggregated; therefore wind tariffs cannot be evaluated. The effectiveness of the respective tariffs is given in table 13 below.

| TARIFF | EFFECTIVENESS | |
|---|---|---|
| | 2010 | 2011 |
| Solar Photovoltaic | 36% | 25% |

**Table 13 - Germany, Tariff Effectiveness 2010-2011 (Steinhilber et al., 2011; own elaboration)**

The policy effectiveness of the feed-in tariff for solar photovoltaic in Germany has decreased from 2010 to 2011.

*Spain*

For Spain, we only evaluate the effectiveness of the feed-in tariffs for solar photovoltaic and concentrated solar energy. The effectiveness of feed-in tariffs for hydropower cannot be evaluated, as the figures in the NCE dataset refer to different capacity sizes than the NREAP targets. Similarly, wind power tariffs cannot be evaluated as the data available is not normalized according to NREAP methodology and therefore cannot be appropriately compared to the NREAP target. The effectiveness of the respective tariffs is given in table 14 below.

| TARIFF | EFFECTIVENESS | |
|---|---|---|
| | 2010 | 2011 |
| Solar Photovoltaic | 2% | 2.8% |
| Concentrated Solar | N/A | 7.4% |

**Table 14 - Spain, Tariff Effectiveness 2010-2011 (Steinhilber et al., 2011; own elaboration)**

The policy effectiveness of the feed-in tariff for solar photovoltaic in Spain has increased somewhat from 2010 to 2011. While no yearly comparison can be made for concentrated solar tariffs, its effectiveness in 2011 was higher than that for solar photovoltaic tariffs.

*Slovenia*

For Slovenia, we only evaluate the effectiveness of the feed-in tariffs for solar photovoltaic and wind. Accurate data for 2011 hydropower production was unavailable, so feed-in tariffs for hydropower cannot be evaluated. Wind power capacity in 2011 was zero, so no evaluation is necessary; the feed-in tariff has an effectiveness of zero.

| TARIFF | EFFECTIVENESS | |
|---|---|---|
| | 2010 | 2011 |
| Solar Photovoltaic | 3% | 34.9% |

**Table 15 - Slovenia, Tariff Effectiveness 2010-2011 (Steinhilber et al., 2011; own elaboration)**

The policy effectiveness of the feed-in tariff for solar photovoltaic in Slovenia has seen a large increase from 2010 to 2011.

## 5. DISCUSSION

Having presented our results, it is now time to discuss their impact and answer our research questions.

### 5.1. Research Question 1

*Is there a point in the NREAP indicative trajectories at which the benefits from emissions avoided due to the feed-in tariffs exceed the additional costs imposed on society by the feed-in tariffs? And, if so, for which technology types and under which assumptions regarding the social cost of carbon?*

In 4.1., we conducted a cost-benefit analysis of the feed-in tariffs and the NREAP indicative trajectories, where the costs were defined as the *additional* costs imposed on society by the use of feed-in tariffs and the benefits were defined as the value of damages from the emissions of carbon dioxide avoided. We applied the feed-in tariffs in ranges from minimum to maximum, and compared these to the value of damages prevented by reducing emissions, using four different estimates of the social cost of carbon: a lower benchmark minimum, the maximum price from the EU ETS, an EU-income weighted estimate, and the estimate used in the Stern Review. The accuracy of our results varies – for example, avoidance factors used had been derived for Germany, so that the results for Germany are more realistic than those for Spain and Slovenia – but, given the number of assumptions used (see 3.), it is clear that the results should be taken as illustrative.

Regardless, we arrived at some interesting conclusions. For some technologies and certain estimates of the social cost of carbon, the benefits from emissions avoided exceed the minimum of the potential cost range, which means that depending on the actual distribution of the feed-in tariffs applied, it is theoretically possible (if not plausible) that the feed-in tariffs pay for themselves as the damages avoided by their implementation exceed the cost of their implementation. This should, however, be taken only as an illustration of the theoretical possibility thereof, and not as evidence of it being true.

Looking at the illustrative results in more detail, we may make a few comments. It is not too surprising that the benefits of emissions avoided exceed the minimum of the potential cost curve in some situations when using the highest of the social cost of carbon estimates used, the estimate from the Stern Review. Under this estimate, the benefits of emissions avoided exceeded the minimum of the potential cost range for each technology type in each member state of interest, except for solar photovoltaic (in any member state) and geothermal energy (in Germany). It is interesting that in some situations, the EU-income weighted estimate also exceeds the minimum of the potential cost range. This was the case for hydropower in each member state of interest as well as for wind power in Spain. Notably, the benefits from emissions avoided using the Stern Review estimate for wind power in Spain also come close to the *maximum* of the potential cost range.

It is interesting that in some situations, the EU-income weighted estimate also exceeds the minimum of the potential cost range. This was the case for hydropower in each member state of interest as well as for wind power in Spain. In one case, the benefits of emissions avoided exceeded the minimum of the potential cost curve even for the social cost of carbon estimate based on the EU ETS maximum price. This was the case for hydropower in Spain.

However, the benefits of emissions avoided using the lower benchmark estimate suggested by Downing et al. were below the minimum of the potential cost range for every technology in every member state of interest. Furthermore, the additional costs imposed on society by feed-in tariffs for solar photovoltaic are, in each member state of interest, markedly higher than the benefits, regardless of the social cost of carbon estimate used. However, the trend of the potential costs in Germany shows that although the overall costs increase, the pace of increase is diminishing, while the benefits from the emissions avoided are increasing linearly, somewhat approximating our discussion in 2.8. However, the difference between the costs and benefits, is sufficiently large that the benefits will not outweigh the costs, except in the long-term when support from feed-in tariffs is no longer necessary.

## 5.2. Research Question 2

*How have the Member States of interest progressed in reaching the targets for electricity from renewable energy sources as stated in their respective NREAP indicative trajectories? What other developments are significant?*

In 4.2 to 4.4, we looked at the progress made in the Member States of interest in 2010, 2011, and 2012, and discovered that there were some important differences.

We begin by commenting on the reporting requirements. Member States are to submit progress reports to inform the European Commission on their progress every two years, starting with 2011 (DIR 2009/28/EC). However, not all countries have in fact submitted their 2011 reports; the data provided by the European Commission (EC, 2011) contains only 16 progress reports. With regard to the Member States of interest, Germany and Slovenia submitted a progress report, while Spain did not.

The overall progress – in terms of aggregate installed capacity of, and electricity produced by, renewable energy sources – of the three Member States differed from one year to the next. While in 2010, all three Member States of interest met and exceeded their NREAP targets, in 2011 only Germany and Slovenia met and exceeded their NREAP targets, although we cannot be absolutely certain for Spain due to data issues. With preliminary data available for Spain and Slovenia for 2012, we can note that progress so far has been slow for Spain and rapid for Slovenia. Combining additional capacity installed in 2012 with the total installed capacity for Slovenia, it appears that Slovenia has already exceeded its 2017 NREAP installed capacity target.

When looking at the progress made broken down by each technology type, however, it is evident that progress has not been equally distributed among all renewable energy sources. This is the case in all three Member States.

In Germany, the technologies that exceeded their NREAP targets in both 2010 and 2011 were hydropower, solar photovoltaic, and biomass, while geothermal energy and wind power lagged behind.

In Spain in 2010, concentrated solar and wind power exceeded their NREAP targets, while other forms lagged behind; the picture is less clear for 2011, for reasons stated above, but progress was likely lower than the NREAP indicative trajectory. Progress made in the 1st quarter of 2012 was likewise slow, although given the suspension of feed-in tariffs for new installations, this is not surprising.

In Slovenia in 2010, only hydropower exceeded its target, while the target for solar photovoltaic was met; wind and biomass fell short of reaching their targets. In 2011, the situation was similar – the hydropower target was exceeded, wind and biomass targets were not – with one crucial difference: solar photovoltaic. The installed capacity in 2011 for solar photovoltaic more than tripled; a possible explanation is that, unlike Germany and Spain, which have had more developed systems of feed-in tariffs for longer, Slovenia's feed-in tariff structure was not as well-developed prior to 2009. This is suggested by the Slovenian Public Agency for Energy with reference to the high growth in solar installations in 2010 (EA RS, 2011), and it is reasonable to assume that this also explains the high growth in 2011. Finally, the first few months of 2012 saw even faster growth in the installed capacity of solar photovoltaic installations in Slovenia, possibly for the same reason. Notably, there is still no installed wind power capacity in Slovenia, although one turbine is under construction.

The legislative framework for electricity from renewable energy sources, including feed-in tariff systems, was changed to different degrees in all three member states in the 2010-2012 period, to different degrees. To a certain extent, these developments confirm the danger identified in the literature, whereby "*if FITs are set to high, there is likely to be a political backlash that could abruptly halt the entire FIT approach*" (Lesser and Su, 2008). However, this danger is magnified depending on the funding of the tariff system, as Germany and Slovenia, both funding the tariffs through electricity prices, have both made cuts to their tariffs, while Spain, which funded its tariffs through electricity prices and tax revenue, has suspended its feed-in tariffs.

More specifically, in Germany, new measures that have been put in place since the NREAP include a 5 billion program for the promotion of offshore wind farms, in place since 2011 (PR DE, 2011). Importantly, several amendments were made to the Renewable Energy Act in 2011. First, a feed-in premium system was implemented alongside the existing fixed feed-in tariff system. Second, major revisions were made to the Renewable Energy Act that came into effect in 2012, including a lowering of tariff levels and a simplification in the structure of the tariffs for some technology types. A yearly installed capacity quota for solar photovoltaic was also introduced, whereby the yearly degressions vary depending on how much of the quota is fulfilled. In early 2012, additional revisions to the Renewable Energy Act were announced, again to do with solar photovoltaic, their tariff levels, the yearly capacity quota, and the frequency of degression revisions, although as of May 2012, the revisions had been rejected by the Bundestag.

Spanish legislation already had yearly installed capacity quotas set prior to 2010, but other changes to the legislative framework followed in 2010. Thus, Royal Decree 1565/2010 lowered solar photovoltaic tariff levels and reduced the tariff payment duration from 30 to 25 years after installation, while Royal Decree 1614/2010 cut premium tariffs for wind, restricted premium tariffs for concentrated solar for the first year after installation, and set limits to the number of hours per year that wind power and concentrated solar installations can receive support (Held et al., 2010). The most important legislative change that has occurred in Spain since 2010, however, is without doubt Royal Decree 1/2012, which suspends feed-in tariffs – be they premium or fixed – for all new installations. While it is meant as a temporary measure, the Spanish feed-in tariff system was already in 2010 perceived as unstable due to frequent revisions (EREC, 2011), and the suspension of the feed-in tariff system does nothing to help that perception. Even when –if at all – the suspension is lifted, it will be hard to restore confidence in the feed-in tariff system. At the same time, this development further supports the warning found in the literature against funding feed-in tariffs from tax revenue, which is more susceptible to political events (Couture & Gagnon, 2010).

The Slovenian legislative framework also changed in the 2010-2012 period, although less than those of Germany and Spain. Some administrative procedures had been simplified and some of the tariff levels were adjusted; additionally, a 2011 amendment to the Energy Law put in place an annual installed capacity quota for solar photovoltaic of 55MW, with changing degressions depending on fulfillment.

We may also comment on what the actual developments mean with regard to the costs and benefits of the feed-in tariff systems in place. Under the theoretical assumption that the benefits of emissions avoided follow the social cost of carbon from the Stern Review or the EU-income weighted estimate we have used, the minimum of the potential cost range is exceeded for hydropower and for wind, assuming that NREAP trajectories are followed. For solar photovoltaic, the benefits do not come close to reaching the minimum of the potential cost range, regardless of member state or estimate of the social cost of carbon. The actual progress made by the member states of interest that have exceeded their NREAP targets in the period studied - Germany and Slovenia - show that exceeding the targets was done on the basis of developments in hydropower and solar photovoltaic (and, in the case of Germany, biomass). The benefits from supporting hydropower exceed the minimum of the potential cost range under the Stern Review and EU-income weighted social cost of carbon estimates, so it is theoretically possible that the benefits due to feed-in tariffs exceed their costs (if the actual distribution of feed-in tariffs paid is near the lower end of the potential cost range). However, the additional costs of feed-in tariffs for solar photovoltaic are far higher than the benefits, and as solar photovoltaic has exceeded the NREAP targets, there is more installed capacity at an earlier point of time when tariffs are higher, leading to overall higher costs.

This is even truer for Slovenia, where installed capacity of solar photovoltaic has experienced very rapid growth, having already exceeded the NREAP target for 2018.

Furthermore, we may comment on the effectiveness of the feed-in tariffs and how these have changed. Here, we refer to the effectiveness indicator as used by the RE-Shaping project. Comparing the effectiveness indicators for 2010 for solar photovoltaic with the effectiveness indicators for 2011 (see 4.5), we note that the indicators have decreased for Germany, while they have increased for Slovenia and Spain. This result seems paradoxical – particularly the increase for Spain, given the perception of instability already present in 2010. However, it can be explained. The effectiveness of a support policy for the promotion of renewable energy sources should be affected by two factors: its remuneration levels and its (perceived) stability. Thus, higher remuneration levels would lead to higher policy effectiveness, while a policy perceived as stable should also lead to higher policy effectiveness. The decrease in Germany's policy effectiveness of feed-in tariffs for solar photovoltaic can be explained by a decrease in both remuneration levels as well as a decrease in perception of its stability, given the revisions and amendments made in 2011. The increase in Slovenia's policy effectiveness of feed-in tariffs for solar photovoltaic can be explained by noting that 2010 was the first full year of the new feed-in tariff system's operation (EA RS, 2011), and that by 2011, it was perceived as stable, which lead to more new installed capacity despite somewhat lower tariff levels; furthermore, the amendment to the Energy Law implementing the annual capacity quota only came into force towards the end of the year. The increase in Spain's policy effectiveness of feed-in tariffs for solar photovoltaic can be explained as well. Although, as mentioned, the system was perceived as unstable, the remuneration levels were high compared to the minimum to average generation costs (see 2.6.2.); the amendments in 2010 lowered tariff levels and also shortened the period for which the initial tariff was to be paid, which may have led to more capacity to be installed in 2011 in order to benefit from the still higher tariffs before they were going to be cut yet again (a reasonable expectation, given the perceived instability). The same effect may be at work in Slovenia in 2012; the implementation of yearly quotas on which degressions depend may have induced a rush among individual investors to ensure that they were the first and would benefit from the higher remuneration levels, before the quota was reached.

## 5.3. Research Question 3

*What are the implications of the progress made, and the developments that have occurred, in the 2010-2012 period with regard to reaching the NREAP targets for 2020?*

Based on the progress observed in the three member states of interest in the period of 2010-2012, we can make some claims about whether they will reach their 2020 NREAP targets for electricity produced from renewable energy sources. However, we do so with caution, as the period studied is rather short.

For Germany, it looks very likely that the 2020 NREAP targets for electricity from renewable energy sources will be met. Despite some loss of perceived stability in the feed-in tariff system, developments have been largely positive. The NREAP targets have been exceeded in both 2010 and 2011, and although this was achieved by exceeding the targets for some technologies while not meeting the targets for others, the technology-specific targets that were not met were not missed by much (with the exception of geothermal energy). The introduction of a premium feed-in tariff will also contribute to better market integration of renewable energy sources. Although future revisions to the feed-in tariff system – e.g. higher degressions – are likely, given one attempt to do so in 2012 already, it still seems that Germany is well on track to meeting its 2020 targets, and could even exceed them.

If we look at the alternative 2020 projections for Germany in the EU Industry Roadmap Report (see 2.6.1.1) they are higher than the NREAP targets for most technology types. The main issue is solar photovoltaic, for which the EU Industry Roadmap Report projections are lower than those in the NREAP yet the capacity of which has exceeded the NREAP targets in 2010 and 2011. Exceeding its NREAP targets so far therefore means that the costs of achieving the 2020 targets will be higher than in a situation where the NREAP indicative trajectory would have been followed more precisely – but it also means that the shares achieved in 2020 could be closer to the higher EU Industry Roadmap Report projections. Furthermore, given Germany's abandonment of nuclear energy following the Fukushima disaster (ENDS Europe, 2011), higher deployment of renewable energies may be necessary, even if the costs are higher than expected.

For Spain, recent experience points to a qualified 'no' for meeting its 2020 NREAP targets for electricity from renewable energy sources. While the 2010 targets were exceeded, recent data available for 2011 suggests that the 2011 targets were not met; additionally, progress in 2012 has also been slow. Critically, the suspension of feed-in tariffs for new installations, following Royal Decree 1/2012, will certainly make it far less likely that the 2020 targets will be attained. Already in 2010, the future stability of the feed-in tariff system was in question; even when/if the suspension is lifted, it is doubtful that there will be much confidence in the restored (and probably revised) system. Among the reasons for the suspension is the claim that current capacity is enough to meet demand in the coming years; this claim is based on lower-than-expected demand since 2010, and not on the actual installed capacity. The strategy resembles a gamble; the binding target for 2020 is expressed in terms of a percentage share for renewable energy sources in total electricity production and if demand remains low, then the percentage target can be attained even if the actual installed capacity and electricity produced is below the absolute targets. A spike in demand would, of course, easily ruin such a strategy. Finally, latest recommendations from the National Commission on Energy suggest 2017 as the year when the suspension is to be lifted (ENDS Europe, 2012); by then, it will be very likely too late for the feed-in tariff system to help reach the 2020 targets.

There are other questions to consider with regard to Spain. For example, what does the suspension of the feed-in tariff system mean with regard to the binding nature of Directive 2009/28/EC? As mentioned, the European Commission can initiate infringement procedures against member states for a "*significant deviation from plan* *or trajectory*" (EREC, 2011). The likely non-attainment of 2011 NREAP targets and the very slow progress in 2012 so far is a deviation from the NREAP trajectory, to be sure, but it may not be considered 'significant'. The suspension of the feed-in tariff system for new installations, however, is without doubt a significant deviation from the plan. Whether infringement procedures will be initiated or not remains to be seen. The economic problems Spain has faced since the beginning of the 2008 financial crisis have only worsened since and austerity measures are being implemented, which includes the suspension itself. One may doubt whether infringement procedures, justified as they may be, would change the situation for the better and whether the European Commission is willing to take such a step.

For Slovenia, developments so far point to a cautious yes. The overall targets for installed capacity and electricity production have been met in both 2010 and 2011, mainly due to increases in hydropower and solar photovoltaic capacity. The rapid growth in solar photovoltaic is both good news and bad news. From the point of view of reaching the 2020 targets, it is good news, since as of April 2012, installed capacity had already exceeded the NREAP target for 2018. However, from a cost point of view, it is bad news; gradual increases, as foreseen in the NREAP, could have achieved the same installed capacity – and therefore emission reductions – at a much lower cost. Furthermore, the rapid growth of solar photovoltaic in Slovenia can only be described as a boom, similar to the experience of the Spain and Germany in previous years (Steinhilber et al., 2011). The consequence of such a boom in those countries was unscheduled revisions and rapid tariff cuts and, in the case of Spain, the suspension of the feed-in tariff system as a whole for new installations. It is therefore very possible that future developments in Slovenia with regard to solar photovoltaic tariffs will tend in a similar direction, in the sense of rapid cuts or stricter capacity limits. Such developments would undermine the stability of the feed-in tariff system but may be limited to solar photovoltaic, in which case reaching the 2020 target is not necessarily precluded, given that current installed capacity has already exceeded the 2018 target. However, as the feed-in tariff system is funded via the electricity price and not tax revenue as in Spain, a suspension would be extremely unlikely.

A problem with regard to reaching the 2020 targets, however, is with wind power; Slovenia has so far no wind power capacity (although the first turbine is being built). Wind capacity would contribute more to electricity production from renewable energy sources than solar, particularly when we look at potential identified in the EU Industry Roadmap report (see 2.6.1.3.), and if more focus was placed on wind power, the 2020 NREAP targets could easily be exceeded. The problem is not so much the remuneration level of the feed-in tariff structure, as it is higher than the minimum to average generation cost (see 2.6.2), but the fact that administrative procedures require more permits (compared to e.g. solar photovoltaic installations); opposition from environmental groups is also causing delays in those projects that have already secured permits (Ozebek, 2012).

## 6. CONCLUSION

Increasing the share of renewable energy sources in electricity production requires support measures, because both the negative externalities of conventional generation technologies are not taken into account in their price and the positive externalities of renewable energy technologies are not taken into account in their price, making renewable energy sources less competitive (or uncompetitive). By focusing on one positive externality not accounted for in electricity generation from renewable energy sources – the carbon dioxide emissions avoided by deploying renewables instead of fossil fuels – we have shown that for some renewable energy technologies, under some estimates of the social cost of carbon, the minimum of the potential cost range for the additional costs imposed on society by the use of feed-in tariffs is exceeded by the value of the damages from carbon dioxide emissions avoided by increased renewable energy deployment. Thus, theoretically at least, it is possible that the benefits of the feed-in tariffs in terms of emissions avoided are larger than the additional costs they impose on society. This is the case for renewable energy technologies with high avoidance factors and low feed-in tariffs, and our results show that this is theoretically possible for hydropower and wind for different estimates of the social cost of carbon, while it is not theoretically possible for solar photovoltaic regardless of the estimate of the social cost of carbon. However, the assumptions used and the degree of uncertainty involved in estimating the social cost of carbon means that these results should be taken as illustrative only.

With regard to the progress towards reaching the NREAP targets for electricity produced from renewable energy sources in the 2010-2012 period in Germany, Spain, and Slovenia, results were mixed. Germany exceeded its targets in 2010 and 2011; Spain exceeded its target in 2010 but likely failed to meet its 2011 target, with slow progress in 2012 so far; Slovenia exceeded its targets for 2010 and 2011, with rapid progress in 2012 so far, particularly in solar photovoltaic deployment.

In all three Member States of interest, changes were made in the levels and structure of the feed-in tariff systems implemented. The main focus thereof was, in each member state of interest, on solar photovoltaic; Germany and Slovenia both implemented annual capacity quotas for new installations, while Spain already had them in place prior to 2010, and all three reduced the levels of support granted to solar photovoltaic, including unannounced revisions. Germany and Spain implemented the largest changes to the overall structure of their feed-in tariff systems, but in opposing directions. Thus, while Germany expanded its feed-in tariff structure to include a premium-based system, Spain completely suspended its feed-in tariff structure for new installations in early 2012. The effects of the changes on the effectiveness of the feed-in tariff system differed in the three member states in 2011, when compared to the effectiveness in 2010. While data availability limited the comparison for solar photovoltaic, this is a minor problem given that the feed-in tariffs for solar photovoltaic are those associated with the highest costs, most frequent revisions, and most controversy. Thus, the influencing factors for policy effectiveness – remuneration levels and stability – exerted different effects in the different member states. A higher remuneration level leads to higher policy effectiveness, but the (perceived) stability of the system is more important; expectations of future reductions, planned and (especially) unplanned, can lead to a rush to secure higher feed-in tariffs before they are lowered.

With regard to the prospects for reaching the 2020 NREAP targets, the developments in the Member States of interest so far suggest different prognoses. Germany is on track to meeting its targets and even exceeding them. Spain will very likely not meet its targets, given its suspension of support measures for new installations, and faces the possibility of infringement procedures against it. Of course, if demand remains low, Spain may still reach its targets, but this is a risky strategy. Slovenia is on track to meet its targets, but two developments complicate the situation; the lack of wind power installations, which could contribute significantly to meeting the targets, and the rapid boom in solar photovoltaic installations, which as of early 2012 have already exceeded the NREAP indicative trajectory targets for 2018. The latter has been observed in previous years in the other Member States studied, with the consequences being rather large and unannounced cuts in remuneration levels and, in the case of Spain, suspension of the entire feed-in tariff structure.

On a more general level, for Germany and Slovenia, being on track to meeting their 2020 targets, the targets will be met at a higher cost than had the NREAP indicative trajectory been followed, mainly due to increases in capacity in earlier years when feed-in tariff levels are higher. Particularly the more rapid than foreseen increase in solar photovoltaic capacity, associated with the highest feed-in tariff costs, is problematic.

## 7. BIBLIOGRAPHY

Bank of England (2012): Inflation data
http://www.bankofengland.co.uk/education/Pages/inflation/calculator/index1.aspx - accessed on 02.05.2012

BMU 2009 – German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (2009): Renewable Energy Sources in Figures: National and international development. Federal Ministry for the Environment, Nature Conservation and Nuclear Safety Public Relations Division, Berlin, Germany.

BMU 2011 – German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (2011): Renewable Energy Sources in Figures: National and international development. Federal Ministry for the Environment, Nature Conservation and Nuclear Safety Public Relations Division, Berlin, Germany.
http://www.bmu.de/english/renewable_energy/downloads/doc/5996.php - last accessed 15.05.2012

BMU 2012 – German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (2012): Development of renewable energy sources in Germany 2011.
http://www.erneuerbare-energien.de/english/renewable_energy/data_service/graphics/doc/39831.php - accessed 15.05.2012

BMU/BMWi 2012-a - German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, and Federal Ministry of Economics and Technology (2012-a): Energiewende auf gutem Weg: Zwischenbilanz und Ausblick.
http://www.bmu.de/files/pdfs/allgemein/application/pdf/broschuere_energiewende.pdf - accessed on 15.05.2012

BMU/BMWi 2012-b - German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, and Federal Ministry of Economics and Technology (2012-b): EU-Effizienzrichtlinie und Erneuerbare-Energien-Gesetz: Ergebnispapier.
http://www.bmu.de/files/pdfs/allgemein/application/pdf/ergebnispapier__eu-effizienzrichtlinie.pdf - accessed on 15.05.2012

Bojnec Š., and Papler D. (2010): Liberalisation of the electricity market: the case of Slovenia.
http://www.mgrt.gov.si/fileadmin/mgrt.gov.si/pageuploads/DNT/aktualno/Liberalizacija_trga.pdf - accessed on 15.05.2012

Borzen (2009): Določanje višine podpor električni energiji proizvedeni iz OVE in SPTE in višine podpor v letu 2010.
http://www.borzen.si/si/cp/Shared%20Documents/Forms/AllItems.aspx - accessed on 15.05.2012

Borzen (2011-a): Določanje višine podpor električni energiji proizvedeni iz OVE in SPTE in višine podpor v letu 2011.

http://www.borzen.si/si/cp/Shared%20Documents/Forms/AllItems.aspx - accessed on 15.05.2012

Borzen (2011-b):Določanje višine podpor električni energiji proizvedeni iz OVE in SPTE in višine podpor v letu 2012. http://www.borzen.si/si/cp/Shared%20Documents/Forms/AllItems.aspx - accessed on 15.05.2012

Böhringer C., Löschel A., Moslener U., Rutherford T. (2009): EU climate policy up to 2020: An economic impact assessment. Energy Economics 31, 295-305

Brandt T. (2006): Liberalisation, privatisation and regulation in the German electricity sector. Wirtschafts- und Sozialwissenschaftliches Institut (WSI) in der Hans-Böckler-Stiftung.
http://www.boeckler.de/pdf/wsi_pj_piq_sekstrom.pdf - accessed on 23.05.2012

Bundesrat (2012): Solarförderung geht ins Vermittlungsverfahren.
http://www.bundesrat.de/DE/presse/pm/2012/074-2012.html - accessed on 15.05.2012

Canton J., and Linden Å. (2010): Support schemes for renewable electricity in the EU. European Commission Economic Papers 408. European Union, Brussels.
http://ec.europa.eu/economy_finance/publications/economic_paper/2010/pdf/ecp408_en.pdf - accessed on 23.05.2012

Crampes C., and Fabra, N. (2004): The Spanish Electricity Industry: Plus ça change… . http://idei.fr/doc/wp/2004/spanish_electricity.pdf - accessed on 23.05.2012

COMM 2007 – COMMUNICATION FROM THE COMMISSION TO THE COUNCIL, THE EUROPEAN PARLIAMENT, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS: Limiting Global Climate Change to 2 degrees Celsius: The way ahead for 2020 and beyond. (COM (2007) 2 final)

Couture T., and Gagnon Y. (2010): An analysis of feed-in tariff remuneration models: Implications for renewable energy investment. Energy Policy 38, 955-965

CSWD 2008 – COMMISSION STAFF WORKING DOCUMENT: The support of electricity from renewable energy sources. Accompanying document to the Proposal for a DIRECTIVE OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL on the promotion of the use of energy from renewable sources (SEC(2008) 57)

DIR 2009/28/EC - DIRECTIVE 2009/28/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC

Downing T., Anthoff D., Butterfield R., Ceronsky M., Grubb M., Guo J., Hepburn C., Hope C., Hunt A., Li A., Markandya A., Moss S., Nyong A., Tol R., Watkiss P. (2005):

Social Cost of Carbon: A Closer Look at Uncertainty. Department for Environment, Food and Rural Affairs, UK.
http://www.decc.gov.uk/en/content/cms/emissions/valuation/social_cost/social_cost.aspx - accessed on 15.05.2012

EA RS 2010 - Energy Agency of the Republic of Slovenia (2010): Report on the Energy Sector in Slovenia for 2009.
http://www.agen-rs.si/en/informacija.asp?id_meta_type=36&id_informacija=708 – accessed on 15.05.2012

EA RS 2011 - Energy Agency of the Republic of Slovenia (2011): Report on the Energy Sector in Slovenia for 2010.
http://www.agen-rs.si/en/informacija.asp?id_meta_type=36&id_informacija=708 – accessed on 15.05.2012

EA RS 2012 - Energy Agency of the Republic of Slovenia (2012): Register of Declarations. http://www.agen-rs.si/porocila/RegisterDeklaracij.aspx - accessed 01.05.2012

EC 2012 - European Commission (2012): Progress Reports of Member States.
http://ec.europa.eu/energy/renewables/reports/2011_en.htm - accessed on 15.05.2012

ECB Statistical Warehouse (2012): Bilateral exchange rate data
http://sdw.ecb.europa.eu/browse.do?node=2018794 – accessed on 02.05.2012

Egenhofer C., Alessi M., Georgiev A., Fujiwara N. (2011): The EU Emissions Trading System and Climate Policy towards 2050: Real incentives to reduce emissions and drive innovation? Centre for European Policy Studies, Brussels.
http://www.ceps.eu/ceps/download/4097 - accessed on 23.05.2012

Ekins P. (2005): A note on the impossibility of deriving a scientifically valid, ethically sound or policy-useful estimate of the social cost of carbon.
http://www.decc.gov.uk/assets/decc/what%20we%20do/a%20low%20carbon%20uk/carbon%20valuation/social_cost/scc-peerreviewcomments.pdf - accessed on 15.05.2012

ENDS Europe (2011): Germany to phase out nuclear by 2022 at latest.
http://www.endseurope.com/26392/germany-to-phase-out-nuclear-by-2022-at-latest?referrer=search
accessed on 30.05.2012

ENDS Europe (2012): Spain's renewables freeze 'should stay in place'.
http://www.endseurope.com/28389/spains-renewables-freeze-should-stay-in-place – accessed on 15.05.2012

EREC 2011 - European Renewable Energy Council (2011): EU Roadmap: Mapping Renewable Energy Pathways towards 2020. http://www.repap2020.eu/5.0.html - accessed on 15.05.2012

Eurostat (2012): Inflation data
http://epp.eurostat.ec.europa.eu/portal/page/portal/product_details/dataset?p_product_code=TEC00027 – accessed on 02.05.2012

Gillingham K., Sweeney J. (2010): Market Failure and the Structure of Externalities. In: Moselle B., Padilla J., Schmalensee R. (Eds) Harnessing Renewable Energy in Electric Power Systems: Theory, Practice, Policy. Earthscan, Washington, DC, pp. 69-92

Held A., Ragwitz M., Resch G., Nemac F., Vertin K. (2010): Feed-In Systems in Germany, Spain and Slovenia: A comparison.
http://www.feed-in-cooperation.org/wDefault_7/content/research/index.php - accessed on 15.05.2012

Lehmann P., and Gawel E. (2011): Why should support schemes for renewable electricity complement the EU emissions trading scheme? UFZ Discussion Papers 5/2011, Helmholtz Centre for Environmental Research (UFZ), Division of Social Sciences (ÖKUS).
http://ideas.repec.org/p/zbw/ufzdps/52011.html - accessed on 15.05.2012

Lesser J., and Su X. (2008): Design of an economically efficient feed-in tariff structure for renewable energy development. Energy Policy 36, 981-990

London Economics (2007): Structure and Performance of Six European Wholesale Electricity Markets in 2003, 2004 and 2005: Part IV.
http://ec.europa.eu/competition/sectors/energy/inquiry/electricity_final_part4.pdf - accessed on 23.05.2012

MITT 2010 – Spanish Ministry of Industry, Tourism and Trade (2010): La Energía en España 2010.
http://www.minetur.gob.es/energia/en-us/Paginas/Index.aspx - accessed 15.05.2012

NREAP DE 2010 – Government of Germany (2010): National Renewable Energy Action Plan in accordance with Directive 2009/28/EC on the promotion of the use of energy from renewable sources.
http://ec.europa.eu/energy/renewables/action_plan_en.htm - accessed on 15.05.2012

NREAP ES 2010 - Government of Spain (2010): Spain's National Renewable Energy Action Plan 2011-2020.
http://ec.europa.eu/energy/renewables/action_plan_en.htm - accessed on 15.05.2012

NREAP SI 2010 - Government of Slovenia (2010): National Renewable Energy Action Plan 2010-2020 (NREAP) Slovenia.
http://ec.europa.eu/energy/renewables/action_plan_en.htm - accessed on 15.05.2012

NCE 2012 – Spanish National Commission for Energy (2012): Información Estadística sobre las Ventas de Energía del Régimen Especial. http://www.cne.es/cne/Publicaciones?id_nodo=143&accion=1&soloUltimo=si&sIdCat=10&keyword=&auditoria=F – accessed 15.05.2012

Ozebek, N. (2012): Delež zelene energije se povečuje. Dnevnik, Ljubljana, Slovenia. http://www.dnevnik.si/novice/slovenija/1042518827 - accessed on 15.05.2012

Owen A. (2006): Renewable energy: Externality costs as market barriers. Energy Policy 34, 632-642

Point Carbon (2007): Carbon 2007: A new climate for carbon trading. http://www.pointcarbon.com/research/promo/research/ - accessed on 15.05.2012

PR DE 2011 - Government of Germany (2011): Progress report under Article 22 of Directive 2009/28/EC on Promotion of the Use of Energy from Renewable Sources. http://ec.europa.eu/energy/renewables/reports/2011_en.htm - accessed on 15.05.2012

PR SI 2011 - Government of Slovenia (2011): Progress Report of Slovenia under Directive 2009/28/EC. http://ec.europa.eu/energy/renewables/reports/2011_en.htm - accessed on 15.05.2012

Ragwitz M., Resch G., Busch S., Held A., Rosende D., Rudolf F., Schubert G., Steinhilber S. (2011): Assessment of National Renewable Energy Action Plans. Fraunhofer Institute Systems and Innovation Research, Karlsruhe, Germany, and Vienna University of Technology, Energy Economics Group, Vienna, Austria. http://www.repap2020.eu/5.0.html - accessed on 15.05.2012

RD 2012 - Government of Spain (2012): Royal Decree 1/2012. http://www.boe.es/boe/dias/2012/01/28/pdfs/BOE-A-2012-1310.pdf - accessed on 15.05.2012

Stern N. (2006): The Stern Review on the Economics of Climate Change: Executive Summary. http://siteresources.worldbank.org/INTINDONESIA/Resources/226271-1170911056314/3428109-1174614780539/SternReviewEng.pdf - accessed on 15.05.2012

Steinhilber S., Ragwitz M., Rathmann M., Klessmann C., Noothout P. (2011): D17 Report: Indicators assessing the performance of renewable energy support policies in 27 Member States. Fraunhofer Institute Systems and Innovation Research, Karlsruhe, German, and ECOFYS. http://www.reshaping-res-policy.eu/ - accessed on 15.05.2012

Tol R. (2008): The Social Cost of Carbon: Trends, Outliers and Catastrophes. Economics E-Journal. http://www.economics-ejournal.org/ - accessed on 15.05.2012

U.S. Bureau of Labor Statistics (2012): Inflation data
http://www.bls.gov/data/inflation_calculator.htm - accessed on 02.05.2012

Watkiss P., and Downing T. (2008): The social cost of carbon: Valuation estimates and their use in UK Policy. The Integrated Assessment Journal 8, 85-105

## LIST OF TABLES AND FIGURES

# DATA APPENDIX

## A. NREAP INDICATIVE TRAJECTORIES

### Germany (NREAP DE; 2010)

***Table 10a: Estimate of the total contribution (installed capacity, gross electricity consumption) anticipated in Germany of each technology using renewable energy sources with regard to the binding targets for 2020 and the indicative trajectories for the share of energy from renewable sources in the electricity sector in the period 2010-2014*** [58]

| | 2005 | | 2010 | | 2011 | | 2012 | | 2013 | | 2014 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | MW | GWh | MW | GWh | MW | GWh | MW | GWh | MW | GWh | MW | GWh |
| **Hydropower:** | 4329 | 19687 | 4052 | 18000 | 4068 | 18000 | 4088 | 18000 | 4111 | 19000 | 4137 | 19000 |
| <1MW | 641 | 3157 | 507 | 2300 | 511 | 2300 | 515 | 2300 | 521 | 2450 | 527 | 2450 |
| 1 MW -10 MW | 1073 | 3560 | 987 | 4050 | 991 | 4050 | 995 | 4050 | 1000 | 4250 | 1005 | 4250 |
| > 10MW | 2615 | 12971 | 2558 | 11650 | 2567 | 11650 | 2577 | 11650 | 2590 | 12300 | 2604 | 12300 |
| from pumped storage power plant | 4012 | 7786 | 6494 | 6989 | 6494 | 6989 | 6494 | 6989 | 6494 | 6989 | 6494 | 6989 |
| **Geothermal energy:** | 0.2 | 0.2 | 10 | 27 | 17 | 53 | 27 | 97 | 40 | 164 | 57 | 257 |
| **Solar energy:** | 1980 | 1282 | 15784 | 9499 | 20284 | 13967 | 23783 | 17397 | 27282 | 20293 | 30781 | 23218 |
| photovoltaics | 1980 | 1282 | 15784 | 9499 | 20284 | 13967 | 23783 | 17397 | 27282 | 20293 | 30781 | 23218 |
| concentrated solar energy | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Tides, waves, other ocean energy:** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Wind energy:** | 18415 | 26658 | 27676 | 44668 | 29606 | 49420 | 31357 | 53055 | 32973 | 57314 | 34802 | 63657 |
| land-based | 18415 | 26658 | 27526 | 44397 | 29175 | 48461 | 30566 | 51152 | 31672 | 54064 | 32763 | 58420 |
| offshore | 0 | 0 | 150 | 271 | 432 | 959 | 792 | 1903 | 1302 | 3250 | 2040 | 5237 |
| **Biomass:** | 3174 | 14025 | 6312 | 32778 | 6620 | 34682 | 6934 | 36710 | 7214 | 38562 | 7475 | 40359 |
| solid | 2427 | 10044 | 3707 | 17498 | 3860 | 18298 | 4017 | 19294 | 4140 | 20114 | 4253 | 20901 |
| biogas | 693 | 3652 | 2368 | 13829 | 2523 | 14933 | 2680 | 15966 | 2837 | 16998 | 2985 | 18008 |
| liquid biofuels (1) | 54 | 329 | 237 | 1450 | 237 | 1450 | 237 | 1450 | 237 | 1450 | 237 | 1450 |
| **Overall:** | 27898 | 61653 | 53834 | 104972 | 60596 | 116122 | 66189 | 125258 | 71621 | 135333 | 77251 | 146490 |
| from combined heat and power | | - | 1067 | 5328 | 1280 | 6453 | 1503 | 7681 | 1740 | 9002 | 1990 | 10424 |

(1) Only those are to be considered which meet the sustainability criteria of Article 5(1), last subparagraph, of Directive 2009/28/EC.

***Table 10b: Estimate of the total contribution (installed capacity, gross electricity) anticipated in Germany of each technology for the use of renewable energy sources with regard to the binding targets for 2020 and the indicative trajectories for the share of energy from renewable sources in the electricity sector in the period 2015-2020*** [59]

| | 2015 | | 2016 | | 2017 | | 2018 | | 2019 | | 2020 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | MW | GWh | MW | GWh | MW | GWh | MW | GWh | MW | GWh | MW | GWh |
| **Hydropower** [60] **:** | 4165 | 19000 | 4196 | 19000 | 4228 | 19000 | 4258 | 19000 | 4286 | 20000 | 4309 | 20000 |
| <1MW | 534 | 2450 | 539 | 2450 | 546 | 2450 | 552 | 2450 | 558 | 2550 | 564 | 2550 |
| 1 MW -10 MW | 1012 | 4250 | 1019 | 4250 | 1026 | 4250 | 1032 | 4250 | 1038 | 4500 | 1043 | 4500 |
| >10MW | 2620 | 12300 | 2638 | 12300 | 2657 | 12300 | 2674 | 12300 | 2689 | 12950 | 2702 | 12950 |
| from pumped-storage power plant[61] | 6494 | 6989 | 6494 | 6989 | 6494 | 6989 | 7900 | 8395 | 7900 | 8395 | 7900 | 8395 |
| **Geothermal energy:** | 79 | 377 | 107 | 534 | 142 | 730 | 185 | 976 | 236 | 1281 | 298 | 1654 |
| **Solar Energy:** | 34279 | 26161 | 37777 | 29148 | 41274 | 32132 | 44768 | 35144 | 48262 | 38243 | 51753 | 41389 |
| photovoltaics | 34279 | 26161 | 37777 | 29148 | 41274 | 32132 | 44768 | 35144 | 48262 | 38243 | 51753 | 41389 |
| concentrated solar energy | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Tides, waves, other ocean energy:** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Wind Energy** [62] **:** | 36647 | 69994 | 38470 | 76067 | 40154 | 82466 | 41909 | 89210 | 43751 | 96359 | 45750 | 104435 |
| land-based | 33647 | 61990 | 34371 | 64583 | 34815 | 66873 | 35188 | 68913 | 35479 | 70694 | 35750 | 72664 |
| offshore | 3000 | 8004 | 4100 | 11484 | 5340 | 15592 | 6722 | 20297 | 8272 | 25666 | 10000 | 31771 |
| **Biomass:** | 7721 | 42090 | 7976 | 43729 | 8211 | 45299 | 8440 | 46761 | 8648 | 48133 | 8825 | 49457 |
| solid | 4358 | 21695 | 4472 | 22396 | 4575 | 23050 | 4672 | 23633 | 4750 | 24139 | 4792 | 24569 |
| biogas | 3126 | 18946 | 3267 | 19884 | 3399 | 20798 | 3531 | 21678 | 3660 | 22543 | 3796 | 23438 |
| liquid biofuels (1) | 237 | 1450 | 237 | 1450 | 237 | 1450 | 237 | 1450 | 237 | 1450 | 237 | 1450 |
| **Overall**[63]**:** | 82891 | 157623 | 88526 | 168479 | 94009 | 179626 | 99561 | 191092 | 105183 | 204016 | 110934 | 216935 |
| from combined heat and power | 2250 | 11937 | 2530 | 13533 | 2823 | 15220 | 3129 | 16986 | 3444 | 18837 | 3765 | 20791 |

(1) Only those are taken into account which meet the sustainability criteria laid down in Article 5(1), last subparagraph, of Directive 2009/28/EC.

## Spain (NREAP ES,2010)

**Table 10a: Estimation of total contribution (installed capacity, gross electricity generation) expected from each renewable energy technology in Spain to meet the binding 2020 targets and the indicative interim trajectory for the shares of energy from renewable resources in electricity 2010-2014 (C)**

| | 2005 | | 2010 | | 2011 | | 2012 | | 2013 | | 2014 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | MW | GWh | MW | GWh | MW | GWh | MW | GWh | MW | GWh | MW | GWh |
| Hydro | 18,220 | 35,503 | 18,687 | 34,617 | 19,869 | 35 353 | 19 909 | 34 960 | 19 949 | 36 023 | 19 999 | 36 559 |
| *<1MW* | 239 | 893 | 242 | 831 | 244 | 739 | 247 | 677 | 249 | 716 | 251 | 718 |
| *1MW-10MW* | 1,534 | 5,719 | 1,603 | 4,973 | 1,640 | 4 568 | 1 665 | 5 607 | 1 703 | 4 592 | 1 731 | 4 613 |
| *>10MW* | 16,447 | 28,891 | 16,842 | 28,813 | 17,985 | 30 045 | 17 997 | 28 676 | 17 997 | 30 716 | 18 017 | 31 228 |
| *of which pumping:* | 2,727 | 5,153 | 2,546 | 3,640 | 3,700 | 5 130 | 3 700 | 5 130 | 3 700 | 6 577 | 3 700 | 6 577 |
| Geothermal | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Solar | 60 | 41 | 4,653 | 7,561 | 5,877 | 9 945 | 6 949 | 12 553 | 7 693 | 14 570 | 8 300 | 16 123 |
| *photovoltaic* | 60 | 41 | 4,021 | 6,417 | 4 498 | 7 324 | 4 921 | 8 090 | 5 222 | 8 709 | 5 553 | 9 256 |
| *concentrated solar* | 0 | 0 | 632 | 1,144 | 1 379 | 2 621 | 2 028 | 4 463 | 2 471 | 5 861 | 2 746 | 6 867 |
| Tide, wave, ocean | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Wind | 9,918 | 20,729 | 20,155 | 40,978 | 21 855 | 43 668 | 23 555 | 47 312 | 24 986 | 50 753 | 26 466 | 53 981 |
| *onshore* | 9,918 | 20,729 | 20,155 | 40,978 | 21 855 | 43 668 | 23 555 | 47 312 | 24 986 | 50 753 | 26 416 | 53 906 |
| *offshore* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 50 | 75 |
| Biomass | 601 | 2,653 | 752 | 4,517 | 771 | 4 655 | 803 | 4 876 | 844 | 5 151 | 897 | 5 499 |
| *solid* | 449 | 2,029 | 596 | 3,719 | 604 | 3 769 | 624 | 3 898 | 653 | 4 078 | 692 | 4 319 |
| *biogas* | 152 | 623 | 156 | 799 | 167 | 885 | 179 | 978 | 191 | 1 073 | 205 | 1 180 |
| *Bioliquids (29)* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| TOTAL (w/o pumping) | 26,072 | 53,773 | 41,701 | 84,034 | 44 672 | 88 490 | 47 516 | 94 571 | 49 722 | 99 921 | 51 962 | 105 586 |
| *of which co-generated* | 177 | 747 | 246 | 1,462 | 250 | 1 501 | 254 | 1 532 | 266 | 1 604 | 287 | 1 724 |

**Table 10b**: Estimation of total contribution (installed capacity, gross electricity generation) expected from each renewable energy technology in Spain to meet the binding 2020 targets and the indicative interim trajectory for the shares of energy from renewable resources in electricity 2015-2020 (C)

| • | 2015 | | 2016 | | 2017 | | 2018 | | 2019 | | 2020 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | MW | GWh | MW | GWh | MW | GWh | MW | GWh | MW | GWh | MW | GWh |
| Hydro | 20,049 | 36,732 | 22,109 | 37,566 | 22,169 | 38,537 | 22,229 | 38,443 | 22,289 | 38,505 | 22,362 | 39,593 |
| *<1MW* | 253 | 715 | 256 | 760 | 259 | 765 | 262 | 743 | 265 | 819 | 268 | 803 |
| *1MW-10MW* | 1,764 | 4,617 | 1,796 | 4,398 | 1,828 | 4,712 | 1,855 | 4,856 | 1,882 | 5,024 | 1,917 | 5,477 |
| *>10MW* | 18,032 | 31,399 | 20,057 | 32,408 | 20,082 | 33,060 | 20,112 | 32,844 | 20,142 | 32,662 | 20,177 | 33,314 |
| *of which pumping:* | 3,700 | 6,577 | 5,700 | 8,023 | 5,700 | 8,023 | 5,700 | 8,023 | 5,700 | 8,023 | 5,700 | 8,023 |
| Geothermal | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 60 | 30 | 180 | 50 | 300 |
| Solar | 8,966 | 17,785 | 9,700 | 19,649 | 10,508 | 21,741 | 11,394 | 24,088 | 12,371 | 26,719 | 13,445 | 29,669 |
| *photovoltaic* | 5,918 | 9,872 | 6,319 | 10,565 | 6,760 | 11,345 | 7,246 | 12,222 | 7,780 | 13,208 | 8,367 | 14,316 |
| *concentrated solar* | 3,048 | 7,913 | 3,381 | 9,084 | 3,747 | 10,397 | 4,149 | 11,866 | 4,592 | 13,511 | 5,079 | 15,353 |
| Tide, wave, ocean | 0 | 0 | 10 | 22 | 30 | 66 | 50 | 110 | 75 | 165 | 100 | 220 |
| Wind | 27,997 | 57,086 | 29,778 | 60,573 | 31,708 | 64,483 | 33,639 | 68,652 | 35,819 | 73,197 | 38,000 | 78,254 |
| *onshore* | 27,847 | 56,786 | 29,278 | 59,598 | 30,708 | 62,238 | 32,139 | 64,925 | 33,569 | 67,619 | 35,000 | 70,502 |
| *offshore* | 150 | 300 | 500 | 975 | 1,000 | 2,245 | 1,500 | 3,727 | 2,250 | 5,577 | 3,000 | 7,753 |
| Biomass | 965 | 5,962 | 1,048 | 6,510 | 1,149 | 7,171 | 1,265 | 7,931 | 1,410 | 8,876 | 1,587 | 10,017 |
| *solid* | 745 | 4,660 | 810 | 5,066 | 887 | 5,545 | 972 | 6,074 | 1,073 | 6,699 | 1,187 | 7,400 |
| *biogas* | 220 | 1,302 | 238 | 1,444 | 262 | 1,626 | 293 | 1,858 | 337 | 2,177 | 400 | 2,617 |
| *Bioliquids (29)* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| TOTAL (w/o pumping) | 54,277 | 110,988 | 56,945 | 116,297 | 59,863 | 123,975 | 62,687 | 131,261 | 68,294 | 139,619 | 69,844 | 150,030 |
| *of which co-generated* | 310 | 1,866 | 335 | 2,014 | 359 | 2,160 | 385 | 2,317 | 403 | 2,428 | 423 | 2,551 |

## Slovenia (NREAP SI; 2010)

Table 10a RES technology for electricity – estimated total contribution to the binding targets for 2020 and indicative shares for 2010-2014

| | 2005 | | 2010 | | 2011 | | 2012 | | 2013 | | 2014 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | [MW] | [GWh] | [MW] | [GWh] | [MW] | [GWh] | [MW] | [GWh] | [MW] | [GWh] | [MW] | [GWh] |
| **Hydroenergy** | **981** | **4,099** | **1,071** | **4,198** | **1,071** | **4,198** | **1,071** | **4,198** | **1,136** | **4,413** | **1,140** | **4.431** |
| *< 1 MW* | 108 | 451 | 118 | 262 | 118 | 262 | 118 | 262 | 120 | 268 | 120 | 269 |
| *1 MW - 10 MW* | 37 | 155 | 37 | 192 | 37 | 192 | 37 | 192 | 37 | 194 | 41 | 210 |
| *> 10 MW* | 836 | 3,493 | 916 | 3,744 | 916 | 3,744 | 916 | 3,744 | 979 | 3,952 | 979 | 3.952 |
| *Of which pumping* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Geothermal energy** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** |
| **Solar energy** | **0** | **0** | **12** | **12** | **17** | **17** | **22** | **22** | **27** | **27** | **32** | **32** |
| *Photovoltaic* | 0 | 0 | 12 | 12 | 17 | 17 | 22 | 22 | 27 | 27 | 32 | 32 |
| *Concentrated solar power* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Tidal, wave energy** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** |
| **wind energy** | **0** | **0** | **2** | **2** | **2** | **4** | **2** | **4** | **8** | **14** | **8** | **14** |
| *Onshore* | 0 | 0 | 2 | 2 | 2 | 4 | 2 | 4 | 8 | 14 | 8 | 14 |
| ***Offshore*** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Biomass** | **18** | **114** | **51** | **298** | **59** | **344** | **67** | **415** | **74** | **457** | **78** | **482** |
| *Solid* | 15 | 82 | 22 | 150 | 22 | 152 | 23 | 156 | 24 | 158 | 24 | 158 |
| *Biogas* | 3 | 32 | 30 | 148 | 36 | 192 | 44 | 259 | 50 | 299 | 54 | 323 |
| *Liquid biofuel (1)* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **TOTAL** | **999** | **4,213** | **1,136** | **4,510** | **1,149** | **4,563** | **1,162** | **4,639** | **1,245** | **4,912** | **1,258** | **4.959** |
| ***Of which in CHP*** | **18** | **114** | **51** | **298** | **59** | **344** | **67** | **415** | **74** | **457** | **78** | **482** |

Table 10b RES technology for electricity – estimated total contribution to the binding targets for 2020 and indicative shares for 2015-2020

| | 2015 | | 2016 | | 2017 | | 2018 | | 2019 | | 2020 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | [MW] | [GWh] | [MW] | [GWh] | [MW] | [GWh] | [MW] | [GWh] | [MW] | [GWh] | [MW] | [GWh] |
| **Hydroenergy** | **1,193** | **4,559** | **1,227** | **4,662** | **1,232** | **4,685** | **1,318** | **5,003** | **1,318** | **5,003** | **1,354** | **5,121** |
| *< 1 MW* | 120 | 270 | 120 | 270 | 120 | 270 | 120 | 270 | 120 | 270 | 120 | 270 |
| *1 MW - 10 MW* | 52 | 247 | 52 | 247 | 57 | 270 | 57 | 270 | 57 | 270 | 57 | 270 |
| *> 10 MW* | 1,021 | 4,042 | 1,055 | 4,145 | 1,055 | 4,145 | 1,141 | 4,463 | 1,141 | 4,463 | 1,176 | 4,581 |
| *Of which pumping* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Geothermal energy** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** |
| **Solar energy** | **37** | **37** | **49** | **49** | **63** | **63** | **82** | **82** | **107** | **107** | **139** | **139** |
| *Photovoltaic* | 37 | 37 | 49 | 49 | 63 | 63 | 82 | 82 | 107 | 107 | 139 | 139 |
| *Concentrated solar power* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Tidal, wave energy** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** |
| **Wind energy** | **60** | **109** | **60** | **109** | **60** | **109** | **60** | **109** | **106** | **191** | **106** | **191** |
| *Onshore* | 60 | 109 | 60 | 109 | 60 | 109 | 60 | 109 | 106 | 191 | 106 | 191 |
| ***Offshore*** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Biomass** | **83** | **623** | **85** | **637** | **93** | **659** | **95** | **672** | **95** | **675** | **96** | **676** |
| *Solid* | 24 | 272 | 26 | 282 | 33 | 300 | 34 | 309 | 34 | 309 | 34 | 309 |
| *Biogas* | 58 | 351 | 59 | 355 | 60 | 360 | 60 | 363 | 61 | 366 | 61 | 367 |
| *Liquid biofuel f[4])* | | | | | | | | | | | | |
| **TOTAL** | **1,373** | **5,328** | **1,420** | **5,456** | **1,448** | **5,516** | **1,555** | **5,865** | **1,626** | **5,975** | **1,693** | **6,126** |
| ***Of which in CHP*** | **83** | **623** | **85** | **637** | **93** | **659** | **95** | **672** | **95** | **675** | **96** | **676** |

## B. FEED-IN TARIFF LEVELS

### Germany (NREAP DE, 2010; Held et al., 2010; PR DE; 2011)

| Feed-in Tariffs [cent/kWh] | 2010 | | 2011 | | 2012 | | 2013 | | 2014 | | 2015 | | 2016 | | 2017 | | 2018 | | 2019 | | 2020 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Min. | Max. | Min. | Max. | Min. | Max. | Min. | Max. | Min. | Max. | Min. | Max. | Min. | Max. | Min. | Max. | Min. | Max. | Min. | Max. | Min. | Max. |
| Hydro | 3.5 | 12.67 | 3.43 | 12.54 | 3.4 | 12.7 | 3.366 | 12.57 | 3.32 | 12.44 | 3.29 | 12.32 | 3.26 | 12.97 | 3.23 | 12.84 | 3.2 | 12.71 | 3.17 | 12.58 | 3.14 | 12.45 |
| Geothermal | 10.5 | 23 | 14.4 | 23.84 | 25 | 30 | 25 | 30 | 25 | 30 | 25 | 30 | 25 | 30 | 25 | 30 | 23.75 | 28.5 | 22.56 | 27.1 | 21.43 | 25.7 |
| Solar PV | 27 | 47.3 | 22.06 | 30.06 | 17.94 | 24.43 | 16.33 | 22.23 | 14.86 | 20.23 | 13.52 | 18.41 | 12.3 | 16.75 | 11.2 | 15.2 | 10.2 | 13.8 | 9.28 | 12.56 | 8.44 | 11.43 |
| Wind (Onshore) | 5.02 | 10.4 | 5.02 | 9.11 | 4.87 | 9.43 | 4.77 | 9.29 | 4.69 | 9.15 | 4.62 | 9.01 | 4.55 | 8.87 | 4.48 | 8.74 | 4.41 | 8.61 | 4.34 | 8.48 | 4.27 | 7.208 |
| Wind (Offshore) | 15 | 15 | 15 | 15 | 15 | 19 | 15 | 19 | 15 | 19 | 15 | 19 | 15 | 19 | 15 | 19 | 13.95 | 17.67 | 12.97 | 16.43 | 12.06 | 15.28 |
| Biomass | 7.79 | 17.67 | 7.63 | 17.4 | 6 | 14.3 | 6 | 14.01 | 6 | 13.73 | 6 | 13.46 | 6 | 13.19 | 6 | 12.93 | 6 | 12.67 | 6 | 12.42 | 6 | 12.17 |

**Spain (NREAP ES; 2010; Held et al., 2010)**

| Feed-in Tariffs [cent/kWh] | 2010 | | 2011 | | 2012 | | 2013 | | 2014 | | 2015 | | 2016 | | 2017 | | 2018 | | 2019 | | 2020 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Min. | Max. | Min. | Max. | Min. | Max. | Min. | Max. | Min. | Max. | Min. | Max. | Min. | Max. | Min. | Max. | Min. | Max. | Min. | Max. | Min. | Max. |
| Hydro | 2.263 | 8.272 | 2.263 | 8.272 | 2.263 | 8.272 | 2.263 | 8.272 | 2.263 | 8.272 | 2.263 | 8.272 | 2.263 | 8.272 | 2.263 | 8.272 | 2.263 | 8.272 | 2.263 | 8.272 | 2.263 | 8.272 |
| Geotherm. | 4.067 | 7.289 | 4.067 | 7.289 | 4.067 | 7.289 | 4.067 | 7.289 | 4.067 | 7.289 | 4.067 | 7.289 | 4.067 | 7.289 | 4.067 | 7.289 | 4.067 | 7.289 | 4.067 | 7.289 | 4.067 | 7.289 |
| Solar PV | 26.55 | 34 | 23.895 | 30.6 | 21.51 | 27.54 | 19.36 | 24.79 | 17.42 | 22.31 | 15.68 | 20.08 | 14.11 | 18.07 | 12.7 | 16.26 | 11.43 | 14.63 | 10.29 | 13.17 | 9.261 | 11.85 |
| Solar Conc. | 26.87 | 28.49 | 26.87 | 28.49 | 26.87 | 28.49 | 26.87 | 28.49 | 26.87 | 28.49 | 26.87 | 28.49 | 26.87 | 28.49 | 26.87 | 28.49 | 26.87 | 28.49 | 26.87 | 28.49 | 26.87 | 28.49 |
| Tidal etc. | 4.067 | 7.289 | 4.067 | 7.289 | 4.067 | 7.289 | 4.067 | 7.289 | 4.067 | 7.289 | 4.067 | 7.289 | 4.067 | 7.289 | 4.067 | 7.289 | 4.067 | 7.289 | 4.067 | 7.289 | 4.067 | 7.289 |
| Wind (Onshore) | 3.099 | 7.471 | 3.099 | 7.471 | 3.099 | 7.471 | 3.099 | 7.471 | 3.099 | 7.471 | 3.099 | 7.471 | 3.099 | 7.471 | 3.099 | 7.471 | 3.099 | 7.471 | 3.099 | 7.471 | 3.099 | 7.471 |
| Wind (Offshore) | 8.918 | 17.35 | 8.918 | 17.35 | 8.918 | 17.35 | 8.918 | 17.35 | 8.918 | 17.35 | 8.918 | 17.35 | 8.918 | 17.35 | 8.918 | 17.35 | 8.918 | 17.35 | 8.918 | 17.35 | 8.918 | 17.35 |
| Biomass | 2.53 | 16.81 | 2.53 | 16.81 | 2.53 | 16.81 | 2.53 | 16.81 | 2.53 | 16.81 | 2.53 | 16.81 | 2.53 | 16.81 | 2.53 | 16.81 | 2.53 | 16.81 | 2.53 | 16.81 | 2.53 | 16.81 |

## Slovenia (NREAP SI, 2010; PR SI; 2011)

| Feed-in Tariffs [cent/kWh] | 2010 | | 2011 | | 2012 | | 2013 | | 2014 | | 2015 | | 2016 | | 2017 | | 2018 | | 2019 | | 2020 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Min. | Max. | Min. | Max. | Min. | Max. | Min. | Max. | Min. | Max. | Min. | Max. | Min. | Max. | Min. | Max. | Min. | Max. | Min. | Max. | Min. | Max. |
| Hydro | 2.85 | 10.55 | 2.875 | 10.55 | 2.636 | 10.55 | 2.636 | 10.55 | 2.636 | 10.55 | 2.636 | 10.55 | 2.636 | 10.55 | 2.636 | 10.55 | 2.636 | 10.55 | 2.636 | 10.55 | 2.636 | 10.55 |
| Geotherm. | 10.33 | 15.25 | 10.36 | 15.25 | 10.14 | 15.25 | 10.14 | 15.25 | 10.14 | 15.25 | 10.14 | 15.25 | 10.14 | 15.25 | 10.14 | 15.25 | 10.14 | 15.25 | 10.14 | 15.25 | 10.14 | 15.25 |
| Solar PV | 19.69 | 44.43 | 16.23 | 33.24 | 10.57 | 29.08 | 9.728 | 26.76 | 9.005 | 24.62 | 8.285 | 22.65 | 7.622 | 20.84 | 7.01 | 19.17 | 6.449 | 17.64 | 5.933 | 16.23 | 5.458 | 14.93 |
| Wind (Onshore) | 4.081 | 9.538 | 4.105 | 9.538 | 3.876 | 9.538 | 3.876 | 9.538 | 3.876 | 9.538 | 3.876 | 9.538 | 3.876 | 9.538 | 3.876 | 9.538 | 3.876 | 9.538 | 3.876 | 9.538 | 3.876 | 9.538 |
| Biomass | 1.253 | 22.57 | 1.279 | 23.38 | 1.034 | 24.63 | 1.034 | 24.63 | 1.034 | 24.63 | 1.034 | 24.63 | 1.034 | 24.63 | 1.034 | 24.63 | 1.034 | 24.63 | 1.034 | 24.63 | 1.034 | 24.63 |

## C. ADDITIONAL COSTS IMPOSED ON SOCIETY FROM FEED-IN TARIFFS

### Germany

| [million EUR] | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Hydro | | | | | | | | | | | |
| Min: | 630.00 | 630.00 | 630.00 | 663.66 | 663.66 | 663.66 | 663.66 | 663.66 | 663.66 | 6665.36 | 6665.36 |
| Max: | 2280.60 | 2280.60 | 2280.60 | 2406.30 | 2406.30 | 2406.30 | 2406.30 | 2406.30 | 2406.30 | 25321.00 | 25321.00 |
| Geothermal | | | | | | | | | | | |
| Min: | 0.28 | 6.58 | 17.58 | 34.33 | 57.58 | 87.58 | 126.83 | 175.83 | 234.25 | 303.06 | 383.00 |
| Max: | 6.21 | 12.41 | 25.61 | 22.66 | 50.56 | 86.56 | 133.66 | 192.46 | 262.56 | 345.22 | 441.08 |
| Solar PV | | | | | | | | | | | |
| Min: | 2564.73 | 3550.37 | 4165.71 | 4638.63 | 5073.28 | 5471.18 | 5838.58 | 6172.79 | 6480.01 | 6768.16 | 7033.68 |
| Max: | 4493.03 | 5836.11 | 6674.06 | 7317.84 | 7911.61 | 8453.42 | 8953.74 | 9407.31 | 9822.97 | 10212.95 | 10572.54 |
| Wind | | | | | | | | | | | |
| Min: | 2243.23 | 2481.78 | 2658.81 | 2861.96 | 3159.45 | 3452.22 | 3728.54 | 4015.22 | 4312.63 | 4622.89 | 4967.74 |
| Max: | 6700.20 | 7413.00 | 8103.65 | 8912.86 | 10118.03 | 11322.06 | 12475.93 | 13691.74 | 14883.40 | 15193.67 | 16427.68 |
| Biomass | | | | | | | | | | | |
| Min: | 2553.41 | 2698.68 | 2820.36 | 2931.48 | 3039.30 | 3143.16 | 3241.50 | 3335.70 | 3423.42 | 3505.74 | 3585.18 |
| Max: | 5791.87 | 6123.17 | 6413.17 | 6672.64 | 6919.37 | 7152.36 | 7368.54 | 7571.54 | 7756.78 | 7927.18 | 8088.31 |

**Spain**

| [million EUR] | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Hydro | | | | | | | | | | | |
| Min: | 783.38 | 800.04 | 791.14 | 815.20 | 827.33 | 831.25 | 850.12 | 872.09 | 869.97 | 8731.37 | 895.99 |
| Max: | 2863.48 | 2924.36 | 2891.86 | 2979.79 | 3024.12 | 3038.43 | 3107.42 | 3187.74 | 3179.97 | 3185.10 | 3275.09 |
| Geothermal | | | | | | | | | | | |
| Min: | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.44 | 7.32 | 12.20 |
| Max: | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 4.37 | 13.12 | 21.87 |
| Solar PV | | | | | | | | | | | |
| Min: | 1703.71 | 1920.17 | 2084.94 | 2204.77 | 2300.06 | 2396.65 | 2494.43 | 2593.49 | 2693.73 | 2795.19 | 2897.80 |
| Max: | 2181.78 | 2459.32 | 2670.28 | 2823.73 | 2945.76 | 3069.46 | 3194.68 | 3321.51 | 3449.82 | 3579.67 | 3710.97 |
| Solar Conc. | | | | | | | | | | | |
| Min: | 307.41 | 704.31 | 1199.28 | 1574.95 | 1845.28 | 2126.36 | 2441.03 | 2793.85 | 3188.60 | 3630.64 | 4125.61 |
| Max: | 326.02 | 746.94 | 1271.88 | 1670.29 | 1956.98 | 2255.07 | 2588.79 | 2962.97 | 3381.61 | 3850.41 | 4375.34 |
| Tidal | | | | | | | | | | | |
| Min: | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.89 | 2.68 | 4.47 | 6.71 | 8.95 |
| Max: | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.60 | 4.81 | 8.02 | 12.03 | 16.04 |

## Spain (continued)

| [million EUR] | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Wind | | | | | | | | | | | |
| Min: | 1296.83 | 1353.18 | 1466.10 | 1572.73 | 1672.76 | 1778.28 | 1877.04 | 1998.20 | 2127.39 | 2268.20 | 2424.97 |
| Max: | 3061.47 | 3262.44 | 3534.68 | 3791.76 | 4032.92 | 9956.47 | 10509.42 | 11187.80 | 11911.12 | 12699.51 | 13577.24 |
| Biomass | | | | | | | | | | | |
| Min: | 114.41 | 117.91 | 123.50 | 130.47 | 139.28 | 151.01 | 164.89 | 181.63 | 200.84 | 224.82 | 253.72 |
| Max: | 759.29 | 782.49 | 819.64 | 865.86 | 924.36 | 1002.19 | 1094.30 | 1205.42 | 1333.17 | 1492.02 | 1683.82 |

## Slovenia

| [million EUR] | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Hydropower | | | | | | | | | | | |
| Min: | 116.82 | 119.67 | 119.67 | 125.34 | 125.81 | 129.18 | 131.90 | 132.51 | 140.89 | 140.89 | 144.00 |
| Max: | 432.32 | 442.76 | 442.76 | 465.44 | 467.34 | 480.84 | 491.83 | 494.13 | 527.67 | 527.67 | 540.11 |
| Solar Photovoltaic | | | | | | | | | | | |
| Min: | 2.36 | 3.17 | 3.70 | 4.19 | 4.64 | 5.05 | 5.97 | 6.95 | 8.18 | 9.66 | 11.41 |
| Max: | 5.33 | 6.99 | 8.45 | 9.79 | 11.02 | 12.15 | 14.65 | 17.33 | 20.69 | 24.74 | 29.52 |
| Wind | | | | | | | | | | | |
| Min: | 0.08 | 0.16 | 0.16 | 0.55 | 0.55 | 4.23 | 4.23 | 4.23 | 4.23 | 7.41 | 7.41 |
| Max: | 0.19 | 0.38 | 0.38 | 1.34 | 1.34 | 10.40 | 10.40 | 10.40 | 10.40 | 18.22 | 18.22 |
| Biomass | | | | | | | | | | | |
| Min: | 3.73 | 4.32 | 5.06 | 5.49 | 5.75 | 7.21 | 7.35 | 7.58 | 7.71 | 7.74 | 7.76 |
| Max: | 67.22 | 77.97 | 95.46 | 105.81 | 111.96 | 146.69 | 150.14 | 155.56 | 158.76 | 159.50 | 159.74 |

## D. AVOIDANCE FACTORS FOR CARBON DIOXIDE EMISSIONS

**Source: BMU, 2011**

| Technology | Avoidance Factor (gCO2/kWh) |
|---|---|
| Hydropower | 794 |
| Wind | 736 |
| Solar Photovoltaic | 679 |
| Biogenic solid fuels | 778 |
| Biogenic liquid fuels | 602 |
| Biogas | 565 |
| Sewage gas | 748 |
| Landfill gas | 748 |
| Biogenic share of waste | 773 |
| Geothermal energy | 488 |

## E. CARBON DIOXIDE EMISSIONS AVOIDED

### Germany

| [tons $CO_2$] | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Hydro | 14292000 | 14292000 | 14292000 | 15086000 | 15086000 | 15086000 | 15086000 | 15086000 | 15086000 | 15880000 | 15880000 |
| Geothermal | 13176 | 25864 | 47336 | 80032 | 125416 | 183976 | 260592 | 356240 | 476288 | 625128 | 807152 |
| Solar Photovoltaics | 6449821 | 9483593 | 11812563 | 13778947 | 15765022 | 17763319 | 19791492 | 21817628 | 23862776 | 25966997 | 28103131 |
| Wind | 32875648 | 31519180 | 39048480 | 42183104 | 43223103 | 51515584 | 55985312 | 60694976 | 65658560 | 70920224 | 76864160 |
| Biomass | | | | | | | | | | | |
| Min: | 18519570 | 19595330 | 20741150 | 21787530 | 22802835 | 23780850 | 24706885 | 25593935 | 26419965 | 27195145 | 27943205 |
| Max: | 25501284 | 26982596 | 28560380 | 30071256 | 31399302 | 32746020 | 34021162 | 3524622 | 36380058 | 37447474 | 38477546 |

**Spain**

| [tons CO2] | Hydro | Geothermal | Solar PV | Wind | Biomass | Min: | Max: |
|---|---|---|---|---|---|---|---|
| 2010 | 27485898 | 0 | 4357143 | 30159808 | | 2552105 | 3514226 |
| 2011 | 28070282 | 0 | 4972996 | 32139648 | | 2630075 | 3621590 |
| 2012 | 27758240 | 0 | 5493110 | 34821632 | | 2754940 | 3793528 |
| 2013 | 28602262 | 0 | 5913411 | 37354208 | | 2910315 | 4007478 |
| 2014 | 29027846 | 0 | 6284824 | 39730016 | | 3106935 | 4278222 |
| 2015 | 29165208 | 0 | 6703088 | 42015296 | | 3368530 | 4638436 |
| 2016 | 29827404 | 0 | 7173635 | 43864128 | | 3678150 | 5064780 |
| 2017 | 30598378 | 0 | 7703255 | 45807168 | | 4051615 | 5579038 |
| 2018 | 30523742 | 29280 | 8298738 | 47784800 | | 4481015 | 6170318 |
| 2019 | 30572970 | 87840 | 8968232 | 49767584 | | 5014940 | 6905528 |
| 2020 | 31436842 | 146400 | 9720564 | 51889472 | | 5659605 | 7793226 |

## Slovenia

| [tons CO2] | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Hydro | 3254606 | 3333212 | 3333212 | 3503922 | 3518214 | 3619846 | 3701628 | 3719890 | 3972382 | 3972382 | 4066074 |
| Solar PV | 8148 | 11543 | 14938 | 18333 | 21728 | 25123 | 33271 | 42777 | 55678 | 72653 | 94381 |
| Wind | 1472 | 2944 | 2944 | 10304 | 10304 | 80224 | 80224 | 80224 | 80224 | 140576 | 140576 |
| Biomass | | | | | | | | | | | |
| Min: | 168370 | 194360 | 234475 | 258205 | 272330 | 351995 | 359905 | 372335 | 379680 | 381375 | 381940 |
| Max: | 231844 | 267632 | 322870 | 355546 | 374996 | 484694 | 495586 | 512702 | 522816 | 525150 | 525928 |

### F. CONVERSION OF SOCIAL COST OF CARBON ESTIMATES TO EUR2010 VALUES

**Bank of England, 2011; ECB Statistical Data Warehouse, 2012; Eurostat, 2012; U.S. Bureau of Labor Statistics, 2012**

| Original Value | Inflation (Original Year to 2010) | Annualized Bilateral Exchange Rate in 2010 (EUR/currency) |
|---|---|---|
| USD1995 | 43% | 0.73926 |
| GBP2000 | 31% | 1.1657 |
| EUR2006 | 8.1% | N/A |

## G. BENEFITS FROM EMISSIONS AVOIDED

### Germany

| [million EUR] | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Hydro | | | | | | | | | | | |
| SCC=14.51 EUR/tCO2 | 207.38 | 207.38 | 207.38 | 218.90 | 218.90 | 218.90 | 218.90 | 218.90 | 218.90 | 230.42 | 230.42 |
| SCC=34.14 EUR/tCO2 | 487.93 | 487.93 | 487.93 | 515.04 | 515.04 | 515.04 | 515.04 | 515.04 | 515.04 | 542.14 | 542.14 |
| SCC=50.09 EUR/tCO2 | 715.89 | 715.89 | 715.89 | 755.66 | 755.66 | 755.66 | 755.66 | 755.66 | 755.66 | 795.43 | 795.43 |
| SCC=89.86 EUR/tCO2 | 1284.28 | 1284.28 | 1284.28 | 1355.63 | 1355.63 | 1355.63 | 1355.63 | 1355.63 | 1355.63 | 1426.98 | 1426.98 |
| Geothermal | | | | | | | | | | | |
| SCC=14.51 EUR/tCO2 | 0.19 | 0.38 | 0.69 | 1.16 | 1.82 | 2.67 | 3.78 | 5.17 | 6.91 | 9.07 | 11.71 |
| SCC=34.14 EUR/tCO2 | 0.45 | 0.88 | 1.62 | 2.73 | 4.28 | 6.28 | 8.90 | 12.16 | 16.26 | 21.34 | 27.56 |
| SCC=50.09 EUR/tCO2 | 0.66 | 1.30 | 2.37 | 4.01 | 6.28 | 9.22 | 13.05 | 17.84 | 23.86 | 31.31 | 40.43 |
| SCC=89.86 EUR/tCO2 | 1.18 | 2.32 | 4.25 | 7.19 | 11.27 | 16.53 | 23.42 | 32.01 | 42.80 | 56.17 | 72.53 |
| Solar PV | | | | | | | | | | | |
| SCC=14.51 EUR/tCO2 | 93.59 | 137.61 | 171.40 | 199.93 | 228.75 | 257.75 | 287.17 | 316.57 | 346.25 | 376.78 | 407.78 |
| SCC=34.14 EUR/tCO2 | 220.20 | 323.77 | 403.28 | 470.41 | 538.22 | 606.44 | 675.68 | 744.85 | 814.68 | 886.51 | 959.44 |
| SCC=50.09 EUR/tCO2 | 323.07 | 475.03 | 591.69 | 690.19 | 789.67 | 889.76 | 991.36 | 1092.84 | 1195.29 | 1300.69 | 1407.69 |
| SCC=89.86 EUR/tCO2 | 579.58 | 852.20 | 1061.48 | 1238.18 | 1416.64 | 1596.21 | 1778.46 | 1960.53 | 2144.31 | 2333.39 | 2525.35 |

## Germany (continued)

| [million EUR] | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Wind | | | | | | | | | | | |
| SCC=14.51 EUR/tCO2 | 477.03 | 527.77 | 566.59 | 612.16 | 627.17 | 747.49 | 812.35 | 880.68 | 952.71 | 1029.05 | 1115.30 |
| SCC=34.14 EUR/tCO2 | 1122.37 | 1241.78 | 1333.12 | 1440.13 | 1475.64 | 1758.74 | 1911.34 | 2072.13 | 2241.58 | 2421.22 | 2624.14 |
| SCC=50.09 EUR/tCO2 | 1646.74 | 1821.93 | 1955.94 | 2112.95 | 2165.05 | 2580.42 | 2804.30 | 3040.21 | 3288.84 | 3548.85 | 3850.13 |
| SCC=89.86 EUR/tCO2 | 2954.21 | 3268.49 | 3508.90 | 3790.57 | 3884.03 | 4629.19 | 5030.84 | 5454.05 | 5900.08 | 6372.89 | 6907.01 |
| Biomass | | | | | | | | | | | |
| SCC=14.51 EUR/tCO2 | | | | | | | | | | | |
| Min: | 268.72 | 284.33 | 300.95 | 316.14 | 330.87 | 345.06 | 358.50 | 371.37 | 383.35 | 394.60 | 405.46 |
| Max: | 370.02 | 391.52 | 414.41 | 436.33 | 455.60 | 475.14 | 493.65 | 511.37 | 527.87 | 543.36 | 558.31 |
| SCC=34.14 EUR/tCO2 | | | | | | | | | | | |
| Min: | 632.26 | 668.98 | 708.10 | 743.83 | 778.49 | 811.88 | 843.49 | 873.78 | 901.98 | 928.44 | 953.98 |
| Max: | 870.61 | 921.19 | 975.05 | 1026.63 | 1071.97 | 1117.95 | 1161.48 | 1203.18 | 1242.02 | 1278.46 | 1313.62 |
| SCC=50.09 EUR/tCO2 | | | | | | | | | | | |
| Min: | 927.65 | 981.53 | 1038.92 | 1091.34 | 1142.19 | 1191.18 | 1237.57 | 1282.00 | 1323.38 | 1362.20 | 1399.68 |
| Max: | 1277.36 | 1351.56 | 1430.59 | 1506.27 | 1572.79 | 1640.25 | 1704.12 | 1765.30 | 1822.28 | 1875.74 | 1927.34 |
| SCC=89.86 EUR/tCO2 | | | | | | | | | | | |
| Min: | 1666.02 | 1760.84 | 1863.80 | 1957.83 | 2049.06 | 2136.95 | 2220.16 | 2299.87 | 2374.10 | 2443.76 | 2510.98 |
| Max: | 2291.55 | 2424.66 | 2566.44 | 2702.20 | 282.15 | 2942.56 | 3057.14 | 3166.90 | 3269.11 | 3365.03 | 3457.59 |

## Spain

| [million EUR] | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Hydropower | | | | | | | | | | | |
| SCC=14.51 EUR/tCO2 | 398.82 | 407.30 | 402.77 | 415.02 | 421.19 | 423.19 | 432.80 | 443.98 | 442.90 | 443.61 | 456.15 |
| SCC=34.14 EUR/tCO2 | 938.37 | 958.32 | 947.67 | 976.48 | 991.01 | 995.70 | 1018.31 | 1044.63 | 1042.08 | 1043.76 | 1073.25 |
| SCC=50.09 EUR/tCO2 | 1376.77 | 1406.04 | 1390.41 | 1432.69 | 1454.00 | 1460.89 | 1494.05 | 1532.67 | 1528.93 | 1531.40 | 1574.67 |
| SCC=89.86 EUR/tCO2 | 2469.88 | 2522.40 | 2494.36 | 2570.20 | 2608.44 | 2620.79 | 2680.29 | 2749.57 | 2742.86 | 2747.29 | 2824.91 |
| Geothermal | | | | | | | | | | | |
| SCC=14.51 EUR/tCO2 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.42 | 1.27 | 2.12 |
| SCC=34.14 EUR/tCO2 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.00 | 3.00 | 5.00 |
| SCC=50.09 EUR/tCO2 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.47 | 4.40 | 7.33 |
| SCC=89.86 EUR/tCO2 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.63 | 7.89 | 13.16 |
| Solar PV | | | | | | | | | | | |
| SCC=14.51 EUR/tCO2 | 63.22 | 72.16 | 79.71 | 85.80 | 91.19 | 97.26 | 104.09 | 111.77 | 120.41 | 130.13 | 141.05 |
| SCC=34.14 EUR/tCO2 | 148.75 | 169.78 | 187.53 | 201.88 | 214.56 | 228.84 | 244.91 | 262.99 | 283.32 | 306.18 | 331.86 |
| SCC=50.09 EUR/tCO2 | 218.25 | 249.10 | 275.15 | 296.20 | 314.81 | 335.76 | 359.33 | 385.86 | 415.68 | 449.22 | 486.90 |
| SCC=89.86 EUR/tCO2 | 391.53 | 446.87 | 493.61 | 531.38 | 564.75 | 602.34 | 644.62 | 692.21 | 745.72 | 805.89 | 873.49 |

## Spain (continued)

| [million EUR] | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Wind | | | | | | | | | | | |
| SCC=14.51 EUR/tCO2 | 437.62 | 466.35 | 505.26 | 542.01 | 576.48 | 609.64 | 636.47 | 664.66 | 693.36 | 722.13 | 752.92 |
| SCC=34.14 EUR/tCO2 | 1029.66 | 1097.25 | 1188.81 | 1275.27 | 1356.38 | 1434.40 | 1497.52 | 1563.86 | 1631.37 | 1699.07 | 1771.51 |
| SCC=50.09 EUR/tCO2 | 1510.70 | 1609.87 | 1744.22 | 1871.07 | 1990.08 | 2102.45 | 2194.96 | 2294.48 | 2391.15 | 2492.86 | 2599.14 |
| SCC=89.86 EUR/tCO2 | 2710.16 | 2888.07 | 3129.07 | 3356.65 | 3570.14 | 3775.49 | 3941.63 | 4116.23 | 4293.94 | 4472.12 | 4662.79 |
| Biomass | | | | | | | | | | | |
| SCC=14.51 EUR/tCO2 | | | | | | | | | | | |
| Min: | 37.03 | 38.16 | 39.97 | 42.23 | 45.08 | 48.88 | 53.37 | 58.79 | 65.02 | 72.77 | 82.12 |
| Max: | 50.99 | 52.55 | 55.04 | 58.15 | 62.08 | 67.30 | 73.49 | 80.95 | 89.53 | 100.20 | 113.08 |
| SCC=34.14 EUR/tCO2 | | | | | | | | | | | |
| Min: | 87.13 | 89.79 | 94.05 | 99.36 | 106.07 | 115.00 | 125.57 | 138.32 | 152.98 | 171.21 | 193.22 |
| Max: | 119.98 | 123.64 | 129.51 | 136.82 | 146.06 | 158.36 | 172.91 | 190.47 | 210.65 | 235.75 | 266.06 |
| SCC=50.09 EUR/tCO2 | | | | | | | | | | | |
| Min: | 127.83 | 131.74 | 137.99 | 145.78 | 155.63 | 168.73 | 184.24 | 202.95 | 224.45 | 251.20 | 283.49 |
| Max: | 176.03 | 181.41 | 190.02 | 200.73 | 214.30 | 232.34 | 253.69 | 279.45 | 309.07 | 345.90 | 390.36 |
| SCC=89.86 EUR/tCO2 | | | | | | | | | | | |
| Min: | 229.33 | 236.34 | 247.56 | 261.52 | 279.19 | 302.70 | 330.52 | 364.08 | 402.66 | 450.64 | 508.57 |
| Max: | 315.79 | 325.44 | 340.89 | 360.11 | 384.44 | 416.81 | 455.12 | 501.33 | 554.46 | 620.53 | 700.30 |

## Slovenia

| [million EUR] | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Hydropower | | | | | | | | | | | |
| SCC=14.51 EUR/tCO2 | 47.22 | 48.36 | 48.36 | 50.84 | 51.05 | 52.52 | 53.71 | 53.98 | 57.64 | 57.64 | 59.00 |
| SCC=34.14 EUR/tCO2 | 111.11 | 113.80 | 113.80 | 119.62 | 120.11 | 123.58 | 126.37 | 127.00 | 135.62 | 135.62 | 138.82 |
| SCC=50.09 EUR/tCO2 | 163.02 | 166.96 | 166.96 | 175.51 | 176.23 | 181.32 | 185.41 | 186.33 | 198.98 | 198.98 | 203.67 |
| SCC=89.86 EUR/tCO2 | 292.46 | 292.46 | 292.46 | 314.86 | 316.15 | 325.28 | 332.63 | 334.27 | 356.96 | 356.96 | 365.38 |
| Solar Photovoltaics | | | | | | | | | | | |
| SCC=14.51 EUR/tCO2 | 0.12 | 0.17 | 0.22 | 0.27 | 0.32 | 0.36 | 0.48 | 0.62 | 0.81 | 1.05 | 1.37 |
| SCC=34.14 EUR/tCO2 | 0.28 | 0.39 | 0.51 | 0.63 | 0.73 | 0.86 | 1.14 | 1.46 | 1.90 | 2.48 | 3.22 |
| SCC=50.09 EUR/tCO2 | 0.41 | 0.58 | 0.75 | 0.92 | 1.07 | 1.26 | 1.67 | 2.14 | 2.79 | 3.64 | 4.73 |
| SCC=89.86 EUR/tCO2 | 0.73 | 1.04 | 1.34 | 1.65 | 1.91 | 2.26 | 2.99 | 3.84 | 5.00 | 6.53 | 8.48 |
| Wind | | | | | | | | | | | |
| SCC=14.51 EUR/tCO2 | 0.02 | 0.04 | 0.04 | 0.15 | 0.15 | 1.16 | 1.16 | 1.16 | 1.16 | 2.04 | 2.04 |
| SCC=34.14 EUR/tCO2 | 0.05 | 0.10 | 0.10 | 0.35 | 0.35 | 2.74 | 2.74 | 2.74 | 2.74 | 4.80 | 4.80 |
| SCC=50.09 EUR/tCO2 | 0.07 | 0.15 | 0.15 | 0.52 | 0.52 | 4.02 | 4.02 | 4.02 | 4.02 | 7.04 | 7.04 |
| SCC=89.86 EUR/tCO2 | 0.13 | 0.26 | 0.26 | 0.93 | 0.93 | 7.21 | 7.21 | 7.21 | 7.21 | 12.63 | 12.63 |

## Slovenia (continued)

| [million EUR] | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Biomass | | | | | | | | | | | |
| SCC=14.51 EUR/tCO2 | | | | | | | | | | | |
| Min: | 2.44 | 2.82 | 3.40 | 3.75 | 3.95 | 5.11 | 5.22 | 5.40 | 5.51 | 5.53 | 5.54 |
| Max: | 3.36 | 3.88 | 4.68 | 5.16 | 5.44 | 7.03 | 7.19 | 7.44 | 7.59 | 7.62 | 7.63 |
| SCC=34.14 EUR/tCO2 | | | | | | | | | | | |
| Min: | 5.75 | 6.64 | 8.00 | 8.82 | 9.30 | 12.02 | 12.29 | 12.71 | 12.96 | 13.02 | 13.04 |
| Max: | 7.92 | 9.14 | 11.02 | 12.14 | 12.80 | 16.55 | 16.92 | 17.50 | 17.85 | 17.93 | 17.96 |
| SCC=50.09 EUR/tCO2 | | | | | | | | | | | |
| Min: | 8.43 | 9.74 | 11.74 | 12.93 | 13.64 | 17.63 | 18.03 | 18.65 | 19.02 | 19.10 | 19.13 |
| Max: | 11.61 | 13.41 | 16.17 | 17.81 | 18.78 | 24.28 | 24.82 | 25.68 | 26.19 | 2.63 | 26.34 |
| SCC=89.86 EUR/tCO2 | | | | | | | | | | | |
| Min: | 15.13 | 17.47 | 21.07 | 23.20 | 24.47 | 31.63 | 32.34 | 33.46 | 34.12 | 34.27 | 34.32 |
| Max: | 20.83 | 24.05 | 29.01 | 31.95 | 33.70 | 43.55 | 44.53 | 46.07 | 46.98 | 47.19 | 47.52 |

## H. PROGRESS MADE

**Germany (PR DE, 2011; BMU, 2012)**

| Installed Capacity [MW] | 2010 | 2011 |
|---|---|---|
| Hydro | 4395 | 4401 |
| Geothermal | 7.5 | 7.5 |
| Solar Photovoltaic | 17320 | 24820 |
| Wind (Total) | 27191 | 29075 |
| Wind Onshore | 27030 | |
| Wind Offshore | 180 | |
| Biomass | 6664 | 7179 |
| Overall | 55580 | 65483 |

| Electricity Produced [GWh] | 2010 | 2011 |
|---|---|---|
| Hydro | 23500 | 19500 |
| Geothermal | 3 | 18.8 |
| Solar Photovoltaic | 11683 | 19000 |
| Wind (Total) | 43100 | 46500 |
| Wind Onshore | 42900 | |
| Wind Offshore | 210 | |
| Biomass | 33866 | 36920 |
| Overall | 112100 | 121939 |

**Spain (MITT, 2010; NCE, 2012)**

| Installed Capacity [MW] | 2010 | 2011 |
|---|---|---|
| Hydro | 16805 | 16805 |
| Solar PV | 3642 | 4216 |
| Solar Concentrated | 682 | 999 |
| Wind | 20203 | 20766 |
| Biomass | 749 | 724 |
| Overall | 42197 | 42786 |

| Electricity Produced [GWh] | 2010 | 2011 |
|---|---|---|
| Hydro | 42325 | N/A |
| Solar PC | 7186 | 7386 |
| Solar Concentrated | 691 | 1782 |
| Wind | 43784 | 41426 |
| Biomass | 3448 | 3679 |
| Overall | 97406 | 54273 [without hydro] |

| | 2012 Capacity Increase |
|---|---|
| Solar Photovoltaic | 7 MW |
| Solar Concentrated | 150 MW |
| Wind (Onshore) | 278 MW |

**Slovenia (PR SI, 2011; EA RS, 2012)**

| Installed Capacity [MW] | 2010 | 2011 |
|---|---|---|
| Hydro | 1254 | 1255 |
| Solar PV | 12 | 57 |
| Wind | 0 | 0 |
| Biomass | 49 | 53 |
| Overall | 1315 | 1365 |

| Electricity Produced [GWh] | 2010 | 2011 |
|---|---|---|
| Hydro | 4326 | N/A |
| Solar Photovoltaic | 13 | 57 |
| Wind | 0 | 0 |
| Biomass | 222 | 309 |
| Overall | 4561 | 4682 |

| | 2012 Capacity Increase |
|---|---|
| Hydropower | 52 MW |
| Solar Photovoltaic | 47 MW |
| Wind (Onshore) | 0 MW |