Subsidies and costs of EU energy

Annex 1-3

Contents

Annex 1 Definitions of subsidies

A1.1 A typology of interventions

Apart from definitions of subsidies, various classifications and typologies of subsidies have been developed (c.f. OECD 2011[1], OECD 2013[2], World Bank 2010[3], GSI 2011[4], IMF 2013[5]). There are many similarities between these definitions and there is a shared understanding of the essential types of support that subsidies may comprise of. The OECD (2011, 2013) divides subsidies in subsidy types that are briefly discussed below. We have grouped Government tax and other Government revenue foregone in one category and included one additional category non-financial measures.

Direct transfer of funds, also referred to as direct subsidies. Direct transfer of funds includes direct Government payments such as capital grants, production support (e.g. feed-in tariffs and premiums), Government spending on R&D and deficiency payments[6]. These are the most transparent and straightforward types of subsidy and refer to what people commonly understand by the term 'subsidy'. These direct subsidies are most often 'visible', they can be quantified, and they are usually included in annual Government budget statements.

Government tax and other Government revenue foregone. Tax revenue foregone refers to revenue foregone by the Government (or other economic agents) due to a reduction in the tax liabilities of particular groups or of specific activities. Such deviations from benchmark tax structures may take the form of tax and duty exemptions, tax allowances and investment tax deduction. As Member States have significant taxes and duties on energy products, deductions and deviations from reference tariffs play an important role. Evidence shows that tax measures are often a more important source of subsidies than the direct transfer of funds (OECD 2013).

Transfer of risk to Government. This refers to the transfer of risk from market players (e.g. energy producers) to Governments. This includes a wide variety of measures to transfer risk to the Government, including loan guarantees, Government participation in the equity of a project or company, Government acting as an insurer of the last resort (e.g. in case of nuclear accidents or environmental disasters as a result of crude oil extraction) and Government provision of military or police protection to strategic energy facilities or energy-transport corridors (OECD 2013).

Income or price support. Also referred to as induced transfer of funds. Induced transfers refer to Government support that is (indirectly) provided to consumers or producers to keep the end-price of an energy good or service lower or higher than its actual market price, often through some sort of price support or price regulation. Measures may regard both fossil fuels and renewable energy.

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[1] OECD (2011) Inventory of estimated budgetary support and tax expenditures for fossil fuels.
[2] OECD (2013). Inventory of Estimated Budgetary Support and Tax Expenditures for Fossil Fuels 2013, available at http://www.oecd.org/site/tadffss/
[3] World Bank (2010) Subsidies in the energy sector: An Overview. Background Paper for the World Bank Group Energy Sector Strategy, July 2010.
[4] Global Subsidies Initiative – GSI (2011) Subsidies and External Costs in Electric Power Generation: A comparative review of estimates. September 2011.
[5] IMF (2013) Energy subsidy reform: Lessons and implications. Overview of post- Post-tax Subsidies for Petroleum Products, Electricity, Natural Gas, and Coal, 2011 for most EU countries (as a percentage of GDP). Pre-tax subsidies are only available for Poland.
[6] A type of domestic support paid by Governments to producers of certain commodities. The height is based on the difference between a target price and the domestic market price or loan rate.

They may include regulated energy price mark-ups (e.g. through mandated feed-in tariffs and premiums), lignite or peat obligations, import tariffs, export subsidies, consumption mandates and regulated land prices. In essence, measures create a gap between domestic prices and (international) benchmark or reference prices (i.e. the level of prices in the absence of the regulation) (OECD 2013).

Non-financial measures: Non-financial support measures relate to mandates, obligations and (voluntary) agreements that have been settled between the Government and producers and consumers of energy. These measures, although not directly involving a transfer of money, will have an effect on energy prices as they usually result in the mandated or obligated parties making financial decisions that they might not otherwise have made.

A1.2 Production versus consumption side

Energy support measures can be allocated either to energy production or to energy consumption. Although specific policy mixes differ per country, support measures on fossil fuels are often deployed on consumption, while support measures on nuclear energy and renewables are often directed at production.

Production side
Support measures on the production side aim at stimulating production of energy using some specific energy carriers or production technologies. This is done using various economic and non-economic instruments. Some support measures lower the marginal costs of production. Energy policies can maintain energy or fuel prices below a cost coverage level of producing and distributing them including a 'normal or counterfactual energy tax level'. These support measures lower the unit cost of each kilojoule of energy produced and delivered to the consumer. An example of renewable support is the feed-in tariffs or feed-in premiums. In a competitive energy market, production-related support measures alter (relative) prices and thus increase the quantity of production units[7].

Consumption side
Support measures to energy consumption relate to specific transfers of income to certain groups of energy consumers that may be exempt from taxes or allowed for special deductions. Policy measures that provide transfers to consumers of energy include direct payments to final consumers for the purchase of fuels or electricity and the value of transfers to consumers created through Government interventions that artificially depress the domestic price compared with a reference price.
The effect of consumption support measures on the market is that it distorts prices and lowers the end-use prices for consumers, which may increase energy use and reduce incentives for energy saving. As above, lowering the energy cost can be done either via *the marginal* cost (the last unit of energy used) by tariff deductions or via the *average cost.* Lowering the average energy cost can be the result of support measures that do not have a relationship with amount of energy consumed. For example, in the Netherlands households were compensated for the cost burden due to the increased marginal tariff of the Energy Tax. This was done by introducing a tax-free allowance of € 320 (per year) for every household with a grid connection and independent of the amount of energy consumed.

[7] In monopolistic markets these support measures, however, may not alter prices or supply.

Annex 2 Interventions

A2.1 Methodology for 2008 - 2012 interventions

In the Member State reporting of interventions, the values were allocated as much as possible to individual technologies. However, in some cases it was not possible to do this using basic data. In these cases, we allocated to individual technologies on the basis of the shares in the fuel mix. Energy savings and energy demand measures were not allocated to individual technologies.

Public interventions that either could not be identified in one of the Member States or could not be quantified are not included in the section below. It concerns following interventions:

- Support for investment: Exemption from import duty;
- Support for investment: Investment tax credits (part of investment tax incentives);
- Support to production: Price guarantees for district heating or fossil fuels;
- Support to production: Subsidised cooling water;
- Support to production: Tax allowances for decommissioning and remediation;
- Support to production: Tax credits for decommissioning and remediation;
- Support to production: Priority access
- Support to energy savings: Loan guarantees.

A2.2 Support to R&D

A2.2.1 Tax incentives for RD&D: tax credits and tax allowances

Background

Tax incentives for RD&D are intended to make it fiscally more attractive for firms to invest in research development and deployment activities. This is important from an overall economic perspective, and also particularly for energy where there is a continuing need to develop and demonstrate more efficient and sustainable energy technologies and processes. Tax incentives in this sense can include both tax credits and tax allowances:

- Tax credits are applied to the actual amount of tax owed/payable. It is typically based on a percentage of eligible R&D expenditures.
- Tax allowances (which can also be described as deductions, reliefs and exemptions) reduce the amount of income that is taxable. It refers to the amount of money which a taxpayer is allowed to earn and not pay tax on (taxable income), as a result of carrying out activities defined as eligible R&D. These are typically expressed in the form of a, for example, 150% allowance, which allows for a firm to deduct an additional 50% on top of the actual expenditure.

These provisions effectively reduce the cost of RD&D, encouraging higher RD&D spend than may otherwise have been the case. The outputs of RD&D can contribute to lower energy costs and prices through energy efficiency improvements or savings.

Approach to monetisation

Intervention	Tax incentives for RD&D
Tier I	Take annual revenue foregone from national balance sheets if available.
Tier II	The total intervention in any given year can be monetised as follows: For **tax credits**: *Intervention (€) = RD&D expenditure energy (€) * R&D tax credit (%)* For **tax allowances**: *Intervention (€) = regular tariff for corporation tax (%) * (intervention tax deduction or allowance rate (%) – standard tax allowance rate (%)) * RD&D expenditure energy (€)*
Tier III	Custom calculations, relevant for Hungary (tax credits) and Latvia (tax allowances).

A2.2.2 R&D grants

Background
Research and development (R&D) is one of the driving forces behind the continuous improvement of energy technologies. This especially holds for energy technologies that are still in their infancies, but also for technologies in a (early)-commercial stage or even mature technologies. The source of this support may vary, depending on how mature is the technology. Public funding will most likely focus on technologies that are still in an early phase or technologies that have societal benefits. After the technologies have passed the demonstration phase and go towards (pre)-commercial, the R&D is to a greater extent funded by private parties. R&D grants are available for a wide range of electricity or heat generating technologies, energy infrastructure and smart grids.

Approach to monetisation

Intervention	R&D grants
Tier I	Take total annual expenditures from national balance sheets and for the EU-wide grants from EU budgets.
Tier II	Not applicable
Tier III	A consistent set of R&D expenditures can be obtained for most Member States from the IEA R&D database[8]. Where Member States data were incomplete or showed lower values, we took data from that database.

A2.2.3 Government provided R&D facilities and transfer of intellectual property rights

If figures are available in national accounts, we report these. We have not identified an alternative way of quantifying this, but in the period 2008 - 2012 Government spending on building new R&D facilities is expected to be very limited. R&D expenditure on running facilities are covered in the R&D grants section.

[8] http://www.iea.org/statistics/topics/rdd/

Approach to monetisation

Intervention	Government provided R&D facilities and transfer of intellectual property rights
Tier I	Annual expenditure from national balance sheets and official reports.
Tier II	Not applicable

A2.3 Support for investment

A2.3.1 Investment grants

Background

Investments grants are typically awarded per unit of installed capacity (e.g. MW_e of electrical power), per standard unit (e.g. solar hot water boiler), per recipient (e.g. household), but also to other specific variables (e.g. m^2 of isolation). The grant is awarded for a specific goal or purpose and might be spread over several years.

The types of investments expected in this category are grants for the realisation of projects. Small projects, fossil fuelled and renewable projects (e.g. new boilers, PV panels) at the household level are often subsidised through investment grants. Large scale energy projects may also be supported through investment grants, although this is less common.

Approach to monetisation

Intervention	Investment grants
Tier I	Annual expenditure from national balance sheets. Alternative sources for annual expenditure are national evaluation reports or EU reports (for EU-wide interventions). For the volume of grants we fully rely on data from national accounts and/or evaluation reports. Ideally, we would obtain data on total grant volume in a given year split by nuclear, renewables, gas and coal (may only be available at the level of fossil fuel) and infrastructure. If no details on the grant amount per technology are available we present the grant volume on aggregated level.
Tier II	Not applicable

A2.3.2 Soft loans

Background

A loan or debt is the amount of money that is provided to a project by a third party under the condition that this will be (entirely or partially) repaid during or at the end of the agreed debt term. Loan facilities can be very helpful in case the availability of capital is a problem. Loans can cover up to 100% of the financeable cost and are used for both renewable energy and energy saving projects. Interest rates and repayment periods of loans have a major impact on the overall cost of projects. Especially new technologies, smaller projects or project developers without a proven track record often experience difficulties in obtaining commercial loans at reasonable conditions. Governments can increase commercial viability of projects significantly by offering low interest loans or loan guarantees.

Governments can offer low interest loans for specific technologies directly through state-owned banks or through subsidies to commercial banks. These loans can be characterised by lower interest rates and/or longer repayment periods. Low interest loans have been applied successfully in for example Spain and Germany. Governments can also offer just loan guarantees for certain projects. In that case the Government guarantees debt repayment to the lending bank, thus reducing risk and hence interest rate (e.g. 1 to 2%), debt term and debt service conditions of the loan (Ecofys, 2008)[9].

Approach to monetisation

Intervention	Soft loans
Tier I	Not applicable
Tier II	We calculate the volume of the intervention as the difference between the interest paid at commercial loan conditions minus the interest paid at the conditions of the soft loan. It turns out that Governments or (development) banks often report on the total volume of outstanding loans relating to a specific soft loan facility. From this information we quantify the intervention by calculating the total interest paid on the loan and annual payments on the loan (including both principal and interest) and then separately the interest paid on the loan: $$P_t = \frac{\mathrm{L} \cdot \mathrm{r} \quad \cdot (1+\mathrm{r})^n}{(1+\mathrm{r})^n - 1}$$ Where: P_t = annual payment including payback and interest for any given loan in year t L = total of original loan (principal) (cumulative loans until view year) n = average debt term r = (annual) interest rate The total interest (R_{tot}) paid over the debt term equals the difference between the annual payments (including paybacks and interest) and the original loan: $$\mathrm{R}_{tot} = \sum_{t=1}^{n} \mathrm{P}_t - \mathrm{L}$$ For the average annual interest payments we divide by the average debt term *n*, which is believed to be an appropriate approximation of actual interest received. In a final step we calculate the Government intervention I as the difference between annual interest payments for a commercial loan and a soft loan: $$\mathrm{I} = \left(\mathrm{P}_{Com} - \frac{\mathrm{L}}{n_{Com}}\right) - \left(\mathrm{P}_{Pol} - \frac{\mathrm{L}}{n_{Pol}}\right)$$ Where: P_{com} = average annual payment for a commercial loan P_{pol} = average annual payment for a soft loan L = total of original loan (principal) (cumulative loans until view year) n = average debt term r = (annual) interest rate

[9]Ecofys, 2008. Policy instrument design to reduce financing costs in renewable energy technology projects, available at: http://www.ecofys.com/files/files/retd_pid0810_main.pdf

A2.3.3 Investment tax incentives

Background

Investment tax incentives are intended to make it fiscally more attractive to invest. They are applied in a similar way as RD&D tax incentives, depending on whether a tax allowance or tax credit is granted. Again, tax allowances are applied to taxable income, whereby firms are allowed to subtract the costs of an investment from the total of their taxable profits. Tax credits are applied to tax payable, whereby a firm can subtract from the tax they have to pay an amount equal to the investment multiplied by the tax credit %.

The provision of investment tax incentives effectively reduces the cost of an investment, in turn also reducing the cost of production, or increases returns. This provides an incentive for greater investment (and production) than would otherwise occur. There are other economic consequences (opportunity costs) of such policies as investment is diverted from other sectors and greater production will impact on wider fuel demand and prices. Investment tax allowances and credits can be offered on a variety of investment expenditures including capital investments, R&D expenditures and fossil fuel exploration and extraction.

At the margin, tax incentives can make a difference both incrementally and as a go/no-go factor in an investment decision, by reducing the cost of the capital expenditures, or increasing the expected returns on an investment.

Approach to monetisation

Intervention	**Investment tax incentives**
Tier I	Take annual revenue foregone from national balance sheets.
Tier II	For any given technology an annual payment can be monetised as follows: For tax credits: *Intervention (€) = Installed capacity (MW) * CAPEX (€/MW) * R&D tax credit (%)* *For tax allowances:* *Intervention (€) = Installed capacity (MW) * CAPEX (€/MW) * investment tax allowance (%) * regular tariff for corporation tax (%)* Interventions may be subject to any conditions and rules of allowances, i.e. minimums or maximums.
Tier III	Country expert estimation based on own approach

A2.3.4 Accelerated depreciation

Background

Accelerated depreciation is another measure that can be used to provide a tax advantage to firms, resulting in foregone income to the Government. It works by changing the rate at which capital assets can be written off in firm accounts, allowing firms to write off more than would otherwise be allowed in the early years of the asset-life.

Accelerated depreciation can act as an important investment incentive, being advantageous in increasing a firms 'book' costs and therefore reducing the profits on which tax is payable in the short term. Within an individual investment the nominal total tax liability should be unchanged over the asset life, but there are benefits to the firm of using accelerated depreciation due to time preference, i.e. it is preferable to have money now than in the future, as this can be used to generate interest or other returns in the meantime. It is also advantageous within a wider company portfolio to help reduce taxes paid on other incomes, and can be used to attract investors to a project where accounting rules allow for an investor to 'buy' the tax advantage of accelerated depreciation.

Approach to monetisation

Accelerated depreciation tax allowances result in short-term foregone tax receipts for the tax payer, and effective subsidies to the recipient firms as a result of the time preference of money. As such, they are not usually included in national accounts. We draw upon the accounting expertise within the consortium, in particular from KPMG, to provide clear data on depreciation and accounting practice.

<table>
<tr><th>Intervention</th><th>Accelerated depreciation</th></tr>
<tr><td>Tier I</td><td>Not applicable.</td></tr>
<tr><td>Tier II</td><td>
For any given technology the intervention in any given year can be monetised as follows:
Intervention (€) = Installed capacity (MW) * CAPEX (€/MW) * (NPV of accelerated depreciation scheme (%) – NPV regular depreciation (%)) * regular tariff for corporation tax (%)
The regular depreciation % represents the standard % rate at which an investment in the same, or most similar, asset class as the investment asset is depreciated, i.e. straight line, 10 years = 10%, or 20% declining balance. The accelerated depreciation rate is be specified in the intervention text.
NPV is calculated based on the standard NPV formula
$$\mathrm{NPV} = \frac{\mathrm{P}t}{(1+\mathrm{r})^{t}}$$
Where:
P = original investment value
t = # of years
r = annual interest rate (preferably for individual Member States)
For the purposes of this calculation we keep hold P constant, to calculate a country/technology specific accelerated and regular depreciation %. Therefore the important data for this calculation is the profile of depreciation over time in the regular and accelerated situations. The example below demonstrating how a specified accelerated depreciation schedule delivers an NPV around 20% higher than standard (10 year straight-line)– this is the figure that would result from the third step in the calculation above. Note that the % represents the % of the original asset value, not the book value in that year, therefore for declining balance depreciation systems the % each year is not be constant.
<table>
<tr><th></th><th>Accelerated</th><th>Regular</th></tr>
<tr><td>Year 1</td><td>30%</td><td>10%</td></tr>
<tr><td>Year 2</td><td>30%</td><td>10%</td></tr>
<tr><td>Year 3</td><td>30%</td><td>10%</td></tr>
<tr><td>Year 4</td><td>10%</td><td>10%</td></tr>
<tr><td>Year 5</td><td></td><td>10%</td></tr>
<tr><td>…</td><td></td><td>…</td></tr>
<tr><td>Year 10</td><td></td><td>10%</td></tr>
<tr><td>NPV</td><td>81.4%</td><td>61.4%</td></tr>
</table>
</td></tr>
</table>

A2.3.5 Property tax abatement

Background
Property tax abatement is a tax relief associated with property, resulting in foregone income to the Government. It works by reducing the rate of tax which at which property, such as land, buildings or capital assets is taxed.

Approach to monetisation
Property tax reduction results in foregone tax receipts for the tax payer compared to standard tax rates.

Intervention	Property tax abatement
Tier I	Take annual revenue foregone from national balance sheets or evaluation report.
Tier II	Not applicable

A2.3.6 Differentiated grid connection charges

Background
New power plants have to pay costs associated with connecting to grid. “Shallow” costs describe the connection to the next grid connection point. “Deep” costs include the reinforcement of existing grid infrastructure to cope with additional generation capacity. In some cases, Governments intervene to reduce or waive these costs for certain technologies.

Approach to monetisation
Costs for grid connections depend on specific characteristics of the local and regional grid, the geography and the generation capacity. There is no generic way to quantify connection costs. We look for differences in treatments of generating units, e.g. if there are differences between fossil fuel based operations and renewable energy projects.

Intervention	Differentiated grid connection charges
Tier I	Qualitative assessment based on insights from the country experts
Tier II	Not applicable

A2.3.7 Other investment support

Interventions in this category do not fit with any other pre-existing categories, but do relate to investments. Examples of public interventions that fall in this category are loan guarantees, planning exemptions, exemptions from stamp duties etc.

Approach to monetisation

Intervention	Other investment support
Tier I	Annual expenditure from national balance sheets and official reports.
Tier II	Not applicable

A2.4 Support to production

A2.4.1 Feed-in tariffs

Background

In the EU Member States the production of electricity is supported through three main categories of instruments: feed-in tariffs (FIT), feed-in premiums (FIP), and quota obligations. These instruments can be applied to any technology and the method for quantification is the same in each case. Feed-in tariffs have been historically and still are the main instrument of support for renewable energy in the EU. There are feed-in tariffs in the UK, Germany, Ireland, Portugal, Belgium, Greece and some other countries. Sometimes feed-in tariffs co-exist with alternative schemes such as premiums or quota obligations.

In a feed-in tariff (FIT) system, power plant operators receive a fixed payment for each unit of electricity, heat and/or biogas generated, independent of the market price of these energy products. In other words, in tariff systems, generators do not sell the produced electricity on the power market, but a single buyer fulfils this role (often the TSO). Most countries use a differentiation according to technology, which facilitates the development of a range of technologies due to the different level of tariffs they receive. The specific design of the feed-in scheme may differ as well: some countries have a fixed tariff over the complete support term, others have decreasing tariffs.

Approach to monetisation

Intervention	Feed-in tariffs
Tier I	Take total annual expenditures per energy technology from national balance sheets or reports from Government. These annual expenditures refer to the **net** payments made by each TSO to the electricity generators. Thus, the revenues of the sales of energy on the spot market were excluded.
Tier II	A Tier II approach was followed for the Member States, for which the country experts provided Ecofys with: 1. The total amount of subsidised energy production and the feed-in tariffs per technology, **or** 2. The total amount of subsidised energy production and the **gross** payments made by the TSO Depending on the provided inputs, a different calculation methodology was applied for the calculation of the total annual expenditures per energy technology, as described below: **1. Given inputs: subsidised energy production and the feed-in tariffs** Tariffs are established each year for new projects and therefore differ from year to year for as long as a single project receive support (e.g. 15 or 20 years). This is to reflect the (usually) downward cost trend of renewable energy technologies. One should therefore use the particular tariffs that apply for a particular technology, for a particular year. The annual expenditures are hence determined as the sum of the electricity production from units starting production in year x, times the funding gap in year x, plus the sum of the electricity production from units starting production in year x -1, times the funding gap in year x-1 etc. The general formula for calculating the Government intervention (in €) for renewable electricity support schemes from newly installed capacity of technology i in a specific year x is given as:

Intervention	Feed-in tariffs
	$$I_{i,new}(x) = \left(P_i(x) - P_i(x-1)\right) \times FG_i(x)$$ With: $I_{i,new}(x)$ = Government intervention (€) for <u>new</u> capacity in year x of technology i $P_i(x)$ = electricity production (MWh) of technology i in year x $FG_i(x)$ = funding gap (€/MWh) of technology i in year x The total Government intervention (in €) for technology i in year x is given as: $$I_i(x) = \sum_{2000}^{x} I_{i,new}(x) = \sum_{2000}^{x} (P_i(x) - P_i(x-1) \times h) \times FG_i(x)$$ With: $I_{i,}(x)$ = Government intervention (€) for <u>full</u> capacity in year x of technology i The implicit assumption is that the support for renewable energy under these schemes has been negligible in 2000. The funding gap in year x, FG(x), is defined as follows for the feed-in tariff scheme (FIT): $$FG_{FIT,i}(x) = FIT_i(x) - p_{el}(x)$$ With: $p_{el}(x)$ = (average) electricity market price (€/MWh) in year x $FIT_i(x)$ = feed-in tariff of technology i in year x Note: Specifically for interventions referring to feed-in tariffs for electricity generators from hydro plants, a slightly different approach was used.The above mentioned methodology could not be properly applied, since the produced energy from hydro plants was not necessarily increasing over the years. The year with the highest production was considered as a "base" year for the calculation of the gross payments for the rest years. The gross payments of the rest years were calculated proportionately to the "base" year. Two ratios were accounting for this proportionate calculation: produced energy and feed-in tariffs, between base and investigated year. **2. Given inputs: subsidised energy production and gross payments by TSO** The net payments made by the TSO to the electricity producers of technology i in a specific year x can be calculated as: $$Net_i(x) = Gross_i(x) - Revenues_i(x)$$ With: $Gross_i(x)$:Gross payments (€) made by the TSO to the electricity producers of technology i in a specific year x $Revenues_i(x)$ = Revenues (€)of TSO received by the sale of electricity (produced by technology i in a specific year x) on the spot market The implicit assumption is that amount of energy that TSO buys from the electricity producers is equal to the amount of energy they sell on the spot market. The revenues of the sale on the spot market of the electricity produced by technology i in a specific year x, are defined as follows: $$Revenues_{i,}(x) = P_i(x) \times p_{el}(x)$$ With: $P_i(x)$ = electricity production (MWh) of technology i in year x $p_{el}(x)$ = (average) electricity market price (€/MWh) in year x

Intervention	Feed-in tariffs
Tier III	A Tier III approach was followed for the Member States for which the country experts provided Ecofys only with the Gross payments (€) made by the TSO to the electricity producers of technology i in a specific year x. In this case the following formula was used: $$Net_i\ (x) = Gross_i\ (x) - Revenues_i\ (x) \rightarrow$$ $$\frac{Net_i\ (x)}{Gross_i\ (x)} = 1 - \frac{Revenues_i\ (x)}{Gross_i\ (x)}$$ With: $Gross_i$ (x):Gross payments (€) made by the TSO to the electricity producers of technology i in a specific year x, $$Gross_i\ (x) = P_i(x)\ \times\ FIT_i(x)$$ $Revenues_i$ (x) = Revenues (€)of TSO received by the sale of electricity (produced by technology i in a specific year x) on the spot market $$Revenues_{i,}\ (x) = P_i(x)\ \times\ p_{el}(x)$$ With: $P_i(x)$ = electricity production (MWh) of technology i in year x $p_{el}(x)$ = (average) electricity market price (€/MWh) in year x $FIT_i(x)$ = feed-in tariff of technology i in year x Therefore, the net payments made by the TSO to the electricity producers of technology i in a specific year x can be calculated as: $$Net_i\ (x) = \left(1 - \frac{p_{el}(x)}{FIT_i(x)}\right) \times Gross_i\ (x)$$ The values for the feed-in tariffs per technology were derived from publicly available sources, such as: http://www.reshaping-res-policy.eu www.res-legal.eu An average feed-on tariff was assumed, for the technologies that more than one feed-in tariff have been enacted, depending on the capacity of the power plant.

A2.4.2 Feed-in premiums and quota obligations

Background

Feed-in premium schemes have gained ground over the last years and are used as main support instruments for renewable energy in an increasing number of Member States, including the Netherlands, Spain, Finland, Austria and Cyprus.

In a feed - in premium scheme, plant operators have to sell their renewable energy on the market and receive an additional payment on top of the market price - either as a fixed payment or adapted to changing market prices (e.g. with cap and floor prices, sliding premium/Contract for Difference) to limit the price risk for plant operators.

Premium schemes provide a secure additional return for producers, while exposing them to the electricity price risk. The level of premiums is based on future expectations regarding the generation costs of renewable electricity and the average electricity market revenues.

Approach to monetization

Intervention	Feed-in premiums
Tier I	Annual payments reported on national balance sheets
Tier II	Not applicable

A2.4.3 Energy quotas with tradable certificates

In case of quota obligation schemes, Governments impose minimum shares of a particular energy source on suppliers (or consumers and producers). Quota obligations are frequently combined with tradable green certificates (e.g. the renewable obligation certificates (ROCs) in the UK). Plant operators receive certificates for their electricity, heat and biogas, which they may sell to the actors obliged to fulfil their quota obligation. Hence, green certificates provide support in addition to the market price and are used as proof of compliance. A green certificate represents the value of the energy and facilitates trade in that value.

Some countries apply what is called technology banding: distributing different amounts of certificates according to the cost of a particular technology. This is to avoid that only the cheaper energy options are deployed. There are also examples of Governments that apply minimum/'floor' prices and sometimes prices are capped by the Government.
Quota systems with tradable certificates are used in Sweden, Poland, UK[10], Belgium[11] and Romania. Sometimes quota systems are combined with other support schemes.

Approach to monetisation

Intervention	Renewable energy quotas with tradable certificates
Tier I	Take the total value of the intervention (per energy technology) from national accounts or reports from Government. Tier I approach was followed for Belgium.
Tier II	The total annual values of this intervention can be calculated on the basis of average annual certificate prices and the total annual volume of certificates that have been traded (or value of certificates issued). The corresponding formula is: *Intervention (€/year) = Average annual price of traded certificates (€/MWh or €/certificate)) * value of certificates issued (MWh or # of certificates).* A Tier II approach was followed for Poland, Romania, Sweden and the UK. The country experts provided Ecofys with the average annual prices of traded certificates and the value of certificates issues (volume). The country experts derived these data from official reports from Government, energy regulators and national agencies. Ecofys calculated the total value of the intervention using these data and the above formula.

[10] The UK is in the process of replacing its quota system with a (floating) premium system (CfD).
[11] Belgium is in the process of replacing its quota system with a premium system.

A2.4.4 Support schemes for fossil and nuclear electricity production

For fossil and nuclear energy conversion technologies similar support schemes can be applied as for renewable electricity (RES-E).

Intervention	Support schemes for fossil and nuclear electricity production
Tier I	Take annual expenditure from national balance sheets if available. Alternative sources are national reports on the operation of the support scheme from the regulator or Government
Tier II	Interventions for any given technology can be quantified as *Intervention (€) = specific production support (€/MWh) * production (MWh)* For quota obligations: • *Description of quota scheme (quota, terms, other parameters);* • *Historic prices or levies per default technology under the scheme, 2000 – 2012 in €/MWh (and/or €/GJ);* • *Value of quota in terms of final energy.*

A2.4.5 Free allocation of emission allowances in the EU ETS in phase II (2008 - 2012)

Background

In the context of the EU ETS, installations in the manufacturing and power sector received free allocation of emission allowances during Phase I (2008 - 2012). The allowances were grandfathered on the basis of historic emissions. Annually, industry and the power producers received in total about two billion EU emissions allowances (EUAs).

Approach to monetisation

The value of the free annual allocation declined from 38 to 14 billion Euros per year in the period 2008 – 2012 due to declining CO_2 prices[12]. The amount of allowances is monetised on the basis of the annual average EUA prices in the respective years shown in the table below.

Intervention	Free allocation of ETS allowances
Tier I	Not applicable
Tier II	Intervention (€) = # of free allowances in year (tCO_2) * EUA price in year (€/tCO_2) Annual average EUA prices (€/tCO_2) were taken from EC (2014), Impact Assessment Carbon Leakage list 2015 - 2019 and are listed below.

Year	2008	2009	2010	2011	2012
EUA price (€/tCO_2)	19.41	14.04	13.67	10.78	6.67

[12] This is expected to drop further because since 2013 free allocation is mainly limited to sectors with risk of carbon leakage and in general the power sector does not receive free allocation anymore.

A2.4.6 Production tax incentives

Background

Production tax incentives provide a similar function as investment tax incentives. However, production incentives are linked to each unit of energy production, rather than to the investment cost. Allowances or credits could be supplied for the production of primary fuels or power, and therefore are measured per MJ for fuels or per kWh for electricity.

Approach to monetisation

Production tax allowances result in foregone tax receipts for the tax payer, and effective subsidies to the recipient firms. As such, they are usually not be included in national accounts, but as they have a direct link to a production measure, there should be some record of their size.

Intervention	Production tax incentives
Tier I	Take revenue foregone from national balance sheets.
Tier II	For any given technology the intervention in any given year is monetised as follows: For tax credits: *Intervention (€) = Production (MWh/GJ) * production tax credit ((*€ per MWh/GJ*)* For tax allowances: *Intervention (€) = Production (MWh/GJ) * production tax allowance ((*€ per MWh/GJ*) * regular tariff for corporation tax (%)*

A2.4.7 Royalty exemption

Background

Royalty exemption is where a project or firm is provided with an exemption from paying royalties on energy production. This type of benefit is typically associated with primary energy production where royalty payments are made to the treasury to compensate the country for extraction and use of its resources. They can also apply to electricity generation. The exemptions are therefore typically quoted in production quantities, i.e. m^3 of natural gas, barrels of oil, MJ or kWh of heat and/or electricity.

Approach to monetisation

Royalty exemption results in foregone tax receipts for the tax payer, compared to what would have been received. In the period 2008 - 2012, we expect these to be insignificant.

Intervention	Royalty exemptions
Tier I	Take revenue foregone from national balance sheets.
Tier II	Not applicable.

A2.4.8 Support to stranded assets

Background

Stranded asset is a financial term that describes an asset that has become obsolete or non-performing, but must be recorded on the balance sheet as a loss of profit. In the EU an increasing number of recently built gas power plants have, or may become, stranded assets, and face either closure or mothballing.

Generation assets become uneconomic to operate when their marginal cost of generation exceeds the price of electricity over an extended period of time. Currently, many gas-fired have a poorer competitive position compared to coal plants, following the recent drop in coal prices, low carbon prices and lower electricity consumption in general.

We define public support to stranded assets here as any financial help provided on an ad-hoc basis to stranded energy assets, notably gas-fired electricity generation capacity. As such, it differs from capacity mechanisms, which are based on a regulation and therefore result in more predictable support levels.

Approach to monetisation

Intervention	Support to stranded assets
Tier I	Take total annual expenditures per energy technology from national balance sheets. National reports from regulators may be an alternative source
Tier II	Not applicable

A2.4.9 Capacity payments in electricity markets

Background

In general, payments on the EU's electricity markets are based on the energy provided. In wholesale markets, prices reflect the marginal costs of additional energy production, i.e. the theoretical costs to produce one more unit of energy. Marginal costs of production include mainly fuel costs. If payments for electricity production are only distributed by generated electricity ("energy only market"), generators with high fuel costs may run into financial problems. While power plants with low fuel costs can recover their capital costs when prices exceed their marginal costs, those "peak" power plants may not be able to refinance their investment costs. Excess generation capacity in the market tightens the situation for all power plants because peak prices become rare.

At the same time, excess capacity is needed as a back-up reserve for unexpected system failures, or insufficient production from renewable energy sources to secure adequacy of supply at each point in time. Some Member States have decided to set up capacity payments for generators to refinance investment costs. Depending on the market design, these payments can be granted to all market players ("comprehensive capacity market") or for a limited amount of capacity that is not allowed to take part in the energy only market ("strategic reserve").

In contrast to compensation for stranded assets, capacity payments are designed to implement a new market balance with a defined amount of secured capacity. They are no ad hoc payments for short term back-up capacity, but long term regulation with no date of termination.

Approach to monetisation

The state intervention can be quantified by simply multiplying the contracted capacity and the average payment per amount of capacity.

Intervention	Investment grants
Tier I	Annual expenditure from national balance sheets.
Tier II	Not applicable

A2.4.10 Support to decommissioning and waste disposal

Background

Decommissioning and rehabilitation costs for plants are in the most cases included in the financial planning of the operator e.g. for nuclear they must put aside funds to cover eventual costs of decommissioning and waste disposal. In certain cases (e.g. nuclear, lignite mining), the Government have picked up the costs associated with historic activities. Note that funds set aside for decommissioning do not always cover the full cost of decommissioning and waste disposal. This implies a subsidy, and we assess this in section A2.3 of this annex.

Approach to monetisation

Figures are taken from national balance sheets and other official reports. Only a tier I approach is followed.

Intervention	**Support to decommissioning and waste disposal**
Tier I	Annual payments from national balance sheets
Tier II	Not applicable

A2.4.11 Exemptions from fuel taxes

Background

Fuels are taxed for a number of reasons, including providing an incentive for energy saving. If the fuels are converted to other energy carriers (e.g. electricity, petrol) which in turn are taxed, any exemption or reduction is not be calculated at the level of the primary but at the level of the secondary energy carrier. In other words, they are not be considered as an exemption/reduction for coal. As heat is not taxed by additional energy taxes, exemptions from fuel taxes for CHP are covered by this chapter.

Some Member States reduce or abolish the energy tax on energy from certain sources, especially, from renewable energy sources. The production of energy from these sources becomes more attractive.

Approach to monetisation

The amount of fuel that is subject to reduced rates can be multiplied by the general rate of the tax. If demand data is not available at a detailed level, estimations have to be done by taking into account the values from Eurostat (nrg_105a). Differences between actual and maximum tariff are defined as public intervention in this study.

Intervention	**Exemptions from fuel taxes**
Tier I	Take total annual expenditures per energy technology from national balance sheets.
Tier II	Support in any given year can be monetised as *Intervention (€) = (General fuel tax tariff (€/GJ) – applicable fuel tax tariff (€/GJ)) * fuel consumption (GJ)*
Tier III	Qualitative description by country expert.

A2.4.12 Support to social costs of closures of fossil operations

Background

If fossil fuel operations are closed during the transition to a sustainable energy system, regulations may be put in place to mitigate the social impacts, notably related to unemployment. Should this occur, we anticipate that such support is explicitly reported by Governments and OECD, and no alternative method is needed.

Approach to monetisation

Intervention	R&D grants
Tier I	Take total annual expenditures per energy technology from national balance sheets.
Tier II	Not applicable

A2.5 Support to energy demand

A2.5.1 Interruptible load schemes

Background

In several countries, there are interruptible load schemes that provide payment to electricity consumers that agree to be switched off remotely where there is a danger of system black outs. These schemes are implemented additional to balancing markets. Participants have to meet high standards to take part. These prequalification standards only apply to energy intensive industries. The payments for capacity are tendered in an auction, but because of the low number of eligible participants, the result of the auction often hits the maximum price limit.

Approach to monetisation

The applicable costs of grid services in interruptible load schemes are the “value of lost load”. This value depends on the process and the product of the participating industrial consumers. If the production can be caught up, costs are very low. It is not feasible to calculate this value of lost load for the participating companies as their names are not disclosed to the public.

Three interruptible load schemes have been reported, in Spain, Germany and Italy. The German one started in 2013 and there have been no payments before. In Italy, payments have started in 2011, but there is no data available about actual payments and contracted capacity. Additionally, there are interruptible load schemes at least in Spain and Slovenia, but there is no public information on actual payments.

Payments are organised via the transmission system operators. They do not appear on national balance sheets. Tier I is not applicable. Tier II would require information about participants, which is not disclosed to public. Tier III is used, where possible.

Intervention	Interruptible load schemes
Tier I	Not applicable
Tier II	Calculate payments from information about participants and payments per unit.
Tier III	Calculate maximum payment by multiplying maximum amount to be contracted and price limit.

A2.5.2 Exemptions from value added taxes (VAT)

Background
Electricity is an input factor for production. For industrial customers, VAT payments are refundable. In households, electricity is required to serve the basic needs. Therefore, in some countries, a reduced rate is applied to the electricity consumption of households. There is some discussion in literature whether this should be classified as a subsidy. We assume it is if there is a difference between the general level of VAT and that on energy.

Approach to monetisation
The amount of electricity that is subject to reduced rates can be multiplied by the general rate of VAT. Differences for payments are defined as state intervention in this study.

Intervention	Exemptions from value added taxes (VAT)
Tier I	Take annual revenue foregone from national balance sheets
Tier II	Support to any given end-user group in a given year can be calculated as *Intervention (€) = (regular VAT (%) – reduced VAT (%)) * energy consumption (MWh) * retail price (€/MWh)* Note: we use retail price because in general VAT is applied to taxes and levies as well

A2.5.3 Exemptions from energy taxes

Background
Energy is taxed for a variety of reasons, including as an incentive to energy saving. Certain customer groups can be exempted from taxes for social reasons. Some industrial customers might be exempted because of other energy efficiency measures, e.g. sector specific demand reduction targets. There are countries where all customers get some form of compensation to lift the financial burden.

Approach to monetisation
The amount of energy that is subject to reduced rates can be multiplied by the general rate of the tax. If demand data is not available at a detailed level, estimations have to be done by taking into account the values from Eurostat (nrg_105a).
Differences between the actual and general tariff are defined as state intervention in this study. In some cases, reduced tariffs or exempted parties are not disclosed to public. In these cases, there is only a tier III qualitative assessment based on the insights from the country experts.

Intervention	Exemptions from energy taxes
Tier I	Take annual revenue foregone from national balance sheets
Tier II	For any given enduser group support in any given year can be monetised as For electricity: *Intervention (€) = (Highest energy tax tariff (€/kWh) – applicable energy tax tariff (€/kWh)) * electricity consumption (kWh)* For natural gas: *Intervention (€) = (Highest energy tax tariff (€/GJ) – applicable energy tax tariff (€/GJ)) **

Intervention	Exemptions from energy taxes
	natural gas consumption (GJ) For coal: *Intervention (€) = (Highest energy tax tariff (€/GJ) – applicable energy tax tariff (€/GJ)) * coal consumption (GJ)* For heat: *Intervention (€) = (Highest energy tax tariff (€/GJ) – applicable energy tax tariff (€/gJ)) * heat consumption (GJ)*
Tier III	Qualitative assessment based on insights from the country experts

A2.5.4 Exemptions from other taxes and levies

Background

There are several Member State specific taxes and levies to finance other electricity related costs and to support generation from renewable energy sources. Specific customers are exempted from these payments. These exemptions most often apply to large consumers such as the energy intensive industry or customers that are defined as 'poor'. Some Member States also put a limit on the grid fee and concession fee payments for specific customers. These reductions are mainly granted to energy intensive industries and industrial customers with specific characteristics.

Approach to monetisation

The maximum tariff is multiplied by the total amount of electricity consumption and compared to the actual payment. The reduction in grid fees is granted compared to a defined benchmark, e.g. disclosed grid fees. The value of reduction is quantified by the grid operators to support their demand for compensation. Concession fees differ per region: they depend on the municipality and are not centrally published.

Intervention	Other taxes and levies
Tier I	Take annual revenue foregone from national balance sheets
Tier II	*Intervention (€) = (General energy tax tariff (€/unit) – applicable energy tax tariff (€/unit)) * energy consumption (unit)*
Tier III	Qualitative assessment based on insights from the country experts

A2.5.5 Price guarantee for fuels and electricity

Background

Price guarantees refer to measures that protect producers or consumers of energy by setting the price of fuels or electricity below or higher than a reference price. Examples of the first variant include social tariffs for electricity that protect certain target groups against too high burdens of energy costs in total household expenditures or the provision of fossil fuels as input to electricity generation below actual cost. The last example protects producers.
In case governments set prices higher than the market price one may speak of a negative subsidy. The country experts did not identify this type of subsidy in any of the EU Member States.

Approach to monetisation

Intervention	Price guarantee for electricity
Tier I	Take estimate straight from national balance sheet
Tier II	Intervention (€) = (marginal cost fuel/electricity (€/MWh) – regulated electricity/fuel price (€/MWh)) * electricity/fuel consumption (MWh)

A2.6 Support to energy savings

There are a wide variety of Government interventions to support energy savings including energy labelling, Ecodesign, building regulations and energy efficiency obligations. In case of regulations there will be an impact on the energy market, monetising these interventions without extensive modelling is not straightforward. In this study we include energy saving grants and subsidies, soft loans, loan guarantees and energy efficiency obligations.

A2.6.1 Energy saving grants and subsidies

Background
Investment grants (or subsidies) are typically provided by Governmental organisations and do not need to be repaid and require no payment of dividends. Grants are typically provided to projects that are not commercially feasible or bankable, or with high transaction costs. Sometimes the conditions of the grant may involve conversion into debt or equity in case of commercial success.

Energy saving grants reduce investment costs of energy efficiency measures. By means of grants, (parts of) investments are directly refunded. Often the refund is a fixed percentage of the initial investment.

Energy saving grants are used in all economic sectors but are most widely applied in the buildings sector to stimulate the uptake of energy saving technologies (e.g. energy efficient boilers, energy efficient electrical appliances) or stimulate investments in building renovation (e.g. home insulation). Grants are often addressed at the consumption of heat, for electricity consumptions financial measures are less widespread. The target audiences of such measures are house-owners, landlords, housing associations etc.

It is often Governments that initiate grants with the aim to help households keep their energy bills as low as possible, support those most in need and take action to help secure energy supplies in the long term. In addition to energy saving grants and subsidies, in some countries there are direct payments to households to help with energy costs e.g. winter fuel payments in the UK.

Approach to monetisation
In general, Member States report on grant amounts explicitly in national accounts (Tier I).

Intervention	Energy saving grants and subsidies
Tier I	Take total annual expenditure from national balance sheets.
Tier II	Member State calculations/estimate.

A2.6.2 Soft loans

Background

Soft loans have been introduced as in instrument to support investment. They are used frequently to finance energy efficiency projects and measures.

Approach to monetisation

Intervention	Soft loans
Tier I	Not applicable
Tier II	We calculate the volume of the intervention as the difference between the interest paid at commercial loan conditions minus the interest paid at the conditions of the soft or zero-interest loan. It turns out that Governments or (development) banks often report on the total volume of outstanding loans relating to a specific soft loan facility. From this information we quantify the intervention by calculating the total interest paid on the loan and annual payments on the loan (including both principal and interest) and then separately the interest paid on the loan: $$P_t = \frac{\mathrm{L} \cdot \mathrm{r} \quad \cdot (1+\mathrm{r})^n}{(1+\mathrm{r})^n - 1}$$ Where: P_t = annual payment incl payback and interest for any given loan in year t L = total of original loan (principal) (cumulative loans until view year) n = average debt term r = (annual) interest rate The total interest (R_{tot}) paid over the debt term equals the difference between the annual payments (including paybacks and interest) and the original loan: $$\mathrm{R}_{tot} = \sum_{t=1}^{n} \mathrm{P}_t - \mathrm{L}$$ For the average annual interest payments we divide by the average debt term *n*, which is believed to be an appropriate approximation of actual interest received. In a final step we calculate the Government intervention I as the difference between annual interest payments for a commercial loan and a soft loan: $$\mathrm{I} = \left(\mathrm{P}_{Com} - \frac{\mathrm{L}}{n_{Com}}\right) - \left(\mathrm{P}_{Pol} - \frac{\mathrm{L}}{n_{Pol}}\right)$$ Where: P_{com} = average annual payment for a commercial loan P_{pol} = average annual payment for a soft loan L = total of original loan (principal) (cumulative loans until view year) n = average debt term r = (annual) interest rate

A2.6.3 Energy efficiency obligations

Background

In an energy efficiency obligation, an energy supplier (or other entity) is given an obligation by the Government to achieve a certain level of savings (either in energy or in carbon). Often, these obligations include a social element requiring a certain proportion of the savings to be delivered in poorer households.

Approach to monetisation

Intervention	Energy efficiency obligations
Tier I	National reports with estimates of the support level, or the energy savings and specific costs (e.g. €/kWh of electricity or €/GJ of gas/heat).
Tier II	The approach is similar to the quantification of renewable energy quota systems and tradable certificates. We have quantified the subsidy volume as *Intervention (€) = Price white certificates (€/kWh) * value of white certificates issued (kWh)*

A2.6.4 Other

Background

The category 'Other' includes a variety of energy saving interventions. Among others, these interventions include for example, tax exemptions for investments in energy saving technologies or zero-energy buildings, VAT exemptions for investments in home insulation measures, energy saving advice and redemption of energy saving loans.

Approach to monetisation

Intervention	Energy efficiency other
Tier I	Data from national accounts or other national report
Tier II	Calculation or estimation by country expert

A2.7 Member State results for 2008 - 2012 interventions

A2.7.1 Summary tables of Member State interventions

In the tables below 0* indicates that there is a value but it is below the threshold for rounding. In case individual Member States reported EU level support, for example structural funds, the Member State value is set to zero to ensure that there is no double counting.

Table A2-1 Total support per Member State

	2008 (M€2012)	2009 (M€2012)	2010 (M€2012)	2011 (M€2012)	2012 (M€2012)
Austria	2,310	2,090	1,820	2,020	2,000
Belgium	2,410	2,710	3,050	3,110	3,280
Bulgaria	100	100	190	180	410
Croatia	0 *	10	10	20	30
Cyprus	20	0 *	10	20	20
Czech Republic	670	820	1,560	1,810	1,600
Denmark	100	320	990	1,000	1,210
Estonia	50	60	100	130	150
Finland	270	310	270	340	300
France	5,990	5,740	5,580	5,300	7,250
Germany	18,020	19,150	20,760	22,330	25,470
Greece	50	90	150	330	680
Hungary	300	360	430	530	620
Ireland	250	260	420	440	510
Italy	8,550	8,040	9,580	12,300	10,360
Latvia	120	150	140	160	220
Lithuania	210	330	340	310	330
Luxembourg	90	90	80	100	90
Malta	50	40	60	70	50
Netherlands	2,710	2,640	3,120	2,750	2,740
Poland	720	1,020	860	1,130	970
Portugal	510	700	970	790	790
Romania	490	470	550	730	680
Slovakia	130	250	340	570	590
Slovenia	60	60	80	90	100
Spain	4,480	7,480	8,470	8,580	10,430
Sweden	3,320	3,220	2,960	2,660	2,690
United Kingdom	10,580	10,190	12,300	11,570	13,280
EU-level	3,270	8,410	9,070	12,010	12,460
Total Member States (28) + EU-level support	**65,830**	**75,120**	**84,250**	**91,370**	**99,330**

Table A2-2 Total support per technology

Technologies	2008 (M€2012)	2009 (M€2012)	2010 (M€2012)	2011 (M€2012)	2012 (M€2012)
RE - Solar	3,430	6,410	9,180	14,580	14,730
RE - Wind offshore	40	130	550	1,140	1,360
RE - Wind onshore	5,700	6,810	7,560	7,930	10,120
RE - Wind Total	**5,740**	**6,930**	**8,110**	**9,070**	**11,480**
RE - Biomass	4,460	5,590	6,760	7,360	8,340
RE - Hydro	6,320	6,460	6,670	5,150	5,180
RE - Geothermal	190	190	170	180	70
RE - Other	940	910	980	750	1,020
RE - Total	**21,090**	**26,490**	**31,870**	**37,090**	**40,810**
FF - Coal	7,360	8,370	7,920	9,610	10,120
FF - Natural gas	3,930	4,970	5,150	5,370	5,190
FF - Oil products	0 *	0 *	0 *	0 *	0 *
FF - Other	130	170	360	200	40
Free allocation of EUAs	38,000	27,700	27,300	21,700	13,700
FF - Total	**11,430**	**13,510**	**13,430**	**15,180**	**15,350**
Heat pumps	40	30	30	10	0 *
Nuclear	3,650	5,380	5,430	6,120	6,960
Infrastructure	30	30	410	290	200
Support to energy demand	23,690	23,100	25,950	25,470	27,360
Support to energy savings	5,820	6,500	7,040	7,120	8,590
Total	**65,740**	**75,040**	**84,160**	**91,270**	**99,270**
Not specified	90	80	100	100	60
Grand Total	**65,830**	**75,120**	**84,250**	**91,370**	**99,330**
Free allocation of EUAs	38,000	27,700	27,300	21,700	13,700

Notes: Support to natural gas is largely for use in cogeneration or district heating. Support to coal is largely to production of coal. Note interventions in the household sector are often forms of grants for both renewable energy and energy savings. It has not been possible in all cases to separate these components, so some support to energy savings is also included in the total for renewables.

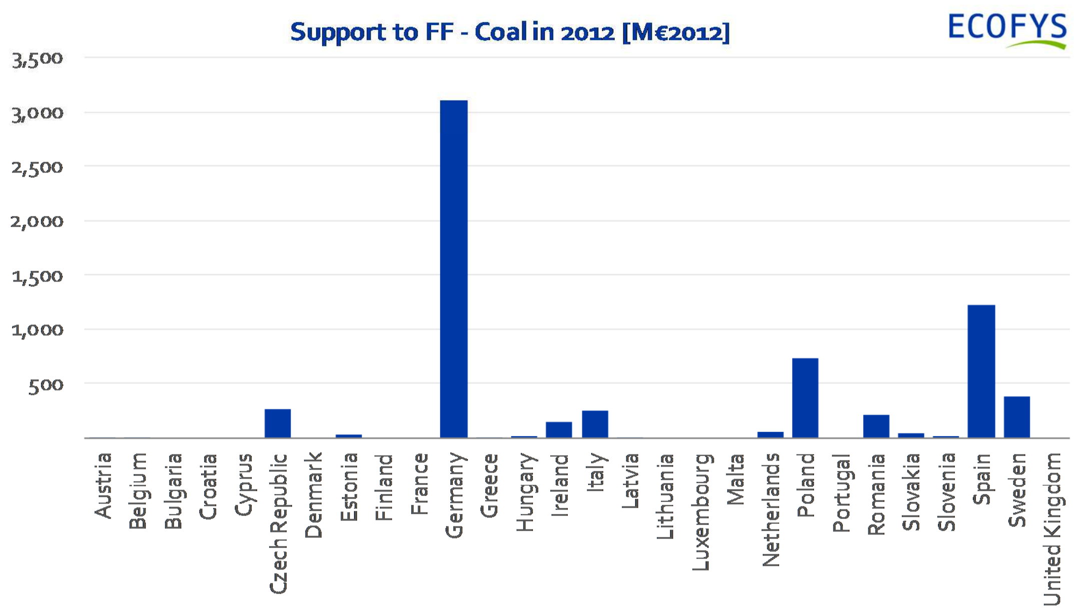
Table A2-3 Total support per sub category of intervention (note *indicates non-zero figures rounded to zero)

Main category	Interventions	No. of inter-ventions	Sum of interventions (M€2012) 2008 (M€2012)	2009 (M€2012)	2010 (M€2012)	2011 (M€2012)	2012 (M€2012)
Support for investment	Accelerated depreciation	5	0 *	20	0 *	0 *	10
	Differentiated grid connection charges	3	-	-	-	-	20
	Exemption from import duty	0	-	-	-	-	-
	Grants (investment)	130	3,950	9,420	9,940	12,680	13,050
	Investment tax allowance	14	4,130	3,050	2,960	1,920	1,500
	Investment tax credits	0	-	-	-	-	-
	Property tax abatement	1	0 *	0 *	0 *	0 *	0 *
	Soft loans (investment)	26	80	100	120	90	70
	Other (not listed) [Inv]	7	10	10	20	20	20
Support to energy demand	Exemptions from energy taxes	60	12,280	12,100	13,410	11,820	12,100
	Exemptions other taxes and levies	9	1,520	1,570	1,810	2,850	3,430
	Exemptions value added taxes (VAT)	16	5,270	4,580	5,650	6,010	7,090
	Interruptible load schemes	3	230	390	400	1,300	1,260
	Price guarantees for electricity	4	70	70	70	70	80
	Other (not listed) [Dem]	26	4,310	4,400	4,610	3,420	3,390
Support to energy savings	Energy efficiency obligation	5	110	230	450	500	1,940
	Energy saving grants and subsidies	63	5,600	6,010	6,380	6,500	6,560
	Loan guarantees	0	-	-	-	-	-
	Soft loans (energy savings)	10	0 *	130	50	10	0 *
	Other (not listed) [Sav]	11	120	130	150	120	90
Support to production	Capacity payments in electricity markets	1	10	20	10	30	30
	Exemptions from fuel taxes	13	3,210	3,400	3,360	3,060	3,060
	Feed-in premiums	47	2,750	2,880	4,370	5,600	6,650
	Feed-in tariffs	107	14,820	18,680	21,410	24,850	26,960
	Price guarantees for district heating	0	-	-	-	-	-
	Production tax allowance	7	50	50	50	50	50
	Production tax credits	4	-	-	0 *	0 *	0 *
	Renewable energy quotas with tradable certificates	25	990	1,260	2,550	3,040	3,930
	Royalty exemption	1	0 *	0 *	0 *	0 *	0 *
	Subsidised cooling water	0	-	-	-	-	-
	Support to decommissioning and waste disposal	13	4,140	3,820	3,800	3,840	4,330
	Support to fossil or nuclear electricity production	12	590	640	650	1,350	1,590
	Support to social costs of industry restructuring	8	380	460	360	360	360
	Support to stranded assets	4	500	570	350	530	200
	Tax allowances for decommissioning and remediation	0	-	-	-	-	-
	Tax credits for decommissioning and remediation	0	-	-	-	-	-
	Underwriting insurance nuclear	1	10	10	10	10	10
	Other (not listed) [Prod]	16	140	570	670	670	840
Support to R&D	Government provided R&D facilities and transfer of IP	3	20	20	30	30	30
	Grants (R&D)	50	550	500	590	650	690
	Tax allowance for R&D	3	0 *	0 *	0 *	0 *	0 *
	Tax credits for R&D	4	10	10	10	0 *	10
	Other (not listed) [R&D]	1	-	-	-	-	-
	EU28 Total + EU-level	**713**	**65,830**	**75,120**	**84,250**	**91,370**	**99,330**

A2.7.2 Figures total subsidies per fuel per Member State 2008 - 2012

Note in the figures below there are data gaps in some of the time series and this should be considered when analysis trends.

Support to FF - Coal (M€2012)	2008	2009	2010	2011	2012
Austria	0 *	0 *	0 *	0 *	0 *
Belgium	10	0 *	0 *	0 *	0 *
Bulgaria	-	-	-	-	-
Croatia	-	-	-	-	-
Cyprus	-	-	-	-	-
Czech Republic	260	360	280	300	260
Denmark	-	-	-	-	-
Estonia	10	30	30	30	40
Finland	-	-	-	-	-
France	10	10	-	-	-
Germany	3,780	3,360	3,250	3,240	3,100
Greece	0 *	0 *	0 *	0 *	0 *
Hungary	-	-	-	-	20
Ireland	20	10	70	110	150
Italy	440	280	250	210	250
Latvia	0 *	0 *	0 *	0 *	0 *
Lithuania	0 *	-	-	-	-
Luxembourg	-	-	-	-	-
Malta	-	-	-	-	-
Netherlands	40	50	70	50	50
Poland	680	920	760	980	730
Portugal	-	-	-	-	-
Romania	110	80	60	150	210
Slovakia	60	60	70	70	50
Slovenia	30	30	20	20	20
Spain	450	490	480	990	1,220
Sweden	530	380	340	340	380
United Kingdom	-	-	-	-	-
EU level support	*930*	*2,300*	*2,220*	*3,100*	*3,630*
EU28 Total+EU-level	**7,360**	**8,370**	**7,920**	**9,610**	**10,120**

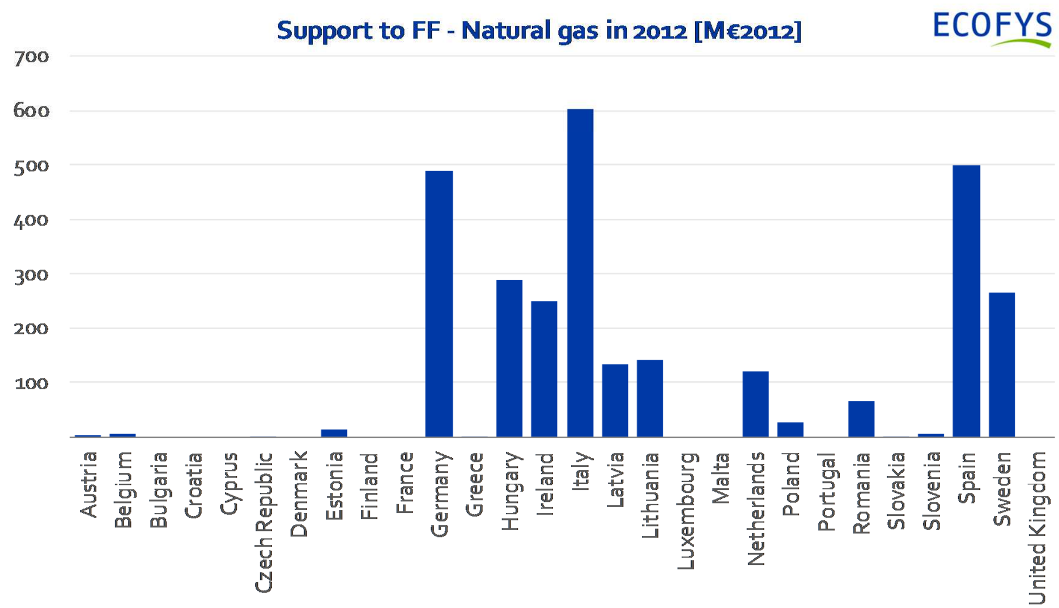


Note: EU level support is not shown in the graph

Figure A2-1 Support to FF-Coal (M€2012)

Note * indicates non-zero figures rounded to zero.

Support to FF - Natural gas (M€2012)					
	2008	2009	2010	2011	2012
Austria	10	10	10	10	0 *
Belgium	20	20	20	20	10
Bulgaria	-	-	-	-	-
Croatia	-	-	-	-	-
Cyprus	-	-	-	-	-
Czech Republic	0 *	0 *	0 *	0 *	0 *
Denmark	-	-	-	-	-
Estonia	30	10	20	20	10
Finland	-	-	-	-	-
France	10	10	-	-	-
Germany	550	570	590	570	490
Greece	0 *	0 *	0 *	0 *	0 *
Hungary	130	140	140	220	290
Ireland	40	30	200	230	250
Italy	1,570	930	850	610	600
Latvia	70	90	90	90	130
Lithuania	100	170	130	110	140
Luxembourg	-	-	-	-	-
Malta	-	-	-	-	-
Netherlands	100	130	200	140	120
Poland	20	30	20	30	30
Portugal	-	-	-	-	-
Romania	0 *	0 *	0 *	50	70
Slovakia	0 *	0 *	0 *	0 *	0 *
Slovenia	0 *	0 *	10	10	10
Spain	380	470	540	520	500
Sweden	140	360	370	270	270
United Kingdom	-	-	-	-	-
EU level support	*780*	*1,990*	*1,960*	*2,470*	*2,270*
EU28 Total+EU-level	**3,930**	**4,970**	**5,150**	**5,370**	**5,190**

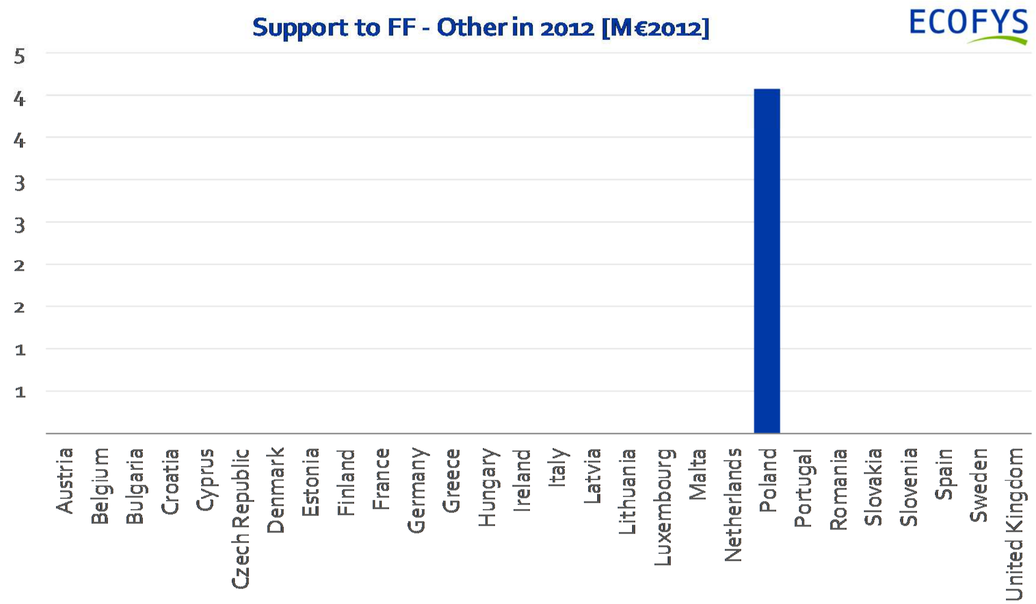


Note: EU level support is not shown in the graph

Note * indicates non-zero figures rounded to zero. Figures for Italy and Spain are high due to the fact that also CHP related interventions are included.

Figure A2-2 : Support to FF – Natural gas (M€2012)

Support to FF - Other (M€2012)	2008	2009	2010	2011	2012
Austria	-	-	-	-	-
Belgium	-	-	-	-	-
Bulgaria	-	-	-	-	-
Croatia	-	-	-	-	-
Cyprus	-	-	-	-	-
Czech Republic	-	-	-	-	-
Denmark	-	-	-	-	-
Estonia	-	-	-	-	-
Finland	-	-	-	-	-
France	-	-	-	-	-
Germany	-	-	-	-	-
Greece	-	-	-	-	-
Hungary	-	-	-	-	-
Ireland	-	-	-	-	-
Italy	-	-	-	-	-
Latvia	-	-	-	-	-
Lithuania	-	-	-	-	-
Luxembourg	-	-	-	-	-
Malta	-	-	-	-	-
Netherlands	-	-	-	-	-
Poland	-	-	-	0 *	0 *
Portugal	-	-	-	-	-
Romania	-	-	-	-	-
Slovakia	-	-	-	-	-
Slovenia	-	-	-	-	-
Spain	-	-	-	-	-
Sweden	130	170	160	-	-
United Kingdom	-	-	-	-	-
EU level support	-	-	*200*	*190*	*40*
EU28 Total+EU-level	**130**	**170**	**360**	**200**	**40**

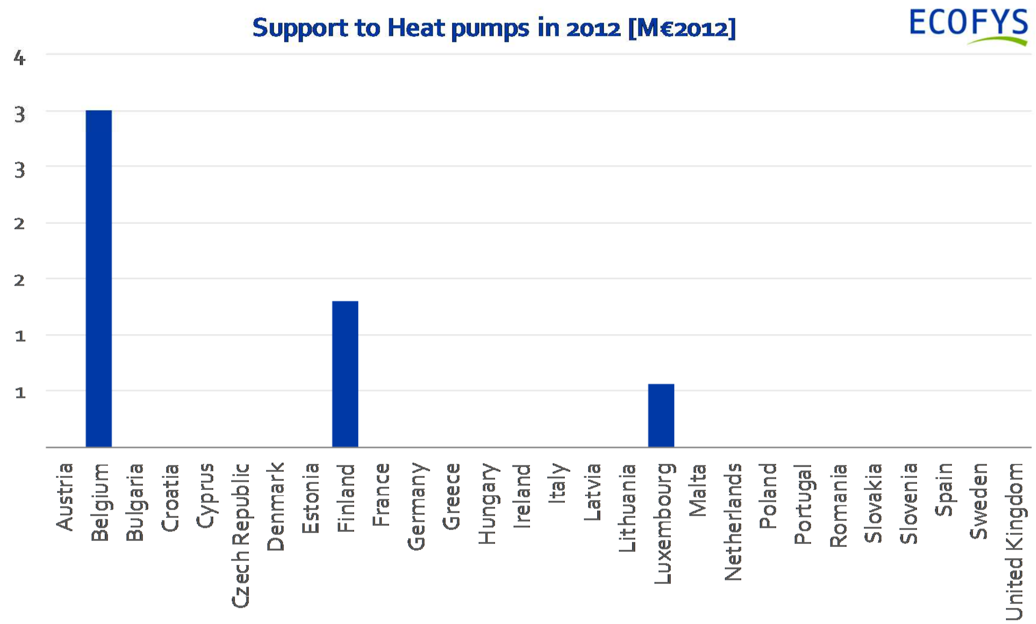


Note: EU level support is not shown in the graph

Note * indicates non-zero figures rounded to zero. Fossil fuel other largely refers to peat.

Figure A2-3 : Support to FF – Other (M€2012)

Support to Heat pumps (M€2012)					
	2008	2009	2010	2011	2012
Austria	-	-	-	-	-
Belgium	-	-	-	0 *	0 *
Bulgaria	-	-	-	-	-
Croatia	-	-	-	-	-
Cyprus	-	-	-	-	-
Czech Republic	-	-	-	-	-
Denmark	-	-	-	-	-
Estonia	-	-	-	-	-
Finland	0 *	0 *	0 *	0 *	0 *
France	-	-	-	-	-
Germany	-	-	-	-	-
Greece	-	-	-	-	-
Hungary	-	-	-	-	-
Ireland	20	10	10	0 *	-
Italy	-	-	-	-	-
Latvia	-	-	-	-	-
Lithuania	-	-	-	-	-
Luxembourg	0 *	0 *	0 *	0 *	0 *
Malta	-	-	-	-	-
Netherlands	20	20	20	-	-
Poland	-	-	-	-	-
Portugal	-	-	-	-	-
Romania	-	-	-	-	-
Slovakia	-	-	-	-	-
Slovenia	-	-	-	-	-
Spain	-	-	-	-	-
Sweden	-	-	-	-	-
United Kingdom	-	-	-	-	-
EU level support	-	-	-	-	-
EU28 Total+EU-level	**40**	**30**	**30**	**10**	**0 ***

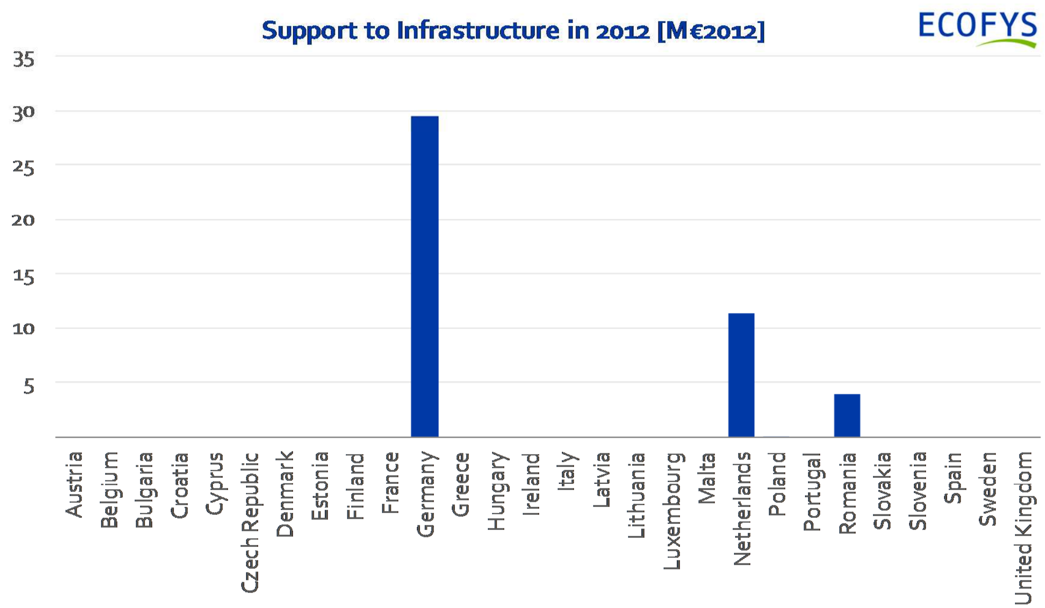


Note: EU level support is not shown in the graph

Note * indicates non-zero figures rounded to zero.

Figure A2-4 : Support to Heat Pumps (M€2012)

Support to Infrastructure (M€2012)					
	2008	2009	2010	2011	2012
Austria	-	-	-	-	-
Belgium	-	-	-	-	-
Bulgaria	-	-	-	-	-
Croatia	-	-	-	-	-
Cyprus	-	-	-	-	-
Czech Republic	-	-	-	-	-
Denmark	-	-	-	-	-
Estonia	-	-	-	-	-
Finland	-	-	-	-	-
France	-	-	-	-	-
Germany	-	0 *	10	30	30
Greece	-	-	-	-	-
Hungary	-	-	-	-	-
Ireland	-	-	-	-	-
Italy	-	-	-	-	-
Latvia	-	-	-	-	-
Lithuania	-	-	-	-	-
Luxembourg	-	-	-	-	-
Malta	-	-	-	-	-
Netherlands	10	-	-	20	10
Poland	-	-	-	0 *	0 *
Portugal	-	-	-	-	-
Romania	-	-	-	0 *	0 *
Slovakia	-	-	-	-	-
Slovenia	-	-	-	-	-
Spain	-	-	-	-	-
Sweden	-	-	-	-	-
United Kingdom	-	-	-	-	-
EU level support	*20*	*20*	*400*	*250*	*150*
EU28 Total+EU-level	**30**	**30**	**410**	**290**	**200**

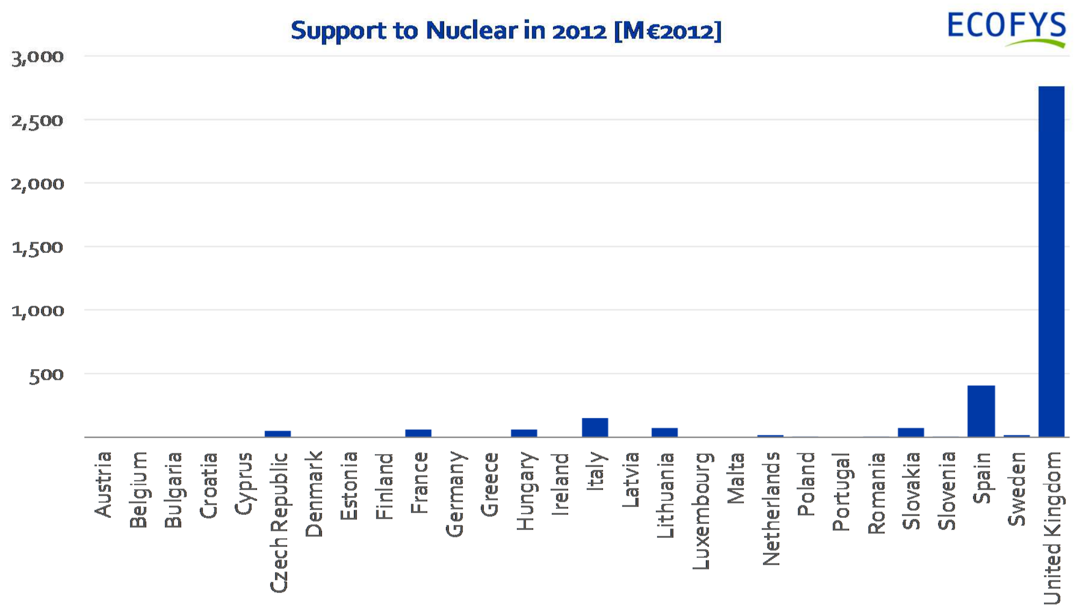


Note: EU level support is not shown in the graph

Note * indicates non-zero figures rounded to zero.

Figure A2-5 : Support to Infrastructure (M€2012)

Support to Nuclear (M€2012)	2008	2009	2010	2011	2012
Austria	-	-	-	-	-
Belgium	-	-	-	-	-
Bulgaria	-	-	-	-	-
Croatia	-	-	-	-	-
Cyprus	-	-	-	-	-
Czech Republic	30	40	50	50	50
Denmark	-	-	-	-	-
Estonia	-	-	-	-	-
Finland	-	-	-	-	-
France	170	220	70	60	60
Germany	-	-	-	-	-
Greece	-	-	-	-	-
Hungary	90	90	80	80	70
Ireland	-	-	-	-	-
Italy	280	290	420	260	150
Latvia	-	-	-	-	-
Lithuania	40	110	120	100	80
Luxembourg	-	-	-	-	-
Malta	-	-	-	-	-
Netherlands	20	20	20	20	20
Poland	-	-	-	-	0 *
Portugal	-	-	-	-	-
Romania	0 *	0 *	0 *	0 *	0 *
Slovakia	0 *	0 *	0 *	70	70
Slovenia	0 *	0 *	0 *	0 *	0 *
Spain	150	200	290	290	400
Sweden	30	20	20	20	20
United Kingdom	1,910	2,020	2,060	2,110	2,770
EU level support	*920*	*2,360*	*2,280*	*3,050*	*3,260*
EU28 Total+EU-level	**3,650**	**5,380**	**5,430**	**6,120**	**6,960**

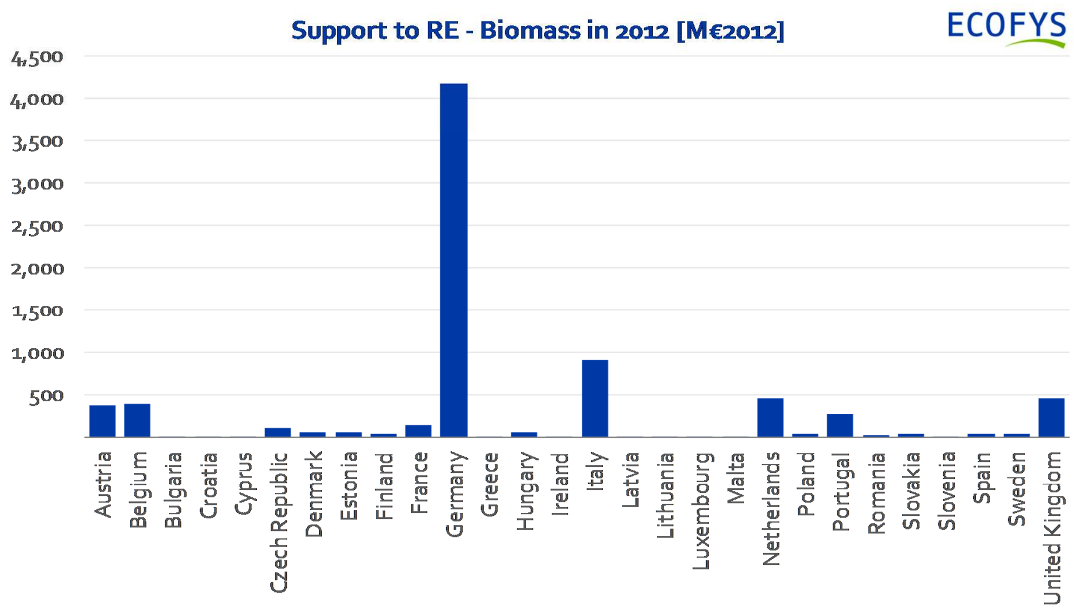


Note: EU level support is not shown in the graph

Note * indicates non-zero figures rounded to zero. UK figures include military nuclear legacy as well as power.

Figure A2-6 : Support to Nuclear (M€2012)

Support to RE - Biomass (M€2012)	2008	2009	2010	2011	2012
Austria	380	370	380	370	380
Belgium	110	240	320	380	400
Bulgaria	-	0 *	0 *	0 *	0 *
Croatia	0 *	0 *	0 *	0 *	0 *
Cyprus	0 *	0 *	0 *	0 *	0 *
Czech Republic	50	50	90	100	110
Denmark	20	20	30	40	50
Estonia	0 *	20	30	50	60
Finland	30	50	40	60	40
France	210	200	200	170	140
Germany	2,160	3,010	3,340	3,450	4,180
Greece	0 *	0 *	0 *	0 *	0 *
Hungary	60	70	70	70	60
Ireland	10	0 *	0 *	0 *	0 *
Italy	480	530	710	920	920
Latvia	0 *	0 *	0 *	0 *	10
Lithuania	20	0 *	0 *	10	10
Luxembourg	10	10	10	10	10
Malta	-	-	0 *	0 *	0 *
Netherlands	390	360	470	490	460
Poland	10	40	40	50	50
Portugal	190	210	260	260	270
Romania	0 *	0 *	10	10	20
Slovakia	0 *	0 *	0 *	30	50
Slovenia	10	10	10	10	10
Spain	10	20	30	30	40
Sweden	50	60	70	50	40
United Kingdom	140	10	320	320	460
EU level support	*100*	*300*	*320*	*470*	*590*
EU28 Total+EU-level	**4,460**	**5,590**	**6,760**	**7,360**	**8,340**



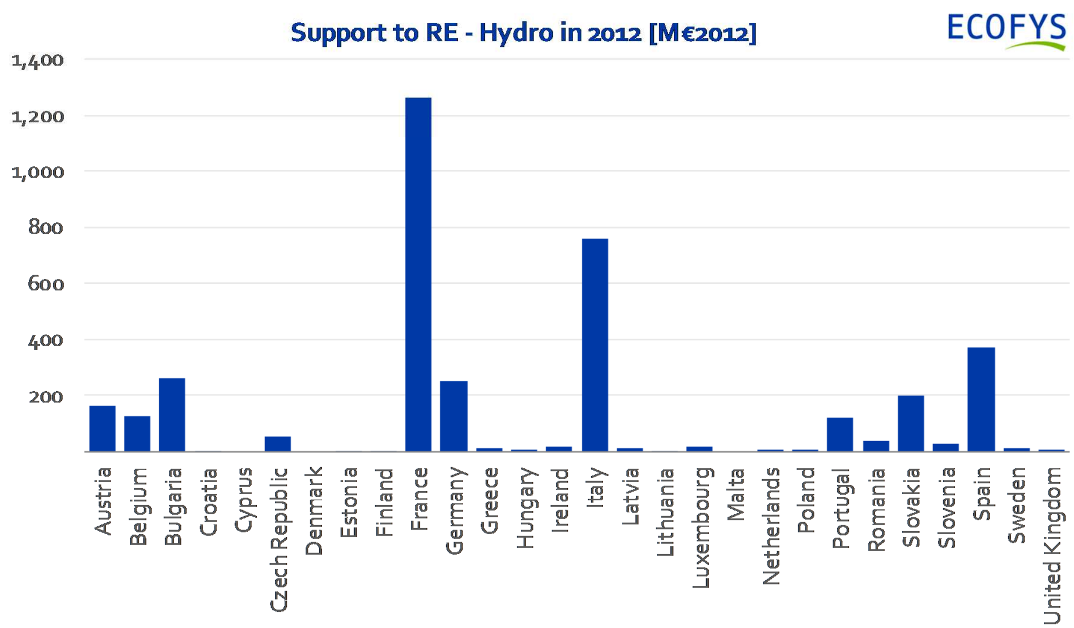
Note: EU level support is not shown in the graph

Note * indicates non-zero figures rounded to zero, a low volume of tradable certificates was reported in 2009 in the UK.

Figure A2-7 : Support to RE – Biomass (M€2012)

Support to RE - Hydro (M€2012)	2008	2009	2010	2011	2012
Austria	150	150	180	180	170
Belgium	60	110	120	120	130
Bulgaria	30	60	110	90	260
Croatia	0 *	0 *	0 *	0 *	0 *
Cyprus	-	-	-	-	-
Czech Republic	30	20	60	50	50
Denmark	-	-	-	-	-
Estonia	0 *	0 *	0 *	0 *	0 *
Finland	0 *	0 *	10	0 *	0 *
France	3,520	2,780	2,500	1,500	1,260
Germany	270	320	310	160	250
Greece	0 *	20	20	10	10
Hungary	0 *	0 *	0 *	10	10
Ireland	40	30	20	10	20
Italy	1,380	1,280	1,260	960	760
Latvia	10	20	10	20	10
Lithuania	-	-	-	0 *	0 *
Luxembourg	20	20	10	20	20
Malta	-	-	-	-	-
Netherlands	10	10	10	0 *	10
Poland	10	20	20	20	10
Portugal	160	200	350	200	120
Romania	10	10	20	10	40
Slovakia	10	10	40	150	200
Slovenia	20	10	30	20	30
Spain	230	360	530	390	370
Sweden	10	10	20	10	10
United Kingdom	-	-	-	0 *	10
EU level support	*370*	*1,000*	*1,050*	*1,190*	*1,420*
EU28 Total+EU-level	**6,320**	**6,460**	**6,670**	**5,150**	**5,180**

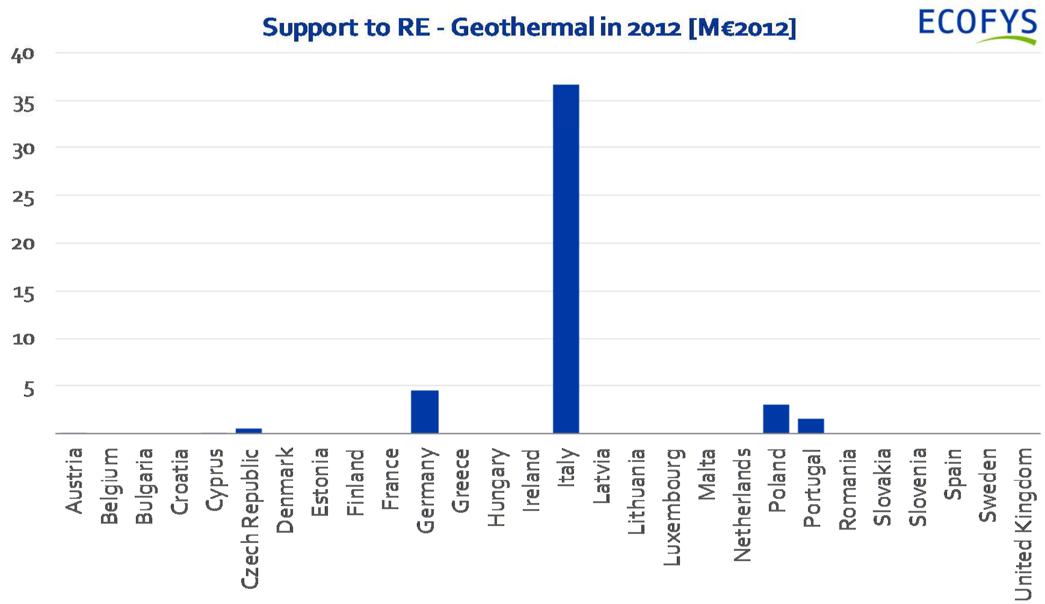
Note * indicates non-zero figures rounded to zero.



Note: EU level support is not shown in the graph

Figure A2-8 : Support to RE – Hydro (M€2012)

Support to RE - Geothermal (M€2012)	2008	2009	2010	2011	2012
Austria	0 *	0 *	0 *	0 *	0 *
Belgium	-	-	-	-	-
Bulgaria	-	-	-	-	-
Croatia	-	-	-	-	-
Cyprus	-	-	-	-	0 *
Czech Republic	0 *	0 *	0 *	0 *	0 *
Denmark	-	-	-	-	-
Estonia	-	-	-	-	-
Finland	-	-	-	-	-
France	-	-	-	-	-
Germany	0 *	0 *	0 *	0 *	0 *
Greece	-	-	-	-	-
Hungary	-	-	-	-	-
Ireland	-	-	-	-	-
Italy	160	150	130	150	40
Latvia	-	-	-	-	-
Lithuania	-	-	-	-	-
Luxembourg	-	-	-	-	-
Malta	-	-	-	-	-
Netherlands	20	20	10	10	-
Poland	-	-	-	0 *	0 *
Portugal	-	-	0 *	0 *	0 *
Romania	-	-	-	-	-
Slovakia	-	-	-	-	-
Slovenia	-	-	-	-	-
Spain	-	0 *	0 *	-	-
Sweden	-	-	-	-	-
United Kingdom	-	-	-	-	-
EU level support	*10*	*10*	*10*	*20*	*20*
EU28 Total+EU-level	**190**	**190**	**170**	**180**	**70**

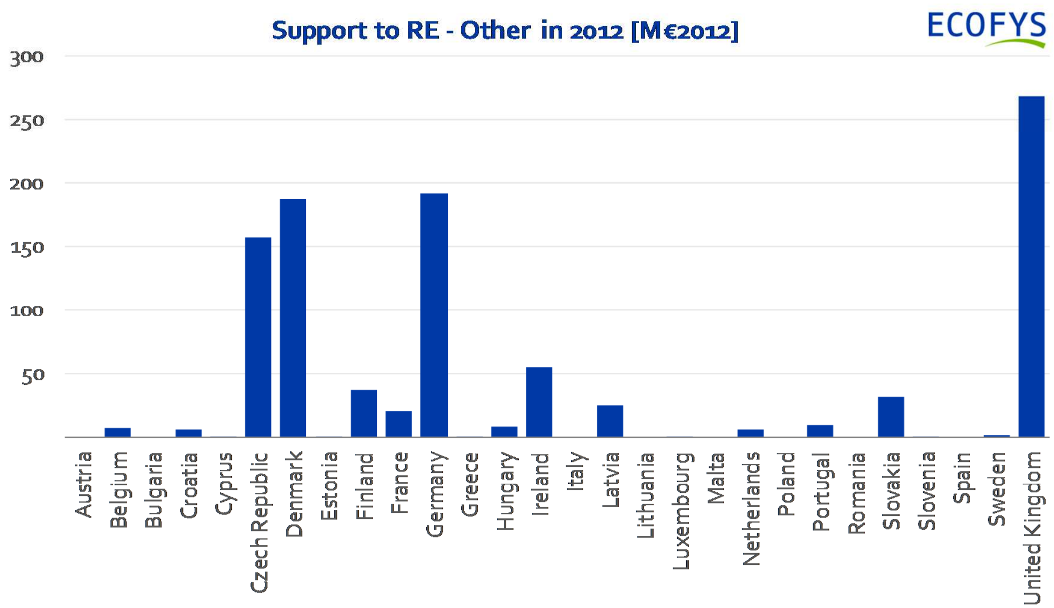


***Note:** EU level support is not shown in the graph*

Note * indicates non-zero figures rounded to zero.

Figure A2-9 : Support to RE – Geothermal (M€2012)

Support to RE - Other (M€2012)					
	2008	2009	2010	2011	2012
Austria	-	-	-	-	-
Belgium	-	-	-	10	10
Bulgaria	-	-	-	-	-
Croatia	-	0 *	0 *	0 *	10
Cyprus	10	-	0 *	0 *	0 *
Czech Republic	20	30	70	100	160
Denmark	30	200	90	80	190
Estonia	0 *	0 *	0 *	0 *	0 *
Finland	-	-	-	10	40
France	-	30	10	10	20
Germany	490	430	320	140	190
Greece	-	-	0 *	0 *	0 *
Hungary	0 *	10	10	10	10
Ireland	70	110	90	40	50
Italy	-	-	-	-	-
Latvia	0 *	0 *	0 *	10	20
Lithuania	-	-	-	-	-
Luxembourg	-	-	-	-	0 *
Malta	-	-	-	-	-
Netherlands	-	-	0 *	0 *	10
Poland	-	-	-	-	-
Portugal	0 *	0 *	0 *	10	10
Romania	-	-	-	-	-
Slovakia	-	-	30	40	30
Slovenia	-	-	-	0 *	0 *
Spain	-	-	-	-	-
Sweden	0 *	10	0 *	0 *	0 *
United Kingdom	310	90	350	270	270
EU level support	-	-	-	-	-
EU28 Total+EU-level	**940**	**910**	**980**	**750**	**1,020**

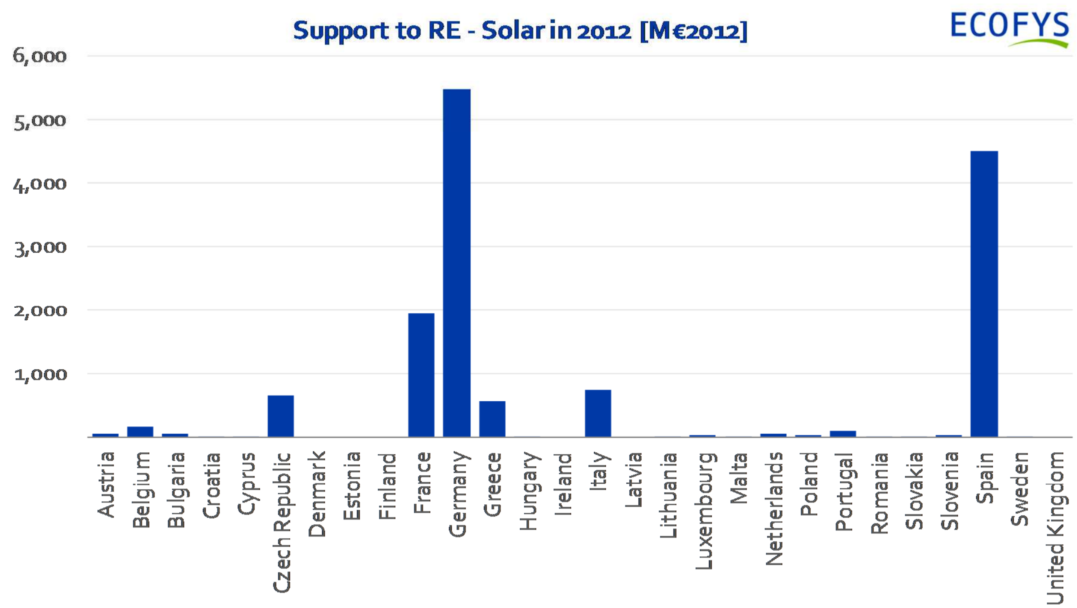


Note: EU level support is not shown in the graph

Note * indicates non-zero figures rounded to zero. This generally refers to support to biogas and ocean.

Figure A2-10 : Support to RE – Other (M€2012)

Support to RE - Solar (M€2012)	2008	2009	2010	2011	2012
Austria	20	30	40	50	60
Belgium	0 *	10	40	120	170
Bulgaria	-	0 *	0 *	20	50
Croatia	-	0 *	0 *	0 *	0 *
Cyprus	10	0 *	0 *	0 *	0 *
Czech Republic	10	40	250	650	650
Denmark	-	-	-	-	-
Estonia	-	-	-	-	-
Finland	0 *	0 *	0 *	0 *	0 *
France	10	60	280	970	1,950
Germany	1,740	2,340	3,510	5,190	5,470
Greece	0 *	20	60	220	580
Hungary	0 *	0 *	0 *	0 *	0 *
Ireland	-	-	-	-	-
Italy	180	370	1,170	3,360	750
Latvia	-	-	-	-	-
Lithuania	-	-	-	0 *	0 *
Luxembourg	20	20	20	20	30
Malta	0 *	0 *	10	10	0 *
Netherlands	20	0 *	0 *	10	50
Poland	-	-	0 *	20	30
Portugal	0 *	30	50	70	100
Romania	-	-	0 *	0 *	0 *
Slovakia	-	-	0 *	20	20
Slovenia	0 *	0 *	0 *	10	30
Spain	1,420	3,440	3,680	3,640	4,500
Sweden	0 *	0 *	0 *	10	10
United Kingdom	-	-	-	0 *	-10
EU level support	*10*	*40*	*60*	*160*	*260*
EU28 Total+EU-level	**3,430**	**6,410**	**9,180**	**14,580**	**14,730**

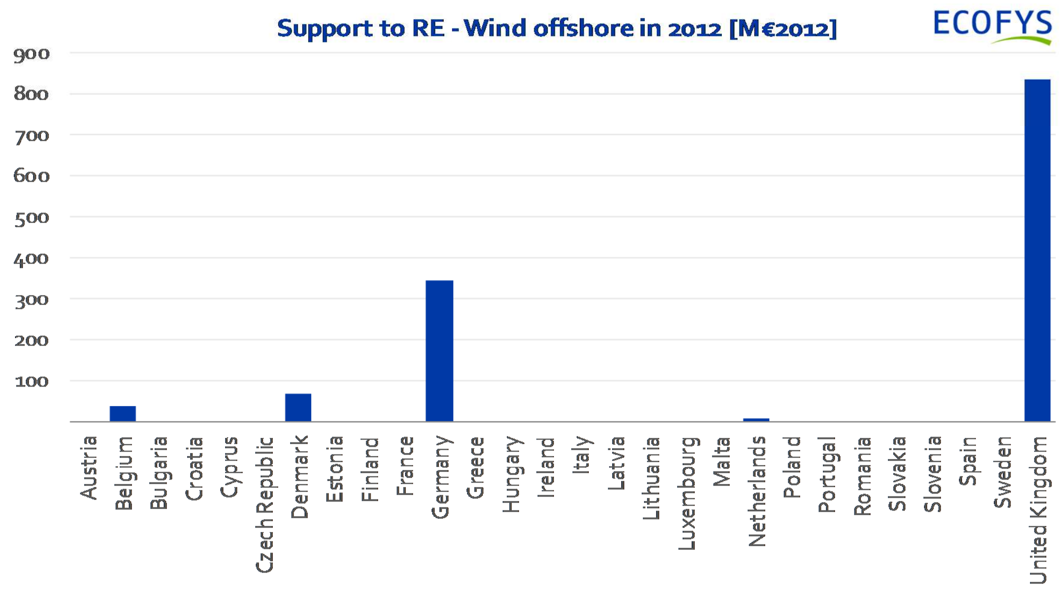


Note: EU level support is not shown in the graph

Note * indicates non-zero figures rounded to zero, Information on grants in Cyprus is only available for the year 2008.

Figure A2-11 : Support to RE – Solar (M€2012)

Support to RE - Wind offshore (M€2012)	2008	2009	2010	2011	2012
Austria	-	-	-	-	-
Belgium	0 *	10	20	30	40
Bulgaria	-	-	-	-	-
Croatia	-	-	-	-	-
Cyprus	-	-	-	-	-
Czech Republic	-	-	-	-	-
Denmark	10	20	20	30	70
Estonia	-	-	-	-	-
Finland	0 *	0 *	0 *	0 *	0 *
France	-	-	-	-	-
Germany	0 *	0 *	0 *	0 *	350
Greece	-	-	-	-	-
Hungary	-	-	-	-	-
Ireland	0 *	0 *	0 *	0 *	0 *
Italy	-	-	-	-	-
Latvia	-	-	-	-	-
Lithuania	-	-	-	-	-
Luxembourg	-	-	-	-	-
Malta	-	-	-	-	-
Netherlands	10	0 *	10	0 *	10
Poland	-	-	-	-	-
Portugal	-	-	-	-	-
Romania	-	-	-	-	-
Slovakia	-	-	-	-	-
Slovenia	-	-	-	-	-
Spain	-	-	-	-	-
Sweden	10	10	-	-	-
United Kingdom	-	60	330	620	830
EU level support	*10*	*20*	*170*	*460*	*60*
EU28 Total+EU-level	**40**	**130**	**550**	**1,140**	**1,360**

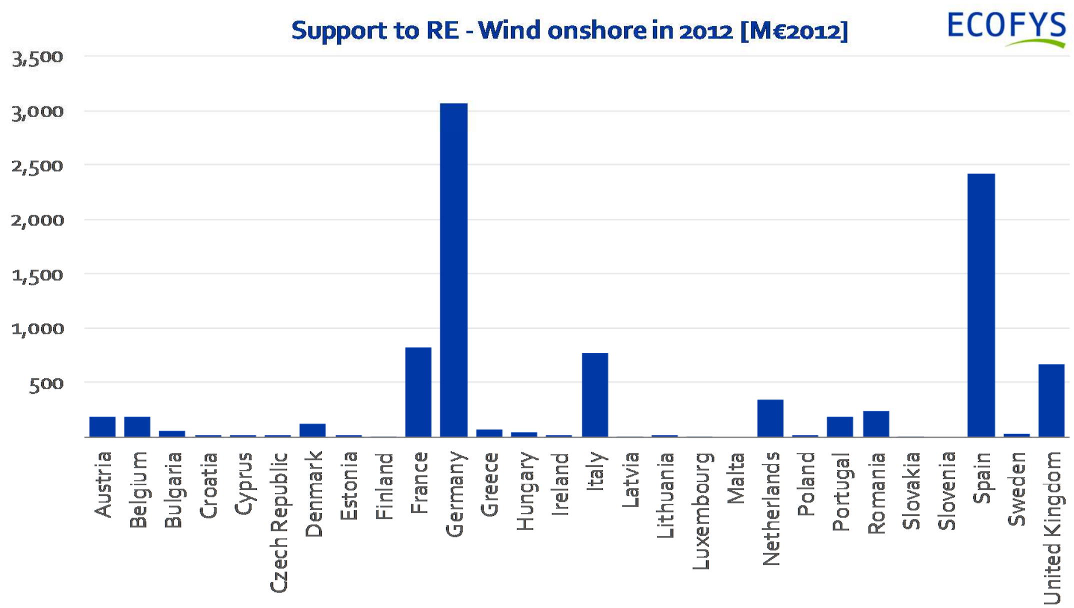


Note: EU level support is not shown in the graph

Note * indicates non-zero figures rounded to zero, Germany introduced Feed-in Premium in 2012.

Figure A2-12 : Support to RE – Wind offshore (M€2012)

Support to RE - Wind onshore (M€2012)					
	2008	**2009**	**2010**	**2011**	**2012**
Austria	170	160	170	150	190
Belgium	20	50	80	160	180
Bulgaria	10	20	40	40	60
Croatia	0 *	0 *	0 *	10	20
Cyprus	-	-	10	20	20
Czech Republic	10	10	10	10	20
Denmark	40	70	50	70	130
Estonia	10	10	10	20	20
Finland	0 *	30	0 *	0 *	10
France	380	680	720	760	830
Germany	2,230	2,130	1,880	2,080	3,060
Greece	20	40	40	60	70
Hungary	10	10	30	40	50
Ireland	50	40	20	10	20
Italy	760	590	810	840	770
Latvia	0 *	0 *	0 *	0 *	0 *
Lithuania	-	-	-	20	20
Luxembourg	0 *	0 *	0 *	0 *	0 *
Malta	-	-	-	-	-
Netherlands	370	360	330	360	340
Poland	0 *	10	10	20	20
Portugal	70	150	190	130	190
Romania	0 *	0 *	20	80	240
Slovakia	0 *	0 *	0 *	0 *	0 *
Slovenia	-	0 *	0 *	0 *	0 *
Spain	1,300	1,840	2,250	1,960	2,410
Sweden	10	20	30	40	30
United Kingdom	110	260	500	470	670
EU level support	*120*	*350*	*370*	*600*	*750*
EU28 Total+EU-level	**5,700**	**6,810**	**7,560**	**7,930**	**10,120**

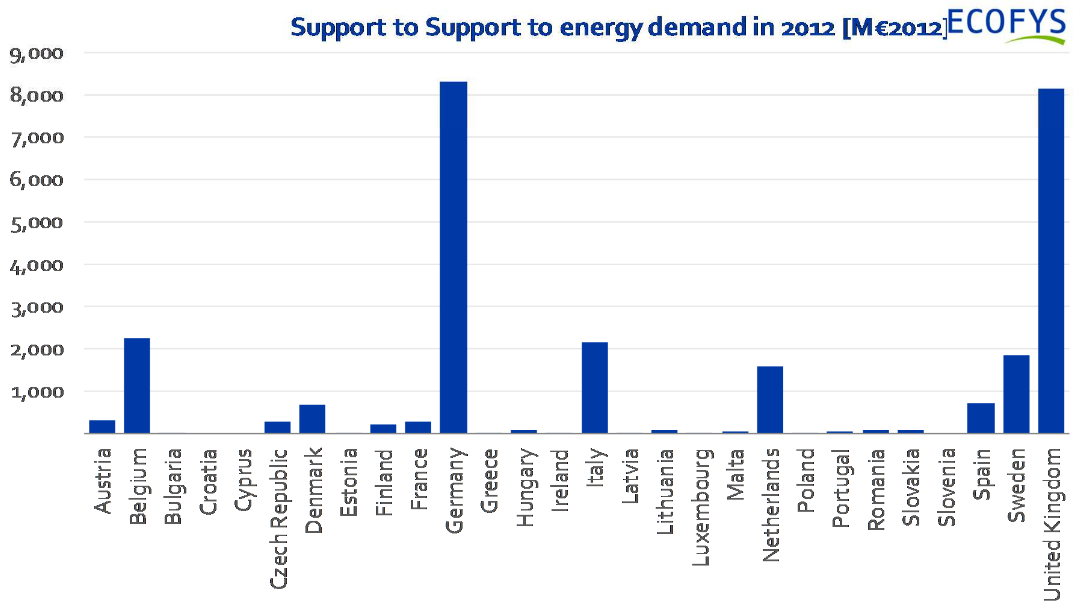


***Note:** EU level support is not shown in the graph*

Note * indicates non-zero figures rounded to zero.

Figure A2-13 : Support to RE – Wind onshore (M€2012)

Support to Support to energy demand (M€2012)					
	2008	2009	2010	2011	2012
Austria	400	390	340	330	330
Belgium	2,110	2,130	2,300	2,190	2,240
Bulgaria	60	20	30	30	30
Croatia	-	-	-	-	-
Cyprus	-	-	-	-	-
Czech Republic	260	240	280	270	280
Denmark	0 *	0 *	710	690	670
Estonia	-	-	0 *	0 *	0 *
Finland	220	220	210	250	220
France	220	250	260	270	270
Germany	6,790	6,940	7,530	7,460	8,330
Greece	20	20	20	40	20
Hungary	-	30	80	80	80
Ireland	0 *	0 *	0 *	0 *	0 *
Italy	1,370	1,220	1,290	1,700	2,160
Latvia	50	30	40	30	30
Lithuania	40	40	90	80	80
Luxembourg	30	30	30	30	30
Malta	50	40	50	50	50
Netherlands	1,600	1,580	1,790	1,560	1,570
Poland	0 *	0 *	0 *	0 *	20
Portugal	70	70	70	50	50
Romania	160	130	240	290	80
Slovakia	60	60	90	90	90
Slovenia	-	-	-	-	-
Spain	230	390	400	500	700
Sweden	2,380	2,160	1,890	1,840	1,840
United Kingdom	7,570	7,110	8,220	7,640	8,160
EU level support	-	-	-	-	-
EU28 Total+EU-level	**23,690**	**23,100**	**25,950**	**25,470**	**27,360**

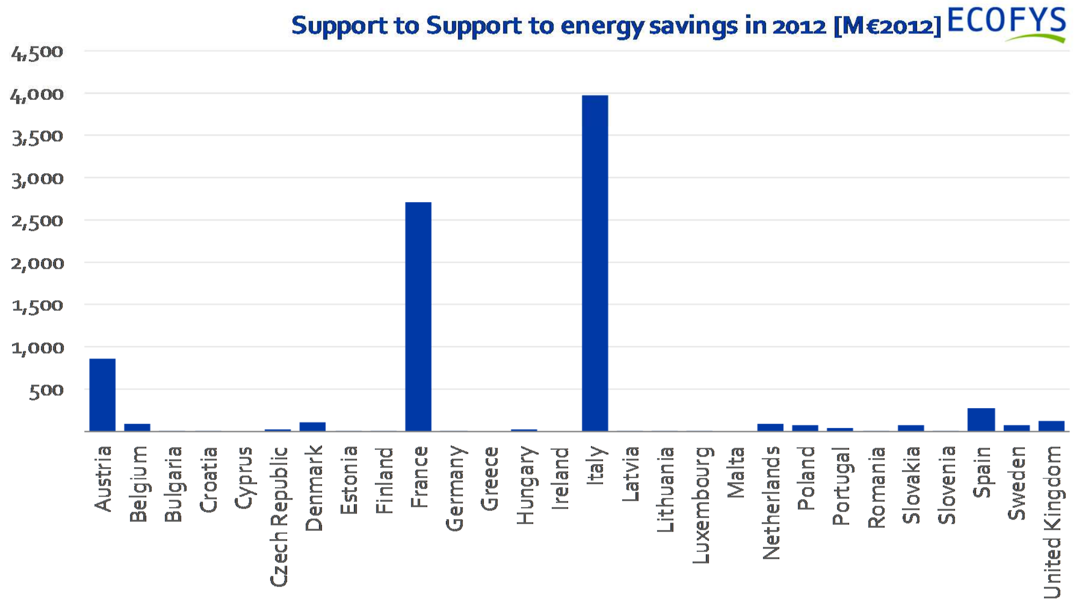


Note: EU level support is not shown in the graph

Note * indicates non-zero figures rounded to zero.

Figure A2-14 : Support to Support to energy demand (M€2012)

Support to Support to energy savings (M€2012)					
	2008	2009	2010	2011	2012
Austria	1,140	950	670	900	850
Belgium	70	130	150	50	100
Bulgaria	0 *	0 *	0 *	0 *	0 *
Croatia	0 *	10	0 *	0 *	10
Cyprus	-	-	-	-	-
Czech Republic	-	20	490	280	20
Denmark	-	-	100	100	110
Estonia	-	-	0 *	0 *	10
Finland	10	10	10	20	0 *
France	1,470	1,510	1,530	1,550	2,710
Germany	10	30	20	10	10
Greece	-	-	-	-	-
Hungary	0 *	0 *	0 *	20	20
Ireland	-	-	-	-	-
Italy	1,910	2,410	2,680	3,280	3,970
Latvia	-	-	-	10	0 *
Lithuania	-	-	0 *	0 *	0 *
Luxembourg	0 *	0 *	0 *	0 *	0 *
Malta	-	-	0 *	-	-
Netherlands	110	80	180	90	90
Poland	0 *	0 *	0 *	0 *	70
Portugal	10	20	40	60	40
Romania	210	240	180	100	10
Slovakia	-	110	100	100	70
Slovenia	0 *	10	10	10	0 *
Spain	310	280	270	270	280
Sweden	20	20	70	80	80
United Kingdom	530	640	510	140	120
EU level support	*10*	*20*	*20*	*40*	*0 **
EU28 Total+EU-level	**5,820**	**6,500**	**7,040**	**7,120**	**8,590**



***Note:** EU level support is not shown in the graph*

Note * indicates non-zero figures rounded to zero. Many grants cover both energy efficiency and renewable energy and it has not been possible to separate these in many cases. Therefore some support to energy efficiency are reported under support to investment for renewable energy.

Figure A2-15 : Support to Support to energy savings (M€2012)

The tables below show total interventions per unit of energy (zeros indicate numbers rounded to zero). For interventions that are associated with only electricity (nuclear and renewables), the total value of the intervention has been divided by the electricity production in that year. For coal, two values are given, the interventions per GJ of primary production of coal and per MWh of electricity production from coal. The majority of interventions for coal are directed towards production of coal. For comparison purposes, the MWh of electricity is also provided. For gas, there is a mixture of support for electricity and for heat. Two figures are also given, namely per GJ of gas consumption and per MWh of electricity from gas.

FF - Coal: €2012 per MWh					
	2008	**2009**	**2010**	**2011**	**2012**
Austria	0 *	0 *	0 *	1	0 *
Belgium	1	1	1	1	0 *
Bulgaria	-	-	-	-	-
Croatia	-	-	-	-	-
Cyprus	-	-	-	-	-
Czech Republic	5	7	6	6	6
Denmark	-	-	-	-	-
Estonia	46	56	49	62	64
Finland	-	-	-	-	-
France	0 *	0 *	-	-	-
Germany	13	13	12	12	11
Greece	0 *	0 *	0 *	0 *	0 *
Hungary	-	-	-	-	4
Ireland	2	2	11	15	18
Italy	9	6	6	4	5
Latvia	0 *	3	2	2	1
Lithuania	25	-	-	-	-
Luxembourg	-	-	-	-	-
Malta	-	-	-	-	-
Netherlands	1	2	3	2	2
Poland	5	7	6	7	5
Portugal	-	-	-	-	-
Romania	4	4	3	6	9
Slovakia	11	14	18	18	13
Slovenia	7	5	4	5	4
Spain	9	13	18	22	22
Sweden	237	235	128	172	298
United Kingdom	-	-	-	-	-
EU-level	1	3	3	4	4
EU28 Total+EU-level	**4**	**6**	**5**	**6**	**6**

Note * indicates non-zero figures rounded to zero.

FF - Coal: €2012 per GJ					
	2008	2009	2010	2011	2012
Austria	-	-	-	-	-
Belgium	-	-	-	-	-
Bulgaria	-	-	-	-	-
Croatia	-	-	-	-	-
Cyprus	-	-	-	-	-
Czech Republic	3,600	5,330	4,200	4,430	4,040
Denmark	-	-	-	-	-
Estonia	1,230	2,500	2,100	2,490	3,010
Finland	-	-	-	-	-
France	11,570	32,040	-	-	-
Germany	23,380	22,780	22,330	21,560	19,930
Greece	20	30	30	30	30
Hungary	-	-	-	-	4,450
Ireland	-	-	-	-	-
Italy	1,845,860	1,865,590	1,194,120	1,122,230	1,539,760
Latvia	-	-	-	-	-
Lithuania	-	-	-	-	-
Luxembourg	-	-	-	-	-
Malta	-	-	-	-	-
Netherlands	-	-	-	-	-
Poland	3,450	5,070	4,270	5,420	3,890
Portugal	-	-	-	-	-
Romania	4,880	3,890	3,270	7,090	10,290
Slovakia	29,050	28,910	37,260	36,940	27,860
Slovenia	9,050	7,420	6,070	6,270	5,200
Spain	33,300	39,770	44,780	116,280	154,560
Sweden	-	-	-	-	-
United Kingdom	-	-	-	-	-
EU-level	1,630	4,360	4,270	5,830	6,780
EU28 Total+EU-level	**6,270**	**7,910**	**7,560**	**9,080**	**9,350**

FF - Natural gas: €2012 per MWh					
	2008	**2009**	**2010**	**2011**	**2012**
Austria	0 *	0 *	0 *	1	0 *
Belgium	1	1	1	1	0 *
Bulgaria	-	-	-	-	-
Croatia	-	-	-	-	-
Cyprus	-	-	-	-	-
Czech Republic	1	1	1	2	1
Denmark	-	-	-	-	-
Estonia	62	103	79	91	118
Finland	-	-	-	-	-
France	0 *	0 *	-	-	-
Germany	6	7	7	6	6
Greece	0 *	0 *	0 *	0 *	0 *
Hungary	8	13	12	21	31
Ireland	2	2	11	15	18
Italy	9	6	6	4	5
Latvia	32	45	30	31	65
Lithuania	49	82	40	40	49
Luxembourg	-	-	-	-	-
Malta	-	-	-	-	-
Netherlands	2	2	3	2	2
Poland	4	6	4	6	4
Portugal	-	-	-	-	-
Romania	0 *	0 *	0 *	6	8
Slovakia	0 *	0 *	0 *	0 *	0 *
Slovenia	0 *	1	17	21	13
Spain	3	4	6	6	7
Sweden	237	235	128	172	298
United Kingdom	-	-	-	-	-
EU-level	1	3	3	4	4
EU28 Total+EU-level	**3**	**4**	**4**	**5**	**5**

Note * indicates non-zero figures rounded to zero.

FF - Natural gas: €2012 per GJ					
	2008	2009	2010	2011	2012
Austria	350	400	410	480	240
Belgium	620	580	570	570	170
Bulgaria	-	-	-	-	-
Croatia	-	-	-	-	-
Cyprus	-	-	-	-	-
Czech Republic	50	60	80	110	70
Denmark	-	-	-	-	-
Estonia	23,330	17,460	35,650	34,530	27,170
Finland	-	-	-	-	-
France	50	80	-	-	-
Germany	3,110	3,480	3,220	3,420	3,030
Greece	60	60	60	40	40
Hungary	6,010	7,070	6,930	11,120	14,600
Ireland	6,950	7,160	38,800	45,480	49,750
Italy	13,070	7,900	6,740	5,260	5,250
Latvia	40,270	65,090	56,280	72,990	113,500
Lithuania	20,660	48,750	36,220	21,150	27,330
Luxembourg	-	-	-	-	-
Malta	-	-	-	-	-
Netherlands	1,430	1,850	2,540	2,100	1,840
Poland	590	910	630	1,010	780
Portugal	-	-	-	-	-
Romania	10	20	20	2,270	3,030
Slovakia	0 *	10	0 *	10	10
Slovenia	30	400	4,180	5,390	4,030
Spain	7,740	10,800	11,200	10,950	10,730
Sweden	92,660	202,830	170,940	124,300	110,990
United Kingdom	-	-	-	-	-
EU-level	880	2,430	2,180	3,040	2,870
EU28 Total+EU-level	**2,480**	**3,360**	**3,390**	**3,880**	**3,830**

Note * indicates non-zero figures rounded to zero.

Nuclear: €2012 per MWh					
	2008	2009	2010	2011	2012
Austria	-	-	-	-	-
Belgium	-	-	-	-	-
Bulgaria	-	-	-	-	-
Croatia	-	-	-	-	-
Cyprus	-	-	-	-	-
Czech Republic	0 *	0 *	0 *	0 *	0 *
Denmark	-	-	-	-	-
Estonia	-	-	-	-	-
Finland	-	-	-	-	-
France	0 *	0 *	0 *	0 *	0 *
Germany	-	-	-	-	-
Greece	-	-	-	-	-
Hungary	10	10	10	10	0 *
Ireland	-	-	-	-	-
Italy	-	-	-	-	-
Latvia	-	-	-	-	-
Lithuania	0 *	10	-	-	-
Luxembourg	-	-	-	-	-
Malta	-	-	-	-	-
Netherlands	10	10	10	10	10
Poland	-	-	-	-	-
Portugal	-	-	-	-	-
Romania	0 *	0 *	0 *	0 *	0 *
Slovakia	0 *	0 *	0 *	0 *	0 *
Slovenia	0 *	0 *	0 *	0 *	0 *
Spain	0 *	0 *	0 *	10	10
Sweden	0 *	0 *	0 *	0 *	0 *
United Kingdom	40	30	40	30	40
EU-level	0 *	0 *	0 *	0 *	0 *
EU28 Total+EU-level	**0 ***	**0 ***	**0 ***	**0 ***	**0 ***

Note * indicates non-zero figures rounded to zero. Nuclear related interventions are mainly RD&D grants for nuclear research (6 out of 21 interventions) as well as support to decommissioning and waste disposal (also 6 out of 21 interventions). Other and fewer interventions are related to production support, support to stranded assets and a few related to investments. In total, we found data for 11 EU Member State on nuclear related interventions.

RE - Biomass: €2012 per MWh					
	2008	2009	2010	2011	2012
Austria	90	90	90	80	80
Belgium	30	60	70	80	80
Bulgaria	-	0 *	0 *	0 *	0 *
Croatia	0 *	0 *	0 *	20	40
Cyprus	140	20	10	0 *	10
Czech Republic	30	30	40	40	30
Denmark	10	10	10	10	10
Estonia	70	50	40	60	60
Finland	0 *	10	0 *	10	0 *
France	50	50	40	30	30
Germany	80	100	100	90	90
Greece	20	20	20	20	10
Hungary	30	30	30	40	30
Ireland	50	20	10	0 *	0 *
Italy	80	70	80	90	70
Latvia	10	10	10	10	20
Lithuania	340	10	10	50	40
Luxembourg	120	120	100	100	100
Malta	-	-	1,720	310	170
Netherlands	80	60	70	70	60
Poland	0 *	10	10	10	0 *
Portugal	100	100	100	90	90
Romania	0 *	170	60	60	90
Slovakia	0 *	0 *	10	40	50
Slovenia	30	30	30	40	40
Spain	0 *	10	10	10	10
Sweden	0 *	10	10	0 *	0 *
United Kingdom	10	0 *	30	20	30
EU-level	0 *	0 *	0 *	0 *	0 *
EU28 Total+EU-level	**20**	**30**	**30**	**30**	**30**

Note * indicates non-zero figures rounded to zero.

RE - Geothermal: €2012 per MWh					
	2008	2009	2010	2011	2012
Austria	0 *	0 *	0 *	0 *	0 *
Belgium	-	-	-	-	-
Bulgaria	-	-	-	-	-
Croatia	-	-	-	-	-
Cyprus	-	-	-	-	-
Czech Republic	-	-	-	-	-
Denmark	-	-	-	-	-
Estonia	-	-	-	-	-
Finland	-	-	-	-	-
France	-	-	-	-	-
Germany	180	240	240	160	180
Greece	-	-	-	-	-
Hungary	-	-	-	-	-
Ireland	-	-	-	-	-
Italy	30	30	30	30	10
Latvia	-	-	-	-	-
Lithuania	-	-	-	-	-
Luxembourg	-	-	-	-	-
Malta	-	-	-	-	-
Netherlands	-	-	-	-	-
Poland	-	-	-	-	-
Portugal	-	-	20	10	10
Romania	-	-	-	-	-
Slovakia	-	-	-	-	-
Slovenia	-	-	-	-	-
Spain	-	-	-	-	-
Sweden	-	-	-	-	-
United Kingdom	-	-	-	-	-
EU-level	0 *	0 *	0 *	0 *	0 *
EU28 Total+EU-level	**20**	**20**	**10**	**20**	**10**

Note * indicates non-zero figures rounded to zero.

RE - Hydro: €2012 per MWh	2008	2009	2010	2011	2012
Austria	0 *	0 *	0 *	0 *	0 *
Belgium	30	60	70	80	80
Bulgaria	10	20	20	20	70
Croatia	0 *	0 *	0 *	0 *	0 *
Cyprus	-	-	-	-	-
Czech Republic	10	10	20	20	20
Denmark	-	-	-	-	-
Estonia	40	40	60	60	60
Finland	0 *	0 *	0 *	0 *	0 *
France	50	50	40	30	20
Germany	10	10	10	10	10
Greece	0 *	0 *	0 *	0 *	0 *
Hungary	10	10	20	30	30
Ireland	30	20	20	20	20
Italy	30	20	20	20	20
Latvia	0 *	0 *	0 *	10	0 *
Lithuania	-	-	-	0 *	0 *
Luxembourg	20	20	10	20	10
Malta	-	-	-	-	-
Netherlands	80	80	80	80	70
Poland	0 *	10	10	10	0 *
Portugal	20	20	20	20	20
Romania	0 *	0 *	0 *	0 *	0 *
Slovakia	0 *	0 *	10	40	50
Slovenia	0 *	0 *	10	10	10
Spain	10	10	10	10	20
Sweden	0 *	0 *	0 *	0 *	0 *
United Kingdom	-	-	-	0 *	0 *
EU-level	0 *	0 *	0 *	0 *	0 *
EU28 Total+EU-level	**10**	**10**	**10**	**10**	**10**

Note * indicates non-zero figures rounded to zero.

RE - Solar: €2012 per MWh					
	2008	**2009**	**2010**	**2011**	**2012**
Austria	640	580	420	300	180
Belgium	30	60	70	110	80
Bulgaria	-	0 *	250	210	70
Croatia	-	-	-	-	280
Cyprus	2,500	250	240	180	140
Czech Republic	420	450	400	300	300
Denmark	-	-	-	-	-
Estonia	-	-	-	-	-
Finland	0 *	0 *	0 *	0 *	0 *
France	250	370	450	470	490
Germany	390	360	300	270	210
Greece	290	370	380	360	340
Hungary	0 *	0 *	0 *	10	10
Ireland	-	-	-	-	-
Italy	940	550	610	310	40
Latvia	-	-	-	-	-
Lithuania	-	-	-	-	400
Luxembourg	1,010	990	840	890	650
Malta	-	-	-	1,580	270
Netherlands	420	30	60	80	200
Poland	-	-	-	70,190	31,290
Portugal	130	210	250	260	250
Romania	-	-	-	70	310
Slovakia	-	-	10	40	50
Slovenia	500	220	260	220	190
Spain	550	580	570	490	550
Sweden	0 *	290	450	850	480
United Kingdom	-	-	-	10	0 *
EU-level	0 *	0 *	0 *	0 *	0 *
EU28 Total+EU-level	**230**	**230**	**200**	**160**	**110**

Note * indicates non-zero figures rounded to zero. Figures are high in Poland as investment grants exist, but solar production is relatively small.

RE - Wind offshore: €2012 per MWh					
	2008	2009	2010	2011	2012
Austria	-	-	-	-	-
Belgium	30	60	70	80	80
Bulgaria	-	-	-	-	-
Croatia	-	-	-	-	-
Cyprus	-	-	-	-	-
Czech Republic	-	-	-	-	-
Denmark	10	10	10	10	20
Estonia	-	-	-	-	-
Finland	0 *	0 *	0 *	0 *	0 *
France	-	-	-	-	-
Germany	0 *	10	0 *	0 *	590
Greece	-	-	-	-	-
Hungary	-	-	-	-	-
Ireland	20	10	10	0 *	0 *
Italy	-	-	-	-	-
Latvia	-	-	-	-	-
Lithuania	-	-	-	-	-
Luxembourg	-	-	-	-	-
Malta	-	-	-	-	-
Netherlands	20	0 *	20	10	10
Poland	-	-	-	-	-
Portugal	-	-	-	-	-
Romania	-	-	-	-	-
Slovakia	-	-	-	-	-
Slovenia	-	-	-	-	-
Spain	-	-	-	-	-
Sweden	60	40	-	-	-
United Kingdom	-	20	100	120	130
EU-level	0 *	0 *	20	40	10
EU28 Total+EU-level	**0 ***	**10**	**40**	**60**	**60**

Note * indicates non-zero figures rounded to zero.

RE - Wind onshore: €2012 per MWh					
	2008	**2009**	**2010**	**2011**	**2012**
Austria	80	80	80	80	80
Belgium	30	60	70	80	80
Bulgaria	60	70	60	50	50
Croatia	0 *	70	30	40	50
Cyprus	-	-	170	140	90
Czech Republic	30	20	20	30	40
Denmark	10	10	10	10	20
Estonia	50	40	40	50	60
Finland	10	110	0 *	10	20
France	70	90	70	60	60
Germany	60	60	50	40	60
Greece	10	10	20	20	20
Hungary	50	50	50	60	70
Ireland	20	10	10	0 *	0 *
Italy	160	90	90	90	60
Latvia	50	80	60	30	40
Lithuania	-	-	-	40	40
Luxembourg	50	50	40	50	50
Malta	-	-	-	-	-
Netherlands	100	90	100	80	80
Poland	0 *	10	10	10	0 *
Portugal	10	20	20	10	20
Romania	100	80	50	50	90
Slovakia	0 *	0 *	10	40	50
Slovenia	-	-	-	-	-
Spain	40	50	50	50	50
Sweden	10	10	10	10	0 *
United Kingdom	20	40	70	40	50
EU-level	0 *	0 *	0 *	0 *	0 *
EU28 Total+EU-level	**30**	**30**	**30**	**20**	**30**

Note * indicates non-zero figures rounded to zero.

EU level support

Most interventions at the EU level have been included in the same way as interventions in the Member States and are included in the results shown in section A2.2. This section gives an overview of the EU's Structural and Cohesions funds and the Intelligent Energy Europe and EU Framework Programmes. Loans provided by the European Investment Bank (EIB) and the European Bank for Reconstruction and Development (EBRD) are not include here as these banks typically provide loans at commercial market rates and are therefore not considered interventions.

A2.7.3 EU Structural funds

The structural fund consists of the European Regional Development Fund (ERDF) and the European Social Fund (ESF). The figures are corrected for possible double counting with Member State contributions from these funds in calculations made for this report. In

Table **A2-4** the figures are presented as we received them from the European Commission. These concern figures for the period 2007 – 2013. An annual breakdown was not available. We therefore calculated and estimate figures for the period 2008 – 2012, assuming an even annual breakdown overall years (see

Table **A2-4**).

Table A2-4: Convergence and Regional Competitiveness and Employment and European Territorial Cooperation budget allocated in 2007 - 2013 in million € (source: personal communication with European Commission July 2014).

	Renewable energy	Energy efficiency, CHP, energy management	Trans-European Networks for petroleum, natural gas & electricity	Petroleum, natural gas & electricity	Total
Grand Total 2007-2013	*4,511*	*6,100*	*556*	*904*	*12,071*
European Territorial Cooperation					
Total	*204*	*132*	*6*	*8*	*350*
Convergence and Regional Competitiveness and Employment					
Total	*4,307*	*5,968*	*550*	*896*	*11,721*
Bulgaria	13	257	0	41	311
Belgium	12	16	0	0	28
Czech Republic	221	1,280	0	0	1,501
Denmark	0	0	0	0	0
Germany	227	392	0	1	620
Estonia	0	29	0	0	29
Greece	459	304	78	73	914
Spain	143	144	0	50	336
France	367	312	0	0	679
Ireland	0	16	0	0	16
Italy	767	1,056	0	39	1,863
Cyprus	10	0	0	0	10
Latvia	67	70	0	0	137
Lithuania	58	374	0	71	503
Luxembourg	2	1	0	0	2
Hungary	349	358	0	0	707
Malta	55	19	0	0	74
Netherlands	19	34	0	10	63
Austria	26	6	0	0	33
Poland	766	578	443	555	2,342
Portugal	60	75	0	6	141
Romania	328	198	29	47	602
Slovenia	54	106	0	0	160
Slovakia	90	91	0	0	181
Finland	21	24	0	0	45
Sweden	52	9	0	0	62
United Kingdom	141	220	0	2	363

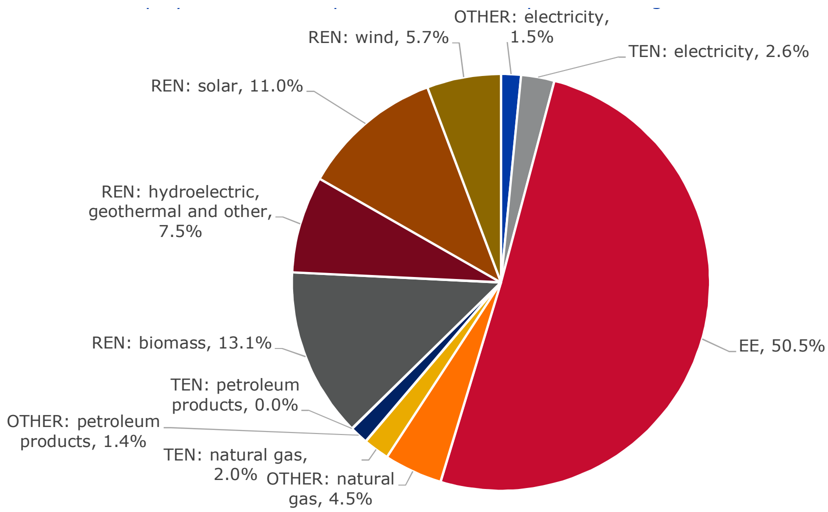


Figure A2-16 Segmentation of Convergence and Regional Competitiveness and Employment and European Territorial Cooperation budget allocated in 2007 - 2013. Total equals 12,071 million € (source: personal communication with European Commission July 2014).

In the table below the estimated figures for the 2008 – 2012 period are presented. These figures are used for the respective calculations in this report.

Table A2-5: Convergence and Regional Competitiveness and Employment and European Territorial Cooperation allocated estimated budget in 2008 - 2012 in millions € (source: personal communication with European Commission July 2014, Ecofys estimate on the basis of previous table, assuming an even distribution over years).

	Renewable energy	Energy efficiency, CHP, energy management	Trans-European Networks for petroleum, natural gas & electricity	Petroleum, natural gas & electricity	Total
Grand Total 2008-2012	*3,222*	*4,357*	*397*	*645*	*8,622*
European Territorial Cooperation					
Total	*146*	*94*	*4*	*6*	*250*
Convergence and Regional Competitiveness and Employment					
Total	*3,076*	*4,263*	*393*	*640*	*8,372*
Bulgaria	*9*	*184*	*0*	*29*	*222*
Belgium	*9*	*11*	*0*	*0*	*20*
Czech Republic	*158*	*914*	*0*	*0*	*1,072*
Denmark	*0*	*0*	*0*	*0*	*0*
Germany	*162*	*280*	*0*	*1*	*443*
Estonia	*0*	*21*	*0*	*0*	*21*
Greece	*328*	*217*	*56*	*52*	*653*
Spain	*102*	*103*	*0*	*36*	*240*
France	*262*	*223*	*0*	*0*	*485*
Ireland	*0*	*11*	*0*	*0*	*11*
Italy	*548*	*754*	*0*	*28*	*1,331*
Cyprus	*7*	*0*	*0*	*0*	*7*
Latvia	*48*	*50*	*0*	*0*	*98*
Lithuania	*41*	*267*	*0*	*51*	*359*

	Renewable energy	Energy efficiency, CHP, energy management	Trans-European Networks for petroleum, natural gas & electricity	Petroleum, natural gas & electricity	Total
Luxembourg	*1*	*1*	*0*	*0*	*1*
Hungary	*249*	*256*	*0*	*0*	*505*
Malta	*39*	*14*	*0*	*0*	*53*
Netherlands	*14*	*24*	*0*	*7*	*45*
Austria	*19*	*4*	*0*	*0*	*24*
Poland	*547*	*413*	*316*	*396*	*1,673*
Portugal	*43*	*54*	*0*	*4*	*101*
Romania	*234*	*141*	*21*	*34*	*430*
Slovenia	*39*	*76*	*0*	*0*	*114*
Slovakia	*64*	*65*	*0*	*0*	*129*
Finland	*15*	*17*	*0*	*0*	*32*
Sweden	*37*	*6*	*0*	*0*	*44*
United Kingdom	*101*	*157*	*0*	*1*	*259*

A2.7.4 Intelligent Energy Europe (IEE)

Intelligent Energy – Europe (IEE) offers a helping hand to organisations willing to improve energy sustainability. Launched in 2003 by the European Commission, the programme is part of a broad push to create an energy-intelligent future. It supports EU energy efficiency and renewable energy policies, with a view to reaching the EU 2020 targets (20% cut in greenhouse gas emissions, 20% improvement in energy efficiency and 20% of renewables in EU energy consumption). In the table below the allocated annual allocated budgets in the period 2008 – 2012 are presented[13].

Table A2-6: Intelligent Energy Europe budgets 2008 – 2012 (€ million 2012)

Sub-programme	Technology	2008	2009	2010	2011	2012	Total
Energy efficiency and rational use of energy (SAVE)	Support to energy demand	9	18	20	10	Not Available	**57**
New and renewable energy resources (ALTENER)	RE-All	16	20	20	13	17	**17**
Integrated initiatives	All Energy	10	19	7	24	15	**75**
Market replication projects	All Energy	0	16	15	3	9	**43**
Total		**35**	**73**	**62**	**50**	**41**	**192**

Source: http://ec.europa.eu/energy/evaluations/doc/2011_iee2_programme.pdf

A2.7.5 EU Framework Programmes

Framework Programme 7 (FP7) is the short name for the Seventh Framework Programme for Research and Technological Development. This is the EU's main instrument for funding research in Europe and it runs from 2007 - 2013. In the table below the allocated annual allocated budgets in the period 2008 – 2012 are presented[14].

[13] Data regarding actual expenditure were not available at the time of writing.
[14] Data regarding actual expenditure were not available at the time of writing.

Table A2-7: EU Framework Programmes (FP7) budgets 2008 – 2012 (€ million 2012)

Sub-programme	Technology	2008	2009	2010	2011	2012	Total
FP7	Non-nuclear energy	290	290	302	354	382	**1,618**
FP7	Nuclear	49	49	51	21	55	**170**

Source: http://ec.europa.eu/research/fp7/index_en.cfm?pg=budget

A2.8 Subnational support

In some countries, specific subnational support (i.e. region or state) have been identified and included in the analysis. In addition the table below provides an overview of regional interventions in energy based on OECD database, we have not quantified these interventions but the values are likely to be small.

Table A2-8: Regional interventions

Region	Tax to which intervention applies	Description of intervention
Baden-Wuerttemberg	Water abstraction charge	• No fees for water extraction which aims to get heat.
Brandenburg	Water abstraction charge	• Charge on abstraction of water for mine draining or dewatering purposes is free of charge.
Bremen	Water abstraction charge	• No fees for water abstraction which aims to get heat and where the water is discharged afterwards.
Schleswig-Holstein	Water abstraction charge	• No fees for water abstraction from mineral springs which aims to get heat and is not used for commercial beverage production.
Andalusia	Tax on air pollution	• Combustion of biomass and biofuel; • CO_2 emissions in excess of assigned emissions, covered with permits bought in the European Emission Trading Scheme.
Aragón	Tax on environmental damage caused by emissions to air	• Emissions of CO_2 produced by combustion of biomass and biofuel; • Emissions of CO_2 in excess of assigned emissions, covered with permits bought in the EU's emissions market.
		• Deduction: Up to 30% of the tax payable for investments in property, plant and equipment, dedicated to preventive, corrective or restorative measures to reduce the environmental impact.
Asturias	Tax on the development of activities that cause environmental damage	• Facilities and other patrimonial elements or assets of the communications networks, located in rural or isolated areas with low demand, disperse population or difficult orographic conditions, lacking basic telecommunication infrastructures prior to their installation; • Facilities and other patrimonial elements or assets owned by the State, the Asturias Principate or the local authorities; • Transformation stations of electricity and distribution networks when the standardized nominal voltage is lower than 30 kv; • Facilities and other patrimonial elements or assets dedicated exclusively to railway traffic.
Canary Islands	Tax on petroleum fuels	• Repealed by Law 4/2012, of 25th of June - Deliveries of K-100 petrol to the Canarian Aerial Clubs;

Region	Tax to which intervention applies	Description of intervention
		• Deliveries of products to be used as fuels by its own manufacturers; • Deliveries of products for the obtention of other products with a defined treatment or chemical transformation; • Sale of products directly to exportation; • Deliveries of products destinated to the obtention of other products subjected to the application of the tax; • Farmers are entitled to a partial rebate of the tax for the fuel used in their economic activity; • Deliveries of diesel to be used as fuels by electrical power plants.
Castilla y León	Tax on environmental damage caused by some uses of water from reservoirs and by high voltage transportation of electricity	• Facilities and other assets owned by the National Government, the Regional Government of Castilla-León or the local authorities; • Not subject: Facilities with a waterfall lower than 20 meters and with a capacity of reservoir lower than 20 Hm3; • Facilities designated to research and development.
Castille-La Mancha	Tax on certain activities that cause environmental harm	• Activities of production of electricity included in the Administrative Registry of Installations of Special Regime Production.
Extremadura	Tax on production and distribution of electricity	• Installations and structures owned by the state, the autonomic communities and the local corporations; • Installations for railway circulation; • Transforming stations of electrical energy and distribution networks in low tension; • Activities made by means of installations and structures dedicated to production and storage of energy for own use.
		• Production of solar or wind energy and production in plants using biomass or biogas as the main fuel.
Valencian Community	Tax on certain activities that cause environmental harm	• Production of electricity in solar or wind power plants and in plants using biomass or biogas as the main fuel; • Production of electricity included in the special regime and used for auto consumption, unless they have serious effects on the environment.

A2.9 Other off budget subsidies

In the sections above we detailed interventions that are either on the budget sheet for a country or relate to revenues foregone. As discussed earlier, there are interventions that relate to the transfer of risk to Government. Examples include limits of liability for accidents and decommissioning and waste management. This transfer of risk, particularly on decommissioning and waste can apply in many industries, see for example the subsidies to lignite mine rehabilitation. However, in the nuclear industry the potential costs are much higher and therefore we look at that in more detail.

A2.9.1 Nuclear Power Plant Liability

Nuclear Power Plant Operators (NPPOs) have limited liability for nuclear accidents set by various conventions. This means that in case of an accident, the NPPOs only have to pay a proportion of the cost. Thus, the costs associated with an accident are not completely internalised, and could be considered a subsidy, as the national Government would have to pay the remaining costs. However, as there is no direct payment, it is arguable whether this is real subsidy, as also discussed in Rothwell (2002)[15], Heyes (2003)[16] and D'haeseleer (2013)[17]. There is an indirect subsidy in that NPPOs do not have to buy full assurance to cover the risk of a nuclear accident. Since nuclear accidents are characterised by a very low risk but severe consequences, the costs of a nuclear accident can be very high. Due to these high costs, if a single insurance company is involved, claims under the insurance would be likely to exceed the financial resources of the insurance company and the NPPO. Solutions to very high cost claims, such as Deepwater Horizon, have been established in the insurance market and could be applied to nuclear accidents. This issue was discussed in some detail at a conference last year organised by DG Energy[18]. It is not however straightforward to estimate the additional insurance costs that would need to be paid by the NPPO, and therefore the indirect subsidy they receive though limited liability. The counterfactual in this case would have to be based on expert opinion on what the price might be if liability was not limited. We have reported the external cost associated with a nuclear accident in the section on external costs.

At the end of 2013, the EC published a public consultation on insurance and compensation of damages caused by accidents of nuclear power plants[19]. It describes the liability schemes that exist in the Member States. The schemes have been adopted after various international conventions and protocols[20], which basically limits the liability of NPPOs whilst making them solely responsible for all accidents. For state-owned NPPOs, or NPPOs in which the Government is the majority stakeholder, the Government is not completely liable from an accounting perspective, but de facto pays the bill in case of an accident.

Conversely, some Member States have chosen to increase the liability to unlimited. However, as discussed above as well as pointed out by D'haeseleer (2013), the liability of any enterprise is limited to its financial value.

Under the conventions, NPPOs are required to pay a financial security irrespective of the liability scheme applied. The amount of the financial security is actually the same as the liability limit when Member States have set the liability limit to the lowest amount possible, and is otherwise lower than the liability limit. The table below summarises the liability limit for NPPOs per Member State, demonstrating the differences between Member States.

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[15] Geoffrey S. Rothwell (January 2002). Does the US Subsidize Nuclear Power Insurance?", SIEPR Policy Brief, Stanford University, CA, USA.
[16] Anthony Heyes (2003). Determining the Price of Price-Anderson.
[17] William D. D'haeseleer (Novermber 2013). Synthesis on the Economics of Nuclear Energy, a Study for the European Commission, DG Energy.
[18] http://ec.europa.eu/energy/nuclear/events/20140120_nuclear_third_party_liability_and_insurance_en.htm
[19] http://ec.europa.eu/energy/nuclear/consultations/20130718_powerplants_en.htm
[20] Which are the 1960 Paris Convention on Nuclear Third Party Liability ("Paris Convention"), the 1963 Brussels Supplementary Convention on Nuclear Third Party Liability, the 1963 Vienna Convention on Civil Liability for Nuclear Damage ("Vienna Convention"), the 1988 Joint Protocol Relating to the Application of the Vienna Convention and the Paris Convention ("Joint Protocol"), and the 1997 Convention on Supplementary Compensation for Nuclear Damage.

Table A2-9: NPPO's liability and financial security limit per Member State, expressed in €. Source: EC, 2013 and OECD-NEA, 2013[21]

Member State	Liability limit (million €)	Financial security limit (million €)
Austria	Unlimited	447
Belgium	1200	1200
Bulgaria	49	49
Croatia	44	44
Cyprus	Unlimited	-
Czech Republic	232	232
Denmark	Unlimited	700
Estonia	Unlimited	-
Finland	Unlimited	700
France	700	700
Germany	Unlimited	2500
Greece	16	-
Hungary	109	109
Ireland	Unlimited	-
Italy	5.4	5.4
Latvia	114	Shall be determined by the Government
Lithuania	154	154
Luxemburg	Unlimited	-
Malta	Unlimited	-
Netherlands	1200	1200
Poland	345	345
Portugal	16	-
Romania	345	345
Slovakia	75	75
Slovenia	700	-
Spain	1200	1200
Sweden	Unlimited	1200
United Kingdom	157	157

A2.9.2 Nuclear decommissioning and waste management

This section describes the potential intervention from transfer of risks associated with nuclear decommissioning and waste management from nuclear power plant operators to Government.

[21] http://www.oecd-nea.org/law/legal-documents.html

Direct interventions in 2008 - 2012 to pay for liabilities already occurred are included in the same way as all other interventions in that period i.e. are part of the reported 2008 - 2012 interventions.

There are three main approaches with regard to nuclear decommissioning[22]:

1. Prompt decommissioning, in which all structures are decommissioned immediately after Nuclear Power Plant (NPP) closure, and waste is either stored on site or stored in a waste disposal site.
2. Safe storage, in which the NPP is kept intact and placed in protective storage for up to 100 years after closure, after which decommissioning commences. Apart from an economic incentive, the main advantage is that radiation levels drop over time.
3. Entombment, in which the radioactive structures are encased in long-lived substances such as concrete.

The approach followed can have a significant impact on the total costs, because of differences in the radioactive load at the time of decommissioning and on the phasing of those costs relative to plant closure.

Generally, NPPs are decommissioned in three separate phases[23]. In the first phase, the nuclear fuel is removed and the reactor is secured. In the second phase, the uncontaminated structures are removed, which basically leaves only the reactor. In the third phase the reactor is removed. Whilst the first and second phase can be completed relatively quickly (in the order of 10-20 years), the third and most difficult phase can take as long as 200 years after plant closure.

In the remainder of this section, the term decommissioning includes all stages leading to complete removal of the NPP, including waste disposal and management, unless otherwise mentioned.
All Member States have agreed that after shutdown the Nuclear Power Plant (NPP) will be decommissioned and that waste is properly managed. There is a general understanding in the EU that "the polluter pays", and the EC has addressed the importance of having the proper financial resources for decommissioning and waste disposal[24]. There is however, some discussion on whether provisions made are adequate.

A2.9.3 Approach

Examples of commercial NPPs that have operated their full life time and that have been completely decommissioned are scarce. Apart from a few small-scale pilot projects in Belgium and Germany, no NPPs have been decommissioned completely in the EU. That provides challenges for providing details on the actual expected cost of decommissioning and subsequent potential subsidies needed to fund shortages.

The need for a subsidy can arise when funding for decommissioning is insufficient. This insufficiency can occur in two situations. Firstly, in all Member States, the Nuclear Power Plant Operator (NPPO) is responsible for the decommissioning costs. In general, the financial resources are built up via a prepayment scheme, in which enough money is built up and stored in funds, which should cover the decommissioning and waste management costs. If the provisions at the time of decommissioning are not enough to cover the cost, the Government would have to intervene to cover that cost.

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[22] http://www.nei.org/Master-Document-Folder/Backgrounders/Fact-Sheets/Decommissioning-Nuclear-Energy-Facilities
[23] http://boell.org/downloads/Thomas_UK_-_web.pdf
[24] http://ec.europa.eu/energy/nuclear/decommissioning/policy_en.htm

As timing of decommissioning is not always clear due to for instance lifetime extension programmes or political decisions to stop using nuclear power, it is not straightforward to estimate if the provisional funds in place are likely to be sufficient to cover future decommissioning costs. We have provided examples of historic subsidies in the section below where Governments had to intervene due to a shortage of provisions.

Secondly, even if the provisions fully cover the estimated decommissioning cost, if the estimated cost does not cover the real cost, a shortage can still arise and the Government would have to intervene. This would be considered an intervention in 2008 - 2012 as if these circumstances apply nuclear power plant operators would not be making high enough pre-payments now for future costs. In the section below, we present available figures on the cost estimates used by Member States to determine the size of the decommissioning fund needed. To allow comparison across Member States and with the (limited) information on actual decommissioning costs we express the decommissioning cost in million euro per MWe.

Although the remaining section focuses solely on nuclear, the same logic applies to other industries such as fossil fuelled power plants and mining operations.

A2.9.4 Member State analysis

There is hardly any experience with full-scale decommissioning of commercial NPPs so the exact costs are not well known or understood. The typical method to express the decommissioning costs (at the time of decommissioning) is a percentage of the overnight construction cost of the NPP. The percentage ranges between 15 and 25 percent[25,26,27]. Nota bene, since the cost of decommissioning is only minor related to the cost of construction, this method reflects the common uncertainty of decommissioning costs as well.

Furthermore, with the very long time spans for decommissioning as explained above, discount rates can dwarf the future costs in terms of present values. That means that although the amount of work and required equipment is very substantial, the present value for decommissioning and waste management is very dependent on the assumption of the discount rates. Two main approaches are possible: a private discount rate and a societal discount rate. Although the discount rate impacts decommissioning of fossil fuelled power plants too, it is smaller compared to nuclear because the decommissioning process is usually shorter.

In the section below, the decommissioning cost estimates used to determine the size of the decommissioning fund, which are mainly based on the first and second EC report on the use of financial resources earmarked for the decommissioning of nuclear power plants[28].

Belgium - In Belgium, the total decommissioning cost is estimated at €$_{2012}$ 9.95 billion (2004, discounted).[28] The sum that was accumulated by the end of 2004 was €$_{2012}$ 3916 million. The funds are held by the Nuclear Provision Company, in which the Government has a golden share. The fund is filled by a share of the electricity price and a yearly contribution from the NPPOs.

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[25] William D. D'haeseleer (Novermber 2013). Synthesis on the Economics of Nuclear Energy, a Study for the European Commission, DG Energy.
[26] NEA-IEA (2010). Projected Costs of Generating Electricity – 2010 Edition, OECD, Paris.
[27] R. Lallement (2004). Démantèlement des installations nucléaires: les voies de la maîtrise industrielle, RGN Nr 5.
[28] http://ec.europa.eu/energy/nuclear/decommissioning/doc/0025_com_2004_719.pdf and http://ec.europa.eu/energy/nuclear/decommissioning/doc/0011_workdoc_sec_2007_1654.pdf

Electrabel itself estimated that their decommissioning costs are €$_{2012}$ 5.2 million[29]. With the total installed Belgian capacity of 5.9 GWe operated solely by Electrabel [30,31], the total estimated decommission cost ranges from 0.87 million€$_{2012}$/MW$_e$ to 1.67 million €$_{2012}$/MW$_e$.

Bulgaria - The total decommissioning cost in Bulgaria is estimated between €$_{2012}$ 2.94 billion[32] and €$_{2012}$ 3.05 billion[28]. For each kWh electricity produced and sold in the markets 7.5% of the electricity price was paid into a decommissioning fund and 3% is paid into the nuclear waste management fund until 2005. By the end of 2005, this was increased to 15% of the Kozloduy NPP annual income from electricity sales, because a shortage was foreseen. In 2012, the decommissioning fund had accumulated €$_{2012}$ 563 million and the waste management fund had €$_{2012}$ 136 million.
Total installed capacity is 3538 MW$_e$[33,34], divided over Kozloduy 6 reactors, of which four are in permanent shut down status. This leads to an estimated 0.83-0.86 million €$_{2012}$/MW$_e$ for decommissioning.

Czech Republic - The total decommissioning cost in the Czech Republic is estimated between €$_{2012}$ 1.25 billion (€$_{2012}$ 690 million for Dukovany 1-4 and €$_{2012}$ 557 million for Temelin 1-2)[35] and €$_{2012}$ 3.13 billion[28]. In 2004, the available funds for decommissioning were €$_{2012}$ 379 million. The fund is filled by a share of the electricity price. The installed capacity in the Czech Republic is 3884 MW[36,37], meaning the decommissioning costs are estimated at 0.32-0.81 million €$_{2012}$/MW.

Finland - The estimated decommissioning cost in Finland range between €$_{2012}$ 1.45 billion[38] and €$_{2012}$ 1.49 billion[28]. This amount was already available in the Nuclear Waste Management Fund held by the State in 2004. The NPPOs have paid contributions to the fund in addition to income from interest. Finland's generating capacity is 2750 MW$_e$ (excluding the OLKILUOTO-3 that is under construction currently)[39,40], which makes the estimated decommissioning cost 0.52-0.54 million €$_{2012}$/MW$_e$.

France - The total estimated decommissioning cost in France is estimated at €$_{2012}$ 84 billion[28]. In 2006, €$_{2012}$ 39.6 billion was managed directly by the NPPOs and the provisions are in their books. In addition, since 2010, the NPPOs have paid a nuclear power plant tax from the date of issue of each plant's construction licence until the decommissioning. Furthermore, NPPOs pay three other taxes introduced in 2006, which are related to waste management. Finally, NPPOs pay an additional fee to the Radioprotection and Nuclear Safety Institute (IRSN).

Expenses for waste management and decommissioning are funded through "dedicated assets" (actifs dédiés – which are more diversified from the electricity business to minimise systemic risk impacts). Those financial resources must be available in sufficient volume to successfully complete back end operations without a time lag and in a manner that meets both safety and industrial criteria. The French heavy water gas cooled reactor (70 MW$_e$) in Brennilis has been in the decommissioning phase since 1980, and currently is in the third phase.

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29 http://epub.wupperinst.org/frontdoor/index/index/docId/2612
30 http://www.world-nuclear.org/info/Country-Profiles/Countries-A-F/Belgium/
31 http://www.iaea.org/PRIS/CountryStatistics/CountryDetails.aspx?current=BE
32 http://epub.wupperinst.org/files/2601/2601_EUDecommFunds_BG.pdf
33 http://www.iaea.org/PRIS/CountryStatistics/CountryDetails.aspx?current=BG
34 http://www.world-nuclear.org/info/Country-Profiles/Countries-A-F/Bulgaria/
35 http://epub.wupperinst.org/files/2608/2608_EUDecommFunds_CZ.pdf
36 http://www.iaea.org/PRIS/CountryStatistics/CountryDetails.aspx?current=CZ
37 http://www.world-nuclear.org/info/Country-Profiles/Countries-A-F/Czech-Republic/
38 http://epub.wupperinst.org/files/2606/2606_EUDecommFunds_FI.pdf
39 http://www.iaea.org/PRIS/CountryStatistics/CountryDetails.aspx?current=FI
40 http://www.world-nuclear.org/info/Country-Profiles/Countries-A-F/Finland/

The current estimate of the cost is around €$_{2012}$ 500 million, which at 7.1 million €$_{2012}$/MW$_e$ is twenty times larger than the original estimation[41,42]. However, it must be noted this is an unusual case and the cost for dismantling of heavy water gas cooled reactors is likely to be much higher than more typical reactors in the EU. The decommissioning of the French Superphoenix NPP (2750 MW$_e$) in Creys-Malville is currently on hold and the cost is estimated at around €$_{2012}$ 8 billion (3 million €$_{2012}$/MW$_e$). With a total generating capacity of 68.5 GW$_e$[43] is the estimated decommission cost in France around 1.23 million €$_{2012}$/MWe.

Germany - In Germany, 19 sites are earmarked for decontamination and immediate dismantling. The four NPPOs have reserved €$_{2012}$ 30 billion for decommissioning and waste management[44]. More specifically, the German Lubmin NPP (2200 MW$_e$) in Greifswald is currently being decommissioned at an estimated cost of €$_{2012}$ 726 million[45]. The decommissioning fund is accumulated with equal instalments over 25 years and discounted at 5.5%. The waste management fund is supplemented by a nuclear fuel tax which came into force on 1 January 2011. The tax paid is 145 €/gram for the isotopes plutonium-239, plutonium-241, uranium-233 and uranium 235[46]. The decommissioning costs are estimated at 0.47 million €$_{2012}$/MW$_e$. In a report of the European Parliament, the decommissioning costs based on two German NPPs are averaged at 0.683 million €$_{2012}$/MW$_e$[47]. The Wuppertal Institute estimates that the decommissioning cost of a typical boiling water reactor (BWR) or pressurized water reactor (PWR) is between €$_{2012}$ 2500-4500 million[48]. If we assume an average generating capacity of 1000 MW$_e$[49], that means a cost estimate of 2.5-4.5 million €$_{2012}$/MW$_e$. The EC estimated that the cost for decommissioning is €$_{2012}$ 29 billion[28], which excludes research reactors and those inherited from the former German Democratic Republic (GDR). The generating capacity – excluding research and former GDR reactors – is 25 GW$_e$[50], which leads to an estimation of 1.16 million €$_{2012}$/MW$_e$.

Hungary - In Hungary, the total estimated decommissioning cost ranges between €$_{2012}$ 2.9 billion[51] and €$_{2012}$ 3.55 billion[28]. In 2004, the Central Nuclear Financial Fund accumulated €$_{2012}$ 261 million. The fund is managed by the Hungarian Atomic Energy Authority, which is independent from the NPPOs. The fund is filled by a share of the electricity price, contributions from nuclear waste producers and contribution from the state budget. Hungary has an installed generating capacity of 1889 MW$_e$[52], which means the decommissioning cost can be estimated at 1.53-1.88 million €$_{2012}$/MW$_e$.

Italy - The estimated cost for decommissioning ranges between €$_{2012}$ 3.6 billion[28] and €$_{2012}$ 4.47 billion[53]. Circa €$_{2012}$ 1500 million was available in the fund in 2004, managed by the state owned company SOGIN. More specifically, the Caorso NPP in Italy is currently in the safe storage mode.

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[41] http://www.ccomptes.fr/content/download/43709/697228/version/2/file/thematic_public_report_costs_nuclear_+power_sector_012012.pdf
[42] http://www.cea.fr/content/download/4858/28999/file/clefs55_p038_044_Garnier.pdf
[43] http://www.iaea.org/PRIS/CountryStatistics/CountryDetails.aspx?current=FR
[44] http://www.world-nuclear.org/info/nuclear-fuel-cycle/nuclear-wastes/decommissioning-nuclear-facilities/
[45] http://de.atomkraftwerkeplag.wikia.com/wiki/Greifswald/Lubmin_%28Mecklenburg-Vorpommern%29
[46] Finnish Energy Industries (2013). Study on the status of the nuclear power sector and its future in the European Union
[47] European Parliament (2013). Nuclear decommissioning: Management of costs and risks.
[48] http://epub.wupperinst.org/files/2604/2604_EUDecommFunds_DE.pdf
[49] http://www.iaea.org/PRIS/CountryStatistics/CountryDetails.aspx?current=DE
[50] http://www.iaea.org/PRIS/CountryStatistics/CountryDetails.aspx?current=DE
[51] http://epub.wupperinst.org/files/2600/2600_EUDecommFunds_HU.pdf
[52] http://www.iaea.org/PRIS/CountryStatistics/CountryDetails.aspx?current=HU
[53] http://epub.wupperinst.org/files/2596/2596_EUDecommFunds_IT.pdf

The generating capacity is 860 MW_e, and the total cost for decommissioning is estimated at $€_{2012}$ 450 million for dismantling the structure and 300 million euro for waste management, altogether 0.87 million $€_{2012}/MW_e$[54]. The total Italian installed capacity is 1423 MWe[55,56], which leads to an estimated 2.53-3.14 million $€_{2012}/MW_e$ for decommissioning costs.

Lithuania - The estimated costs for decommissioning in Lithuania ranges between $€_{2012}$ 2.5 billion[28] and $€_{2012}$ 4.0 billion[57], of which $€_{2012}$ 354 million was available in the central state fund in 2004. The fund is fed with 6% of the yearly Ignalina NPPs revenue. In addition, substantial contribution is given by the EC and other donors, which is also described in the section on historic subsidies below. The total installed generating capacity is 2370 MW_e[58,59], estimating the decommission costs at 1.07-1.69 million $€_{2012}/MW_e$.

The Netherlands - The total estimated cost for decommissioning in the Netherlands is $€_{2012}$ 1.87 billion[28]. The Dutch fund for waste management is transferred to the State. The NPPOs are responsible for the other decommissioning funding. The decommissioning of the Dodewaard NPP (58 MWe) started in 2002, and in 2005 all spent fuel was removed. The decommissioning of the remaining structure is done in 40 years. The estimated total cost is $€_{2012}$ 194 million[60], leading to an estimated 3.35 million $€_{2012}/MW_e$. The installed generating capacity is 537 MW_e[61,62], and decommissioning cost can be estimated at 3.48 million $€_{2012}/MW_e$.

Poland – although there are currently no NPPs in Poland, in 2005 the Polish Government adopted a nuclear power introduction plan to diversify their energy supply and reduce carbon emissions. By the end of 2018, all approvals for construction should be there. The first unit should be completed by 2025, a second NPP is scheduled for 2035. A total generating capacity of around 3000 MW_e is to be developed. The costs associated with the first unit is roughly estimated a € 1 billion[63,64].

Romania - Good and complete cost estimates for Romania could not be found. Therefore, Romania is not further described in this section.

Slovakia - In Slovakia, the cost estimate for decommissioning is $€_{2012}$ 4.2 billion[28]. The centralised state fund had about $€_{2012}$ 408 million for decommissioning available in 2004, of which about 20% stems from the international Bohunice Decommissioning Support Fund. The decommissioning cost of the NPP V1 J. Bohunice plant (two reactors, together 816 MW_e) was estimated at $€_{2012}$ 2.2 billion[65], or 2.7 million $€_{2012}/MW_e$. The total installed capacity in Slovakia is 2724 MW_e[66] (excluding the additional 880 MW_e that is currently under construction), which leads to an estimated 1.54 million $€_{2012}/MW_e$ for decommissioning.

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54 http://www.tecnosophia.org/documenti/Articoli/SessioneI/Guerzoni.pdf
55 http://www.iaea.org/PRIS/CountryStatistics/CountryDetails.aspx?current=IT
56 http://www.world-nuclear.org/info/Country-Profiles/Countries-G-N/Italy/
57 http://epub.wupperinst.org/files/2607/2607_EUDecommFunds_LT.pdf
58 http://www.iaea.org/PRIS/CountryStatistics/CountryDetails.aspx?current=LT
59 http://www.world-nuclear.org/info/Country-Profiles/Countries-G-N/Lithuania/
60 http://epub.wupperinst.org/files/2602/2602_EUDecommFunds_NL.pdf
61 http://epub.wupperinst.org/frontdoor/index/index/docId/2602
62 http://www.world-nuclear.org/info/Country-Profiles/Countries-G-N/Netherlands/
63 http://www.world-nuclear-news.org/NP-Polish-cabinet-approves-new-nuclear-plan-2901144.html
64 http://www.ekonomia.rp.pl/artykul/526104,1138085-PGE---umowa-sprzedazy-udzialow-w-atomowej-spolce.html
65 http://epub.wupperinst.org/files/2605/2605_EUDecommFunds_SK.pdf
66 http://www.iaea.org/PRIS/CountryStatistics/CountryDetails.aspx?current=SK

Slovenia - The cost of decommissioning in Slovenia is estimated at €$_{2012}$ 1.4 billion[28,67]. €$_{2012}$ 104 million was present in 2004 in the dedicated Slovenian fund, which is filled with a levy on the produced electricity. The fund is managed by a specific agency. The only NPP in Slovenia is the Westinghouse NPP in Krsko (696 MW_e), and jointly owned by Croatia and Slovenia. When assuming that the total estimated cost is for the whole NPP, the decommissioning cost is estimated at 2.0 million €$_{2012}$/MW_e.

Spain - In Spain the estimated decommissioning cost ranges between €$_{2012}$ 11.0 billion[68] and €$_{2012}$ 13.3 billion[28]. The state company ENRESA holds and manages the fund that by the end of 2003 had accumulated to €$_{2012}$ 1.73 billion. The fund is supplemented by a share of the electricity price. In addition, a tax is paid based on the nuclear waste generated. The generating capacity in Spain was 8.2 GW in 2011[69,70], which leads to an estimated decommissioning cost of 1.34-1.62 million €$_{2012}$/MW_e.

Sweden - The total cost for decommissioning of the Swedish NPPs are estimated at €$_{2012}$ 8.2 billion[28], of which about 20% is already used for decommissioning. The amount available in the decommissioning fund in 2004 is enough to cover 100% of the decommissioning costs. The fund is managed by the state, independent from the NPPOs, and is funded with a share of the electricity price with a nuclear origin. The installed capacity is 10.6 GW_e[71,72], which leads to an estimated 0.77 million €$_{2012}$/MW_e.

United Kingdom - In the UK, the estimated costs for decommissioning ranges between €$_{2012}$ 75 billion[28] and €$_{2012}$ 110 billion[73]. More specifically, the cost to decommission the Magnox NPPs is roughly estimated around 20 billion pound (~25 billion €). There are 11 sites with Magnox NPPs in the UK, with a combined generating capacity of approximately 4400 MW_e. This translates in decommissioning costs of 5.68 million €$_{2012}$/MW_e. The cost to decommission the NPP (276 MW_e) at the site in Berkeley is estimated around €$_{2012}$ 500 million (1.8 million €$_{2012}$/MW_e)[74].

The total installed generating capacity is 13.456 GW_e[75,76], which leads to an estimated 5.57-8.17 million €$_{2012}$/MW_e for decommissioning. This is much higher than the estimates found in other countries, which may relate to the inclusion of decommissioning of military nuclear facilities and the cost of decommissioning and waste associated with reprocessing of fuels.

A2.9.5 Member State summary and comparison with actual costs

In brief, when the cost is expressed in terms of generating capacity, the estimated costs for decommissioning and waste management range from 0.32 million €$_{2012}$/MWe (Czech Republic) to 3.48 million €$_{2012}$/MW_e (the Netherlands), summarised in the table below. This range excludes estimations for specific sites and the UK due to inclusion of military facilities. The average decommissioning cost is calculated at 1.43 million €$_{2012}$/MWe.

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67 http://epub.wupperinst.org/files/2603/2603_EUDecommFunds_SI.pdf
68 http://epub.wupperinst.org/files/2597/2597_EUDecommFunds_ES.pdf
69 http://www.iaea.org/PRIS/CountryStatistics/CountryDetails.aspx?current=ES
70 http://www.world-nuclear.org/info/Country-Profiles/Countries-O-S/Spain/
71 http://www.iaea.org/PRIS/CountryStatistics/CountryDetails.aspx?current=SE
72 http://www.world-nuclear.org/info/Country-Profiles/Countries-O-S/Sweden/
73 http://epub.wupperinst.org/files/2598/2598_EUDecommFunds_UK.pdf
74 http://www.magnoxsites.co.uk/what-we-do/our-phases-of-work-overview/fsc/
75 http://www.iaea.org/PRIS/CountryStatistics/CountryDetails.aspx?current=GB
76 http://www.world-nuclear.org/info/Country-Profiles/Countries-T-Z/United-Kingdom/

Only few examples of decommissioning NPPs are present, and the examples that do exist are primarily pilot, small-scale projects. In addition to the EU examples given above, there exist some examples in the USA of completely decommissioned NPPs. The Yankee Rowe site was shut down in 1992, and its decommissioning was completed in 2007. The generating capacity was 185 MW_e, and decommissioning cost (excluding operational storage expenditure) was US$671 $million_{2012}$ (~500 million $€_{2012}$)[77], meaning 2.7 million $€_{2012}/MW_e$. The small Shippingport Atomic Power Station (60MW_e) was completely decommissioned in 1990 at a cost of $170 $million_{2012}$, or 2.1 million $€_{2012}/MW_e$[78] The Maine Yankee power plant had a generating capacity of 931 MW_e, and the cost were estimated at $763 $million_{2012}$, or $€_{2012}$ 0.61 million[79]. The Connecticut Yankee power plant (619 MW_e) was decommissioned in 2004 at a cost of $986 $million_{2012}$[80], or $€_{2012}$ 1.2 million. These figures are summarised in the table below and the result in an average of 1.65 million $€_{2012}/MW_e$. This figure fits well with the EU average found in the table above.

Table A2-10: United States decommissioned sites and their actual decommissioning costs

United States decommissioned sites	Decommission cost (in million $€_{2012}$ per MW_e)
Yankee Rowe	2.7
Shippingport Atomic Power Station	2.1
Maine Yankee power plant	0.61
Connecticut Yankee power plant	1.2
Average	**1.65**

Table A2-11: Summary of the reported decommission costs

Member State	Decommissioning cost ($M€_{2012}/MWe$)
Belgium	0.87
	1.67
Bulgaria	0.83
	0.86
Czech Republic	0.32
	0.81
Finland	0.52
	0.54
France (general)	1.3
France (specific sites)	3
	7.1
Germany (general)	1.16
Germany (specific sites)	0.683
	2.5
	4.5
	0.47
Hungary	1.53
	1.88

[77] http://www.yankeerowe.com/decommissioning.html
[78] http://www.osti.gov/scitech/biblio/5660448
[79] http://www.maineyankee.com/public/pdfs/epri/my%20epri%20report-2005.pdf
[80] http://www.connyankee.com/html/decommissioning.html

Member State	Decommissioning cost (M€$_{2012}$/MWe)
Italy (general)	2.53
	3.14
Italy (specific site)	0.87
Lithuania	1.07
	1.69
The Netherlands (general)	3.48
The Netherlands (specific site)	3.35
Slovakia (general)	1.54
Slovakia (specific site)	2.7
Slovenia	2.0
Spain	1.34
	1.62
Sweden	0.77
United Kingdom (general)	5.57
	8.17
United Kingdom (specific site)	5.68
Average (without specific sites and the UK)	**1.43**

A2.9.6 Conclusion: intervention for nuclear decommissioning and waste disposal

As discussed above underestimation of the actual decommissioning costs could result in the need to subsidise the gap in the future and could represent an intervention now because NPPOs might not be prepaying sufficient funds. Naturally, there are many factors that influence the real cost, such as location, type of reactor (amount of radioactive equipment), age and size (economy of scale). However, due to uncertainties and lack of data, robust conclusions on the intervention value cannot be derived although given the range it is likely that there is some Government intervention. The uncertainties are partly demonstrated by the relatively large range of cost estimations found for a country or even a single site.
It is our assumption that a cost estimation lower than 0.8 million €$_{2012}$/MW$_e$ should be considered as an intervention. This conservative threshold is based on our expert judgement and was verified through five interviews with European nuclear experts. In addition to the uncertainty in the cost estimations, a proper multivariate analysis cannot be conducted due to a lack of data. Because of uncertainty in cost estimations for decommissioning certain nuclear technologies, various waste cycles, and variation in for instance labour, capital and resource costs, this threshold cannot be further broken down in a sensible way. Calculating the value of the intervention gives the results below and a total value for this risk transfer intervention of approximately €$_{2012}$ 3 billion. This is small compared to the other interventions identified in this project, particularly as this is not an annual figure but total.

Table A2-12: Risk-transfer intervention for nuclear decommissioning and waste disposal

Member State	Capacity (MW$_e$)	Intervention based on € 0.8 million
Czech Republic	3848	1850
Finland	1770	500
Sweden	11036	330
Total	**16654**	**2680**

It must be noted that in case of an underestimation, the supposed or hidden subsidy is neither typical nor structural, and is only given ad hoc, i.e. when existing funding for decommissioning is insufficient. In addition, we are well aware of the uncertainty of this number, which is also reflected in the difference between estimates in the various studies referenced, and therefore have to be treated with due care.

In addition to the inexperience with commercial-scale decommissioning, the uncertainty is further enlarged by uncertainty in the presented figures, often being outdated (around 2002 - 2004), and unclarity whether the figures are nominal (and if so, which year) or real (and if so, which interest rate is applied). However, the impact of decommissioning on the overall cost in net present value associated with nuclear energy is limited due to the discounting effect, because decommissioning takes a long time before it is complete.

In conclusion, all Member States have laid the first responsibility for decommissioning and associated finance at the NPPOs and funds are being accumulated in all countries. The EC is also monitoring the availability of funding. In principle, it should be possible to assess whether the funds are accumulating at the rate needed to meet the estimated decommissioning and waste costs. However, it is difficult to obtain up to date and comparable data on these funds in every Member State so it was not possible to do this in this study.

A2.10 Historic interventions

A2.10.1 Historic investment support

Methodology

This section describes the methodology used to estimate the intervention of historic investment support following the approach of Oosterhuis (2001)[81]. By applying the methodology as described below we assume that for all high capital, low marginal cost generating capacity built in the period before the establishment of liberalised electricity markets a Government required lower rate of returns than commercial companies would. This lower required rate of return results in a lower Weighted Average Cost of Capital (WACC) and hence lower LCoE for the given technology. The difference in LCoE is assumed to be the intervention.

<u>Input parameters</u>

There are four fixed input parameters and three yearly varying input parameters used to model historic investment support:

- **Fixed input parameters**
  1. WACC for Governments in a non-liberalized electricity market (%).
  2. WACC for commercial companies in a liberalized electricity market (%).
  3. Depreciation period (years).
  4. Full load hours (hours).
- **Varying input parameters (yearly)**
  1. Capacity built (MW).
  2. CAPEX per technology (€ 2012/kW).
  3. EU electricity market liberalisation (0 – 100%).

[81] Oosterhuis, F. (2001), Energy subsidies in the European Union. Final Report, European Parliament, July 2001.

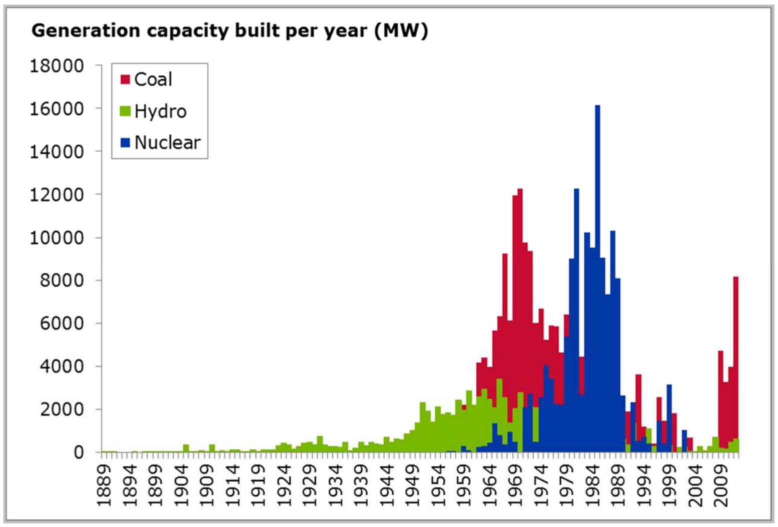
Fixed input parameters are kept constant throughout the years. They have been presented in paragraph 3.1.2 of the main report, and given in the table below.

Table A2-13: Assumption of historic EU28 WACC in a non-liberalized and liberalized electricity market, depreciation period and full load hours for coal, hydro and nuclear generating capacity.

	Coal	Hydro	Nuclear
WACC Non-Liberalized	5.0%	5.0%	5.0%
WACC Liberalized	7.5%	6.0%	8.0%
Depreciation period [years]	20	25	25
Full Load Hours	4127	3405	6785

Yearly varying input parameters are treated in more detail below.

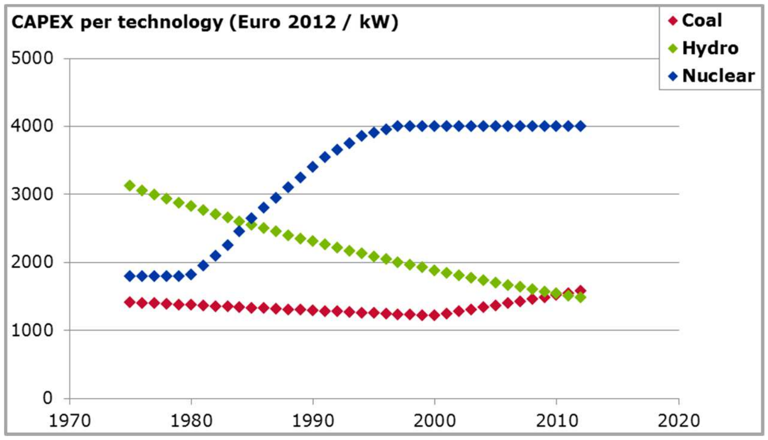
1. **Capacity built per year** (MW) is taken from PLATTS World Electric Power Plants Database. The data goes back to 1889 and is given for 26 EU countries per technology. An EU wide overview of capacity built per technology is given in the figure below.



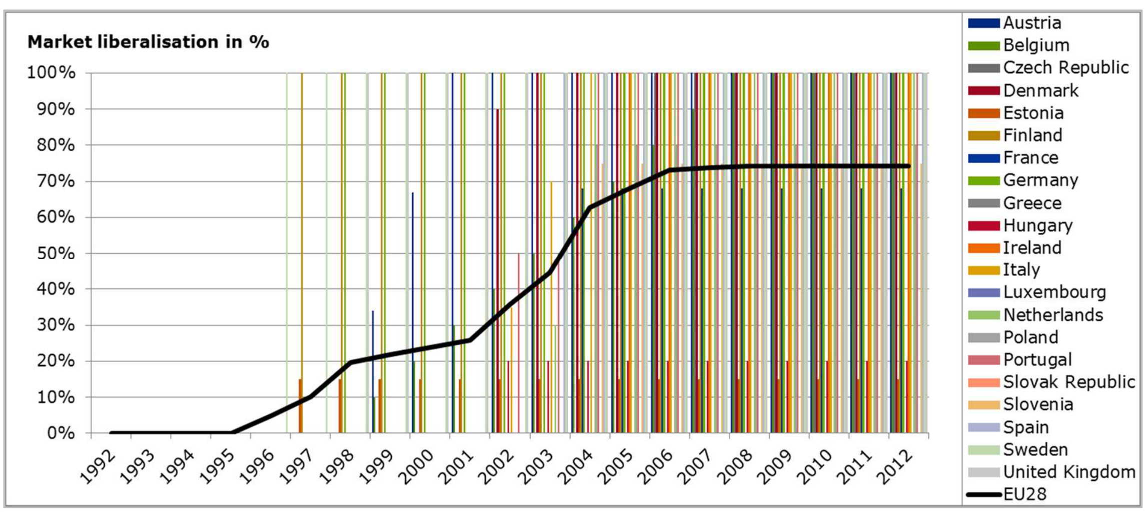
2. **CAPEX per technology per year** (€2012/kW) is estimated through interpolation of literature results and expert judgement[82]. CAPEX for hydropower varies significantly more than coal and nuclear CAPEX as it is highly dependent on the site, design choices and local labour costs (IRENA, 2012)[83]. For hydropower we have therefore assumed a flat learning rate. The yearly varying costs for the different technologies are illustrated in the figure below. CAPEX values before 1975 are kept equal to the values from 1975 due to a lack of literature from the years before.

[82] As an example, the following literature sources were included in developing costs trends for coal and nuclear generation capacity: Komanoff (1981), EPRI (1981), IEA WEOs, Hendriks et al. (2004), IEA ETSAP (2010), D'haeseleer (2013) and others.

[83] IRENA 2012: Renewable Energy Technologies: Cost Analyis Series : Hydropower



3. **EU electricity market liberalisation (0-100%)** is treated as a multiplication factor (in %) over capacity built in a particular year. National electricity markets were not liberalised at once, but more often gradually. This gradual liberalisation of the electricity market is represented by the percentage 0% to 100% liberalised per Member State and multiplied with the capacity built in a certain year. This way, we include the timing aspect of the difference in WACC between investments of Governments in a non-liberalised electricity market versus investments by commercial companies in a liberalised electricity market.
The percentage of liberalised electricity market is based on published data from the European Commission in the "Technical Annex to the Report from the Commission to the Council and the European Parliament on Progress in Creating the Internal Gas and Electricity Market (2005)"[84].



Calculations

Historic investment support is calculated per year and per generation technology based on the CAPEX costs, depreciation period, difference in WACC, full load hours and the multiplication factor from the EU market liberalisation. Note that only the CAPEX costs and multiplication factor vary per year. Using this methodology to calculate historic investment support we allow it to be expressed as €/MWh, as for the other interventions in this study.

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[84] Other literature sources on EU electricity market liberalisation include Eurelectric (2002), Greenpeace (2000) and CEER (2004). For Member States where electricity market liberalisation data was not available, we assumed the EU average.

Whenever capacity is built for a certain technology in a certain year the historic investment support is given by the capacity in MW multiplied by its full load hours and support in €/MWh. Support for this generating capacity is continued up to full depreciation after its depreciation period. Therefore, historic investment support of a certain technology effective in 2012 only comes from generating capacity built after the year 2012 minus the depreciation period of that technology[85].

Results

Interventions from risk transfer to Government

The figure below shows results from 1950 up to 2012, it shows the following trends:

- Installed hydropower capacity has been increasing most rapidly up to the 1970s. Beyond those years installation of hydropower capacity decreased, and as depreciation periods for earlier hydropower plants ended the effect of historic investment support due to hydropower installation is relatively low in 2012.
- Coal fired power plants have mostly been built between the 1960s and 1990s. As for hydropower plants, most of them have been depreciated by 2012, therefore relatively not adding a large sum to 2012 historic investment support. Although there has been an increase again in coal-fired generation capacity added since 2008, the effect is relatively little due to the fact that most of the EU electricity markets had been liberalised to a large extend.
- Most nuclear power has been installed between the years 1970 and 2000. The more recent installation of nuclear generation capacity, the higher CAPEX values, and the higher difference in WACC values make that nuclear generation capacity adds most to the 2012 historic investment support (79%, as shown in paragraph 3.1.2 of the main report).

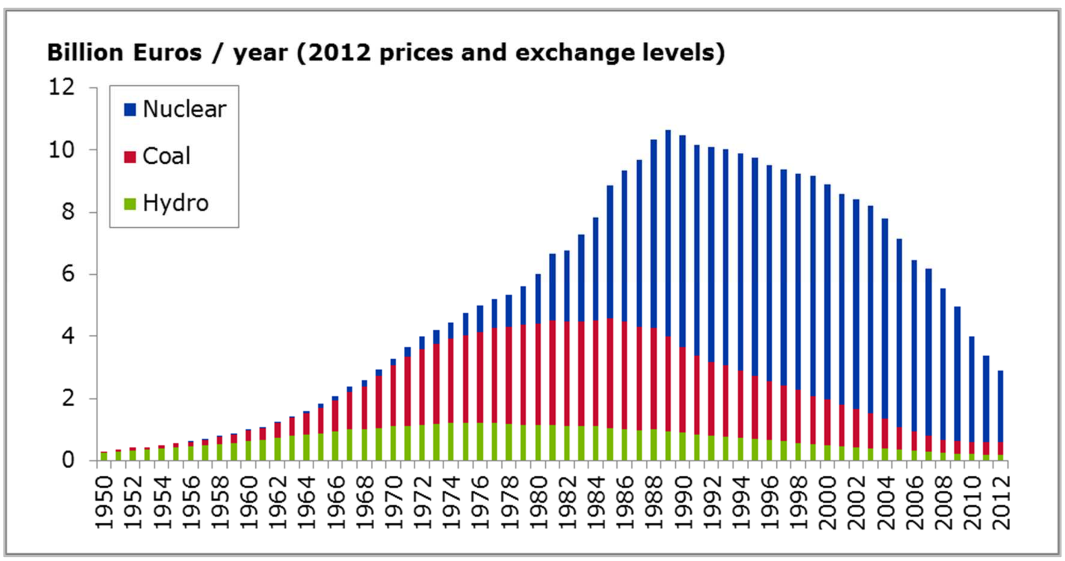

Figure A2-17: Historic investment support for the years 1950 - 2012

For 2012 historic investment support, a breakdown per Member State is given in the figure below. Most historic investment support is associated with nuclear generation capacity built in France and the United Kingdom.

[85] Therefore also justifying the choice not to include a detailed assessment on CAPEX costs prior to 1975: 2012 minus depreciation period is over 1975 for all technologies considered.

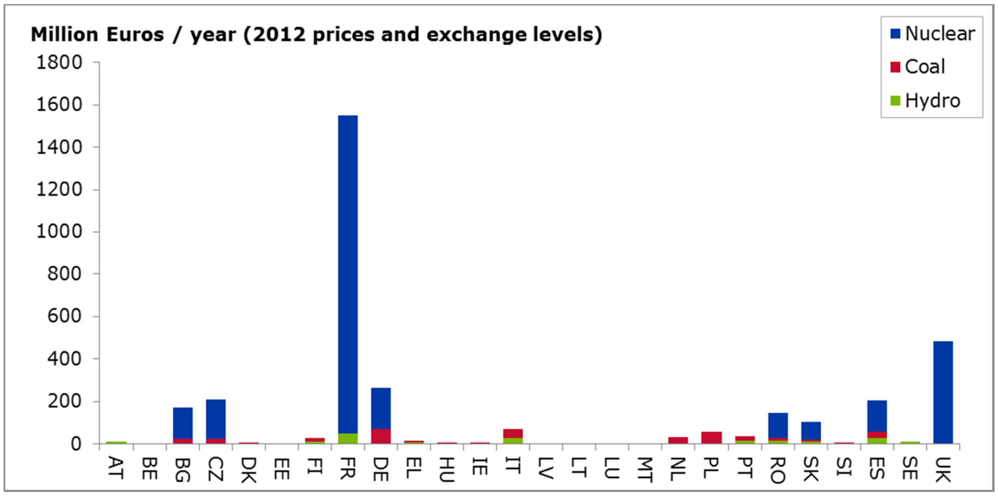

Figure A2-18: Breakdown of historic investment support per technology for the year 2012 per Member State.

A2.10.2 Historic energy related R&D expenditure

The figures below depict how R&D expenditures for renewable, fossil and nuclear fission have developed over the past decades.

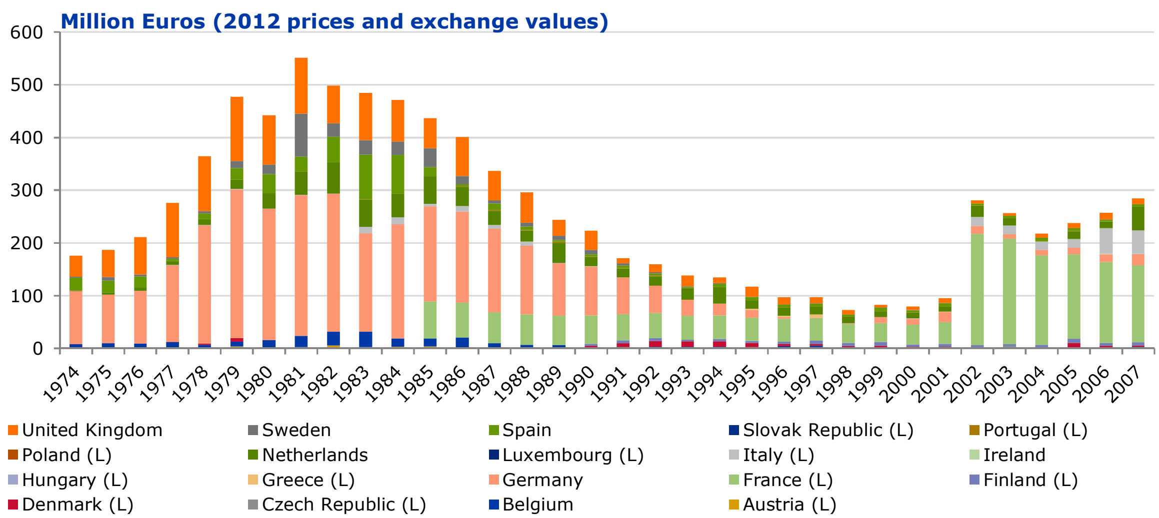

Figure A2-19: Development of annual RD&D fossil energy expenditure per EU Member State in 1974 - 2007. Countries which are superseded by "(L)" have not provided data in all or some of the years shown.

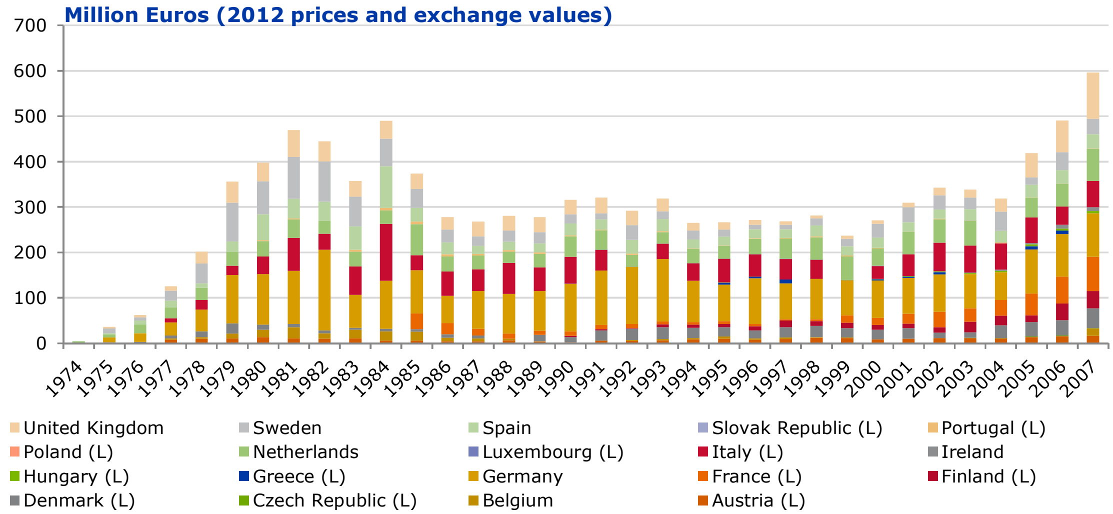

Figure A2-20: Development of annual RD&D renewable energy expenditure per EU Member State in 1974 - 2007. Countries which are superseded by "(L)" have not provided data in all or some of the years shown.

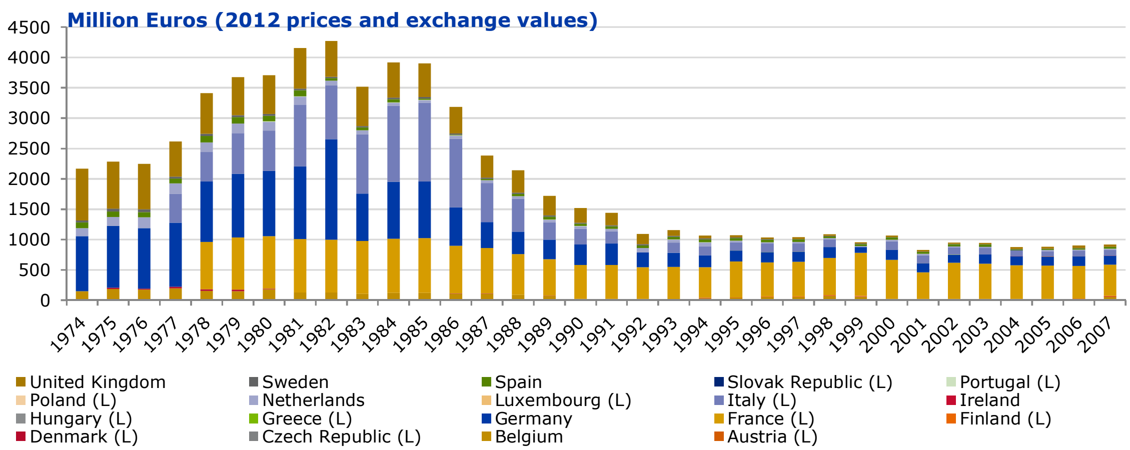

Figure A2-21: Development of annual RD&D nuclear fission energy expenditure per EU Member State in 1974 - 2008. Countries which are superseded by "(L)" have not provided data in all or some of the years shown.

A2.10.3 Production support to coal

This paragraph describes the methodology of estimating support to coal production in the EU-28. We assume that this is the main historic subsidy provided for "other" types of support. Four steps are used to estimate historic cumulative coal support per Member State:

1. Identification of main coal producers.
2. Reconstruction of domestic coal price and import price.
3. Assessment of support per Member State per year.
4. Calculation of cumulative support to coal production.

Identification of main coal producers

The main coal producing countries are identified through the IEA database. The 11 largest producers of coal in the years 1970 – 2007 are identified in the table below. We choose a cut-off for the list at 100.000 ktoe.

The main coal producers in the years considered are Germany and Poland, accounting for over 62% of the total coal production. The UK and Czech Republic account for 25% of total coal productions, and 13% is produced by the remaining countries.

Table A2-14: Cumulative coal production in ktoe over the years 1970 – 2006

Country	Production [ktoe]
Germany	4,124,688
Poland	3,719,901
United Kingdom	1,830,594
Czech Republic	1,257,192
France	360,015
Spain	352,350
Romania	279,783
Greece	210,093
Bulgaria	183,907
Hungary	170,914
Belgium	104,908

Reconstruction of domestic coal price and import price

Both domestic coal prices and import prices are based on literature research and given in the graph below. Data on domestic coal prices is scarce. The table below indicates our main literature sources and the bullets below identify the incorporated assumptions:

- Interpolation is used when sources of overlapping years diverge;
- When data was not available for a Member State in a specific year, extrapolation is used for the previous or subsequent years based on data for Member States that were available. For example domestic prices for the years prior to 1983 have been based on trends seen in the German data;
- Not much data for the eastern EU Member States was found, however the general it is documented that significant subsidies have only come available in the more recent years.

We do note that the methodology of reconstructing domestic coal prices has high uncertainty. However, the described methodology allows us to create the most complete picture of historic subsidies to coal production for all EU Member States.

Table A2-15: Data availability (source and years available) on domestic coal production prices and imported coal prices.

<table>
<tr><th></th><th>Ecorys /EC[86]</th><th>Radetzki/EC[87]</th><th>RWI[88]</th><th>OECD[89]</th><th>OECD[90]</th><th>OECD[91]</th><th>Greenpeace[92]</th></tr>
<tr><td>Germany</td><td rowspan="6">2006 – 2007</td><td rowspan="4">1987 – 1993</td><td>1970 – 2005</td><td rowspan="4">1991 – 2000</td><td rowspan="4">1985 – 1996</td><td rowspan="4">1983 – 1996</td><td></td></tr>
<tr><td>UK</td><td></td><td></td></tr>
<tr><td>France</td><td></td><td></td></tr>
<tr><td>Spain</td><td></td><td></td></tr>
<tr><td>Eastern EU</td><td></td><td></td><td></td><td></td><td></td><td>1990 – 2007</td></tr>
<tr><td>Import price</td><td>1987 – 1993</td><td>1970 – 2005</td><td></td><td></td><td></td><td></td></tr>
</table>

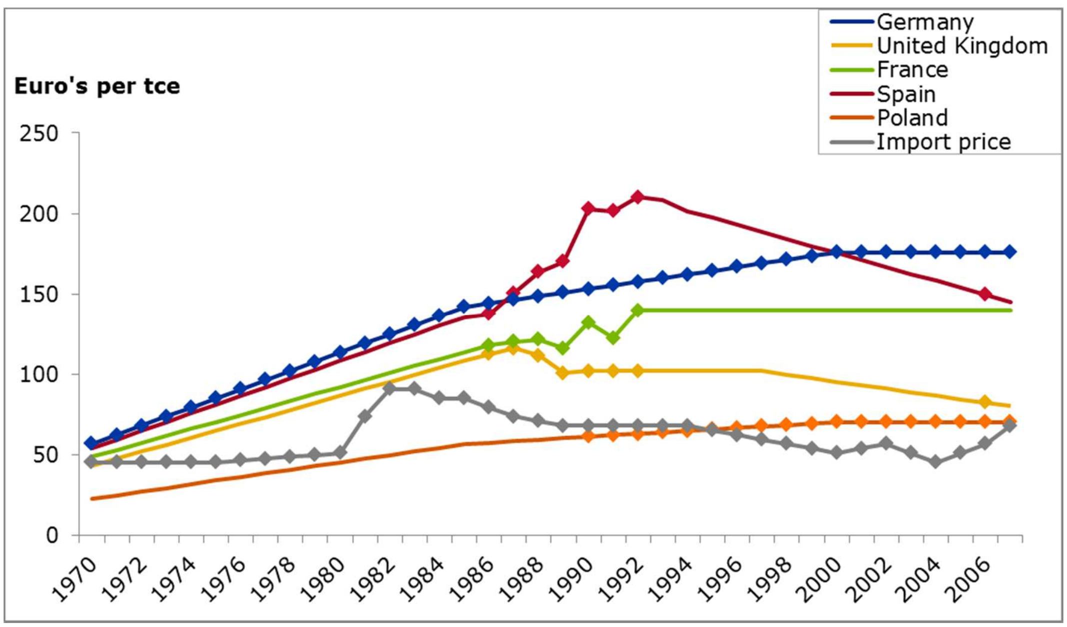

Figure A2-22: Literature sources and data on coal production prices. The table above shows the years for which data was available; the graph shows production prices as lines (estimated); dots indicate data points.

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86 Ecorys Nederland BV. for the European Commission (2008): An evaluation of the Needs for State Aid to the Coal Industry post 2010.
87 EC, Commission Report on the Application of the Community Rules for State Aid to the Coal Industry, Brussels, annual; IEA, Coal Information 1993, OECD, Paris. From: Marian Radetzki (1995): Elimination of West European coal subsidies.
88 Rheinisch-Westfalisches Institut fur Wirtschaftsforschung (RWI) (2006): Hard Coal Subsidies: A Never-Ending Story?
89 OECD (2005): Environmentally harmful Subsidies. Challenges for reform.
90 OECD (1999): Economic Surveys: Labour and product markets enhancing environmentally sustainable growth.
91 OECD (1998): Improving the environment through reducing subsidies: Part 1.
92 Greenpeace (2014): Subsidizing the past.

A2.10.4 Assessment of support per Member States per year

In this step we calculate the estimated support by multiplying the difference in domestic price and import price with the total production per Member State per year. The results are given in the figure below. We elaborate on a couple of trends identified:

- Support builds through the 1970's: domestic coal prices were very similar to import prices for all the MS, but this difference increase, as domestic prices increase but import prices remain equal trough the 1970's;
- The dip in the 1980 is due to the increase of coal prices following the oil crisis: the import price of coal increased much faster compared to the domestic prices, therefore decreasing estimated subsidy;
- Eastern European countries only saw domestic coal prices exceed import prices from the late 1990's onward, which is when the estimate of subsidy is seen;
- All Member States decrease their coal production from around 1990 onward, which results in a sign decrease in the total support towards 2007.

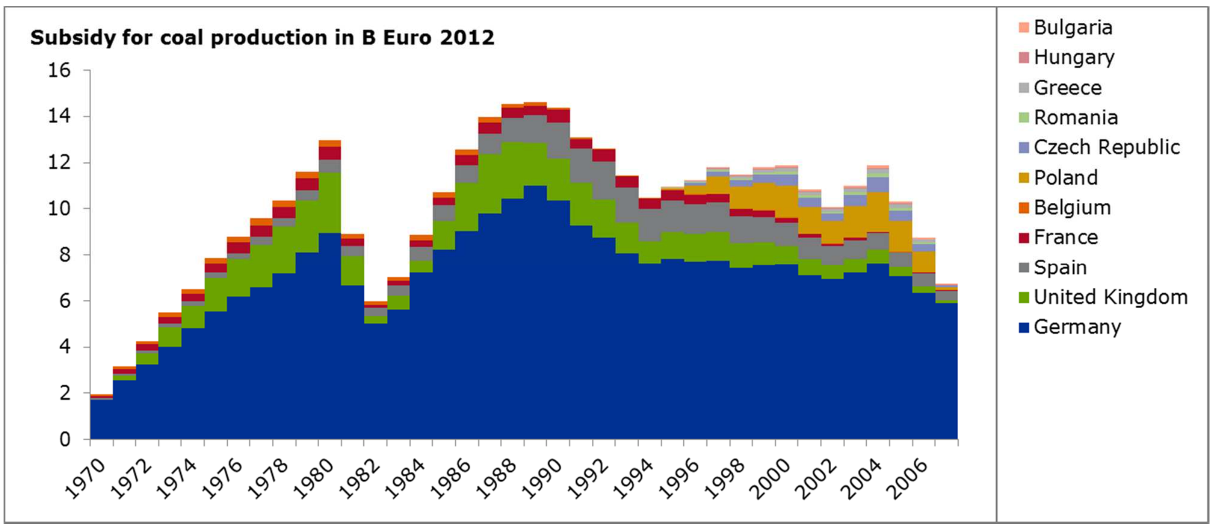

Figure A2-23: Coal production in billion €2012 for the main coal producing countries of the EU 28.

Calculation of cumulative support

Yearly support is cumulated from the 1970 – 2007 to reach the values presented in the main report and copied below. We note the following results:

- Historic support to coal production for the EU28 is estimated at about € 10 billion per year in the years 1970 – 2007, but decreasing from 2000 onward. Most estimated support is allocated to Germany, which accounted for 71% of the total cumulative support in the years 1970 – 2012.
- Domestic prices for coal increased for all Member States relative to import prices throughout the years, which means that production in later years account to higher support estimates. This explains for instance the difference in support between Spain and France: even though their cumulative production is similar, Spain has been producing more coal in the recent years, while France has brought production down to almost zero.
- Domestic prices of coal production are much higher for the western European countries compared to the eastern European countries. For example, Poland produced a similar amount of coal compared to Germany. However, Poland was able to produce coal at very similar prices to the import price up to recent years, leading to a relatively low estimate of cumulative required support.

On the other hand, Germany has had a sharp increase in domestic coal prices throughout the 1970's, up to almost three times the import price, which leads to high estimates of required subsidy.

- When we compare the values in the table below to literature sources they are very much in line, although our estimates are slightly higher:
    - OECD (1998, 1999, 2005) documents a coal support for Germany from 1982 to 2000 increasing to about 8 Billion USD (about 10 Billion €) in the first years and decreasing to about 5 Billion USD (about 6 Billion €) in 2000; for the UK diminishing from an average of 3-4 Billion USD (4-5 Billion €) to almost 0; and for Spain averaging to about 1 Billion (about 1 Billion €) per year.
    - IEA (1987) documents increasing subsidies up to 5.8 Billion USD (7.9 Billion €) in 198\7 for Germany, 3.4 Billion USD (4.7 Billion €) in 1987 for the UK and about 0.4 Billion USD (0.5 Billion €) in 1987 for Belgium.
    - Greenpeace (2014) estimates an average support to coal production in Poland at about 0.45 Billion € from the 1990 - 2007.

Table 2-16: Estimated cumulative coal support for the EU28 Member States with cumulative coal production over 100.000 ktoe.

Country	Cumulative coal support [billion €2012]
Germany	270
United Kingdom	45
Spain	29
France	12
Belgium	5
Poland	12
Czech Republic	4
Romania	1
Greece	1
Hungary	0
Bulgaria	1

A2.10.5 Production support to renewables

The methodology used followed the funding gap approach, in which the gap between retail electricity prices and the levelised costs of renewables was used as an estimate of the historic production support. The funding gap was estimated based on the data we obtained from the Member States in the period 2008 - 2012. This was applied to production data from Eurostat for the period 1990 - 2007 for hydro and 2000 - 2007 for wind, solar and bio.

A2.10.6 Ad-hoc Historic subsidies for nuclear decommissioning

In the section below, examples are given of cases where the national government intervened, and where it provided subsidies for the decommissioning of NPPs. In cases where the NPP is state owned or the Government is the majority shareholder, the bill is picked up by the Government in any case, and when the costs exceed the budgeted funds, the remaining decommissioning costs are de facto subsidised, assuming there is no unexpected additional income.

The EU Nuclear Decommissioning Assistance Programme provides financial support for the early closure of NPPs in Slovakia, Lithuania and Bulgaria. The total funding of the programme in the period 1999 - 2020 is foreseen at an amount of €$_{2012}$ 3816 million, to which the EC is the main contributor. The programme is managed by the EBRD[93,94]. In Slovakia specifically, the Bohunice International Decommissioning Support Fund (BIDSF) was established under the Programme to compensate a deficit resulting from early closure of two units in Bohunice. The BIDSF is managed by the Slovak Government and the European Bank for Reconstruction and Development (EBRD). The historical deficit in 2010 was €$_{2012}$ 2.36 billion[95].

In the UK, the Nuclear Decommissioning Authority (NDA) was established in 2004. This public authority was created to manage the decommissioning of NPPs in the United Kingdom. In case the NPPOs cannot match their liabilities, the UK Government will cover the shortfall. The NDA's yearly budget is £ 3.2 billion, of which 2.3 billion pounds stem from a Government grant-in-aid[96]. The EC conducted an in-depth investigation with the aim to explore to what extent the state aid was justified. The EC concluded that the measure is in line with the objectives of the EURATOM Treaty, and the NDA was allowed to exist following some specific alterations and conditions[97,98].

It must be mentioned, that these cost include decommissioning of military fields and waste disposal as well. Unfortunately, data are lacking to split the civil and military part.

In the extensive report of Cour de Comptes (2012)[99], the costs of the French nuclear power sector are detailed. The yearly public expenditure totals €$_{2012}$ 644 million in 2010, of which €$_{2012}$ 230 million was spent on security and safety (including decommissioning and waste management). The other €$_{2012}$ 414 million is spent on research[41]. Furthermore, in France, the decommission provisions are tax deductible[100].

The German Government granted in total €$_{2012}$ 2430 million until 2009 for decommissioning, including their decommissioning pilot projects[101].

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93 http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2013:346:0007:0011:EN:PDF
94 http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32013R1368&from=EN
95 http://ec.europa.eu/competition/state_aid/cases/238200/238200_1431108_203_3.pdf
96 http://www.nda.gov.uk/what-we-do/#our-budget
97 http://europa.eu/rapid/press-release_IP-04-1430_en.htm?locale=fr
98 http://ec.europa.eu/competition/state_aid/register/ii/by_case_nr_224.html#19337
99 http://www.ccomptes.fr/content/download/43709/697228/version/2/file/thematic_public_report_costs_nuclear_+power_sector_012012.pdf
100 http://ec.europa.eu/energy/nuclear/decommissioning/doc/03_2007_decommissioning_comparison.pdf
101 Bundesregierung 2010, BT Drs. 17/02646 und BMF 2003/2007/2010.

Annex 3 External costs

This annex provides a detailed description of the External-E tool used to estimate external costs, including the underlying life cycle framework, the derivation of the per unit monetary values and internalised values. It also provides further detailed results per technology and Member State.

A3.1 Detailed methodology

A3.1.1 Life cycle assessment and impact assessments

Life cycle assessment (LCA) is carried out for the group of 'reference' power technologies. An LCA consists of two main steps 1) Life cycle inventory analysis (LCI), in which data are collected on the environmental interventions (resource use and emissions to air, water and soil) occurring in the life cycle of the product from cradle (i.e. raw material extraction) to grave (i.e. waste treatment); and 2) Life cycle impact assessment (LCIA), in which these environmental interventions are classified and translated into environmental impacts (e.g. CO_2 and methane emissions are converted into carbon dioxide equivalents). We carried out these two steps by using the LCA software SimaPro.

LCI data for the reference technologies are taken from the latest Ecoinvent databases[102] (version 2.2 for fossil-based technologies and version 3.01 for renewable electricity technologies[103]), which are the most comprehensive LCI databases available. These environmental interventions are across the life cycle stages from raw material acquisition (growth/mining), to transport and combustion/generation and also include environmental interventions occurring outside of the EU. Capital goods are included, for example the impact of steel production that is used in a wind turbine or natural-gas fired power plant. Where available in the Ecoinvent databases, LCI data for specific EU Member States are used, otherwise EU or world average data are selected, or of a similar country we judge as a suitable proxy. The lack of availability of country or region specific datasets for some processes is a source of uncertainty in the results. Another uncertainty is the age of the data for some processes in the Ecoinvent database. Although this is partly corrected for by the country modifications described later in this section, this might lead to an overestimation of some of the impacts if there have been environmental controls implemented since the data was derived.

The specific datasets used for each reference technology can be found in Table A3-1Table A3-1. For some reference technologies, which are not represented in the Ecoinvent database, data for a similar technology are used as a proxy (e.g. the coal-fired CHP is approximated by a coal-fired power plant with adjusted efficiency values). In some cases the datasets are adjusted based on different literature sources or expert knowledge to better reflect the actual power production technologies in the EU. For each dataset, LCIA results excluding upstream energy use occurring within the EU are also generated (see Box A3-1).

[102] Ecoinvent. (2010). Ecoinvent data (version 2.2) and Ecoinvent. (2014). Ecoinvent data (version 3.01) as implemented in SimaPro software (version 8.0.2). Swiss Centre of Life Cycle Inventories.
[103] Datasets for the other technologies were not updated in Ecoinvent version 3.01.

Table A3-1 Overview of Ecoinvent datasets used for external cost calculations of reference technologies

Technology	Ecoinvent version	Dataset(s) used	Country-specific dataset(s) used	Adjustments made to dataset/ Comments
Wind, offshore	3.01	Electricity production, wind, 1-3MW turbine, offshore	NL	Wind power plant requirement per kWh corrected to 1.04E-8 to be consistent with load hours.
Wind, onshore	3.01	Electricity production, wind, 1-3MW turbine, onshore	NL	-
Solar PV, rooftop	3.01	Electricity production, photovoltaic, 3kWp slanted-roof installation, multi-Si, panel, mounted	NL	-
Solar PV, ground (utility)	3.01	Electricity production, photovoltaic, 570kWp open ground installation, multi-Si	NL	-
Hydro, run-of-river	3.01	Electricity production, hydro, run-of-river	AT	-
Hydro, reservoir	3.01	Electricity production, hydro, reservoir, alpine region electricity production, hydro, reservoir, non-alpine region	AT DE	- -
Geothermal	3.01	Electricity production, geothermal	IT, DE	-
Hard coal, power plant	2.2	Hard coal, burned in power plant	AT, BE, CZ, DE, ES, FR, HR, IT, NL, NOR, PL, PT, SK	-
Lignite, power plant	2.2	Lignite, burned in power plant	AT, CZ, DE, ES, FR, EL, HU, PL, SI, SK	-
Oil, power plant	2.2	Heavy fuel oil, burned in power plant	RER*	-
Gas, power plant	2.2	Natural gas, high pressure, at consumer Natural gas, burned in power plant	AT, BE, CZ, DE, DK, EL, ES, FI, FR, HU, IE, IT, NL, RER*,	Additional combinations of upstream fuel and power plant are made.

Technology	Ecoinvent version	Dataset(s) used	Country-specific dataset(s) used	Adjustments made to dataset/ Comments
			SE, SK, UK AT, BE, CEN, DE, ES, FR, IT, LU, NL, NOR, UCT, UK	
Nuclear, power plant	2.2	Electricity, nuclear, at power plant pressure water reactor	DE, FR, UCT	An overestimation of water depletion in this dataset was corrected. Based on the values reported by Dones (2007)[104] 6.1 l water/kWh flowing back to the river or ocean was added to the datasets.[105] Results now in line with water consumption of nuclear power plants as estimated Ecofys (forthcoming)[106]
Biomass, power plant	2.2	Wood chips, burned in cogen 6400kWth, emission control	CH	Wood chips are replaced by wood pellets. PM reduction efficiency is adjusted from 90% to 97% (based on expert knowledge). NOx reduction efficiency is adjusted from 50% to 75% (based on Ecofys internal expert knowledge). Cogeneration dataset is used to approximate dedicated power plant.
Hard coal, CHP	2.2	Hard coal, burned in power plant	AT, BE, CZ, DE, ES, FR, HR, IT, NL, NOR, PL, PT, SK	Hard coal power plant dataset is used to approximate hard coal CHP.
Gas, CHP	2.2	Natural gas, high pressure, at consumer Natural gas, burned in cogen 1 MWe lean burn	AT, BE, CZ, DE, DK, EL, ES, FI, FR, HU, IE, IT, NL, RER*, SE, SK, UK RER*	Addition a; combinations of upstream fuel and cogeneration plant are made.

[104] Dones, R. (2007) Kernenergie. In: Dones, R. (Ed.) et al., Sachbilanzen von Energiesystemen: Grundlagen für den ökologischen Vergleich von Energiesystemen und den Einbezug von Energiesystemen in Ökobilanzen für die Schweiz. Final report ecoinvent No. 6-VII, Paul Scherrer Institut Villigen, Swiss Centre for Life Cycle Inventories, Dübendorf, CH.
[105] RWE Npower 2014 (update) Water Use at Thermal Power Plant –Quantification, Metrics & Societal Benefit Power Plant, prepared for DG Environment ad hoc Water Blueprint Modelling Group.
[106] Ecofys, Deltares, TNO (forthcoming) Pilot project on availability, use and sustainability of water production of nuclear and fossil energy – Geo-localised inventory of water use in cooling processes, assessment of vulnerability and of water use management measures. Commissioned European Commission- Directorate General Environment.

Technology	Ecoinvent version	Dataset(s) used	Country-specific dataset(s) used	Adjustments made to dataset/ Comments
Waste, CHP	2.2	Disposal, municipal solid waste, 22.9% water, to municipal incineration	CH	-
Biomass, CHP	2.2	Wood chips, burned in cogen 6400kWth, emission control	CH	Wood chips are replaced by wood pellets. PM reduction efficiency is adjusted from 90% to 97% and NOx reduction efficiency is adjusted from 50% to 75% (based on expert knowledge).
Solar thermal	2.2	Heat, at flat plate collector , one-family house, for combined system	CH	Transport, van <3.5t/CH is replaced by Transport, van <3.5 t/RER U.
Heat pump	2.2	Heat, borehole heat exchanger, at brine-water heat pump 10kW	RER*	
Gas-fired boiler	2.2	Natural gas, burned in boiler condensing modulating <100kW	RER*	High pressure gas input has been replaced by country-specific datasets (AT, BE, CZ, DE, DK, EL, ES, FI, FR, HU, IE, IT, NL, RER, SE, SK, UK).
Wood pellet boiler	2.2	Pellets, mixed, burned in furnace 15kW	CH	Transport, lorry 20-28t, fleet average/CH is replaced by Transport, lorry 20-28t, fleet average/RER Electricity demand is taken out of the dataset.

* RER stands for average Europe (EU27 plus Norway and Switzerland)

Box A3-1 Preventing double counting of impacts

The aggregation of external costs of the energy system at EU28 or Member State level presents a challenge in respect of the LCA based approach. While the per technology approach enables clear cross-technology comparison of total life cycle impacts, a simple aggregation of these results would lead to double counting of some of the electricity or heat in upstream impacts.

For example a MWh of power produced in a hard coal plant will include the impacts of any electricity or heat used upstream in mining, transport, etc.; the impact of which is calculated from the relevant energy mix. However, this same impact is already included in the direct conversion stage of the external cost calculation for that specific technology. Therefore impacts would be double counted, once in assessment of the external costs of the technology, and the second time in the overall energy mix applied to upstream energy use across all technologies. A further aspect is that only upstream electricity use within the EU would actually be double counted, electricity use outside the EU would be an additional total impact. We have resolved this issue by removing the upstream EU electricity use from the aggregated totals Member States. Due the use of generic datasets it is impossible to achieve a perfect split between EU and non-EU electricity use, but we have used an approach to provide the most relevant aggregate results.

To ensure a fair comparison between technologies, the LCIA dataset including all upstream electricity use is used for all results per MWh or GJ (i.e. impacts per technology). To prevent double counting of impact, the LCIA dataset excluding upstream electricity used produced within the EU is used for all aggregated results (i.e. impacts per Member State).

For the LCIA, we use the standard impact assessment methodology ReCiPe[107] version 1.09 as implemented in the SimaPro[108] software which defines 18 midpoint environmental impact categories for the external impacts we calculate and value in this study. The impact categories terrestrial ecotoxicity, freshwater ecotoxicity and marine ecotoxicity are represented at the endpoint level instead of the midpoint level to enable monetisation.

We selected the ReCiPe approach over other available approaches e.g. LCImpact and Impact World, as it is a relatively widely used and accepted method. The other major advantage of ReCiPe is that external costs values have already been created at midpoint for most of the impact categories and units of ReCiPe, this is not yet the case for the other methods, which are also not yet included in commonly used LCA software.

A3.1.2 Power and heat production by country

Production values for power and heat per technology were obtained from Eurostat[109] for the years 2008 – 2012 for all 28 Member States. The data was mapped to the reference technology categories used in this work (see section 2.4 in main report).

For renewables additional data was used to split solar production into *PV_Land* and *PV_Roof*[110] and wind production into *Wind_Onshore* and *Wind_Offshore*[111]. In addition, data for hydropower was split into *Hydro_Reservoir* and *Hydro_Runof River*[112].

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[107] Goedkoop, M, Heijungs, R., Huijbregts, M., De Schrijver, A., Struijs, J., Van Zelm, R. 2009. ReCiPe 2008 A life cycle impact assessment method which comprises harmonised category indicators at the midpoint and the endpoint level First edition Report I: Characterisation. http://www.pre-sustainability.com/download/misc/ReCiPe_main_report_final_27-02-2009_web.pdf
[108] Pré Consultants (2014). SimaPro (Version 8.0.2). Multi User.
[109] Eurostat Tables nrg_105a and nrg_106a.
[110] EPIA (2013): Global Market Outlook for Photovoltaics 2013-2017.
[111] EWEA (2013): Wind in Power 2012 European Statistics.

For CHP we have used input and output data as reported in Eurostat to calculate efficiencies. CHP statistics can be difficult to collect because they relate to smaller plants on average, often integrated in industry and reporting may not be consistent across all Member States. In addition a wide range of CHP technologies is in use and CHP plants are often not run under optimal conditions. This means that the results for external costs for CHP differ from what the result would have been for a new fully optimised CHP plants but reflect the fleet as reported which is consistent with the other technologies (see also Box A3-2).

A3.1.3 Member State Scaling factors per technology

The impact of the reference technology represents a single model plant for that technology, in some cases differentiated at country-level. Where impact values for a technology were not available for a Member State, the impact values of another 'reference' country were used. To represent the differences between the actual technology mix of a country in comparison to the reference country scaling factors were used: **Full load hours** were used for the renewable power technologies, and **conversion efficiencies** for the combustion and nuclear technologies.

Actual efficiency
For fossil, nuclear and biomass based power generation, the impacts are dominated by the direct emissions during conversion and the impacts of the fuel supply chain. All impacts at a national level are therefore scaled by the ratio of the known efficiency of the whole power park of the technology in that country in 2012 to the efficiency of the reference technology.

For combustible fuels the following equation was used to calculate conversion efficiencies:

$$Conversion\ efficiency = \frac{Output}{Input}$$

The input output data was obtained from Eurostat.[113]

Full load hours (capacity factor)
For renewable technologies the environmental impact is dominated by the infrastructure. A solar PV system operated in southern EU countries generate more electricity during its lifetime compared to similar system operated in northern EU countries. Therefore, for these technologies the impacts are modified based on the average full load hours in the specific country. For a detailed description on the calculation of full load hours, please refer to Annex 4.

A3.1.4 Monetisation values

This section summarises the methodological choices we made for monetisation and our review of the monetisation values we use in our external costs tool.

Damage costs
We have selected a damage cost approach in our monetisation of impacts. There are a few approaches to valuation such as damage (or social) costs, market prices (e.g. EU-ETS) and mitigation/abatement/restoration costs. Damage (or social, as in societal) cost approaches attempt to take all societal costs into account and take a long-term perspective.

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[112] Eurelectric (2013): Power Statistics & Trends 2013.
[113] Tables nrg_100a, nrg_105a and nrg_106a.

This increases complexity but is more complete for externalities. Market prices reflect the current market framework, and the supply and demand conditions that exist at a given moment in time, this can lead to significant price fluctuations making any valuation estimates highly variable over time and by policy. This does not provide a reliable long-term perspective or a comprehensive internalisation of externalities. Mitigation/abatement/restoration costs can also have an element of this price fluctuation as the rate of technological change and other factors such as resource scarcity, taxes, policies and global events can play an important role in changing these costs. This also leads to significant variability over time and only a weak link to full externality costs. The damage cost approaches take all societal costs into account and take a long-term perspective.

Midpoint-endpoint valuation and damage categories

Methodologies to value the environmental impacts focus on the translation of the midpoint impacts to endpoints and the damages they represent. Figure A3-1Figure presents the full ReCiPe framework we use, and its environmental mechanisms, midpoints, damages and endpoints, please read the ReCiPe source document[114] for further explanation of the overall framework.

In monetising impacts we first attach a value to the midpoint, which is characterised into a single substance, for example the CO_2 equivalent unit for climate change also includes all LCI impacts from other greenhouse gases, converted to CO_2 equivalents.

The valuations are in almost every case based on a modelled damage relationship between the midpoint and endpoint, which characterises the midpoint emissions in terms of their endpoint damages. For example emission of the various substances that lead to particulate formation have their damage modelled in terms of the human health impacts they cause. We are able then to apply a value to this damage. This can either be characterised in terms of the impact unit and valued, i.e. for land occupation a €/m^2 valuation; or alternatively, the endpoints can be characterised, aggregated and valued, i.e. for ecotoxicity where a €/species.yr valuation is used. The latter endpoint method, also known as the direct or implicit valuation method, is simple and transparent, but can be based on different assumptions (models, characterisation, discounting) than the midpoint or substance approach as embodied in NEEDS.

We use both midpoint and endpoint methods as appropriate for valuation. In each case the relationships and characterisations of impact and damage are based on scientific literature and modelling, full details of which are available in the ReCiPe source documents.

[114] Goedkoop, M, Heijungs, R., Huijbregts, M., De Schrijver, A., Struijs, J., Van Zelm, R. 2009. ReCiPe 2008 A life cycle impact assessment method which comprises harmonised category indicators at the midpoint and the endpoint level First edition Report I: Characterisation. http://www.pre-sustainability.com/download/misc/ReCiPe_main_report_final_27-02-2009_web.pdf

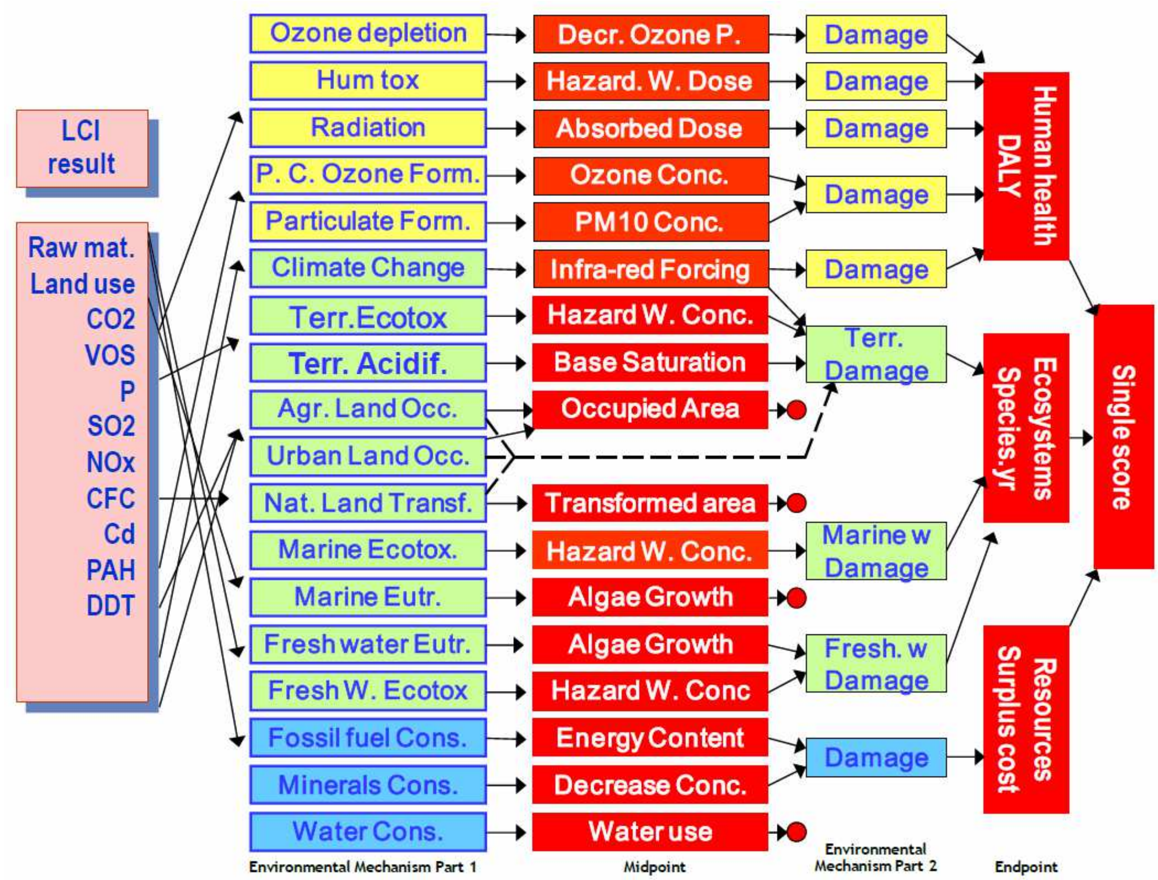

Figure A3-1 Relationships between impact categories, environmental mechanisms, midpoints, damages and endpoints in the ReCiPe framework [Recipe, 2013]

As shown in Figure A3-1 we use three main endpoints:

- Human health damages – as measured in Disability Adjusted (lost) Life Years (DALYs);
- Ecosystems and biodiversity – as measured by changes in the Potentially Disappeared Fraction (species.yr or PDF/m^2 – which are units of biodiversity loss);
- Resources and depletion, primarily water, metals and fuels but also including crops, buildings and other assets – as measured in €.

Table A3-2 summarises for each impact category which damages are included in the values.

Table A3-2 Environmental impacts and monetisation of damages, valued impacts and methods. (L)=literature based, (M)=midpoint valuation, (E)=Endpoint valuation.

Impact categories	Human health (DALYs)	Ecosystems (PDF)	Resources: depletion, crops, land/buildings (€)
Climate change	L	L	L
Ozone depletion	E		
Terrestrial acidification		E	M (crops, buildings)
Freshwater eutrophication		E	
Marine eutrophication		M	
Human toxicity	E		
Photochemical oxidant formation	E		
Particulate matter formation	E		
Terrestrial ecotoxicity		E*	
Freshwater ecotoxicity		E*	
Marine ecotoxicity		E*	
Ionising radiation	E		
Agricultural land occupation		M	
Urban land occupation		M	
Natural land transformation		M	
Water depletion			L
Metal depletion			E
Depletion of energy resources			E

*=valued in species.yr

Human health: DALYs

Human health impacts in the tool are typically valued at their endpoint damages as measured in Disability adjusted (lost) life years or DALYs. A DALY is the sum of Years of Life Lost (YOLL) and Years Lost to Disability (YLD), i.e. DALY = YOLL + YLD. We have attached a value to YOLL and YLD using the value of a life year (VOLY), or life year lost. While this method is straightforward for YOLL, the use of the VOLY to value YLD depends on how a particular disability is measured in life years, known as the disability weighting. This assumption for YLD was also made in work by CE Delft (2010).

We have taken the value for a VOLY, therefore DALY, from the NEEDS project (2008) and EcoSense tool, which valued this at 40,000 €2000 for the year 2006.
When updated to 2012 values, through the NEEDS 0.85% annual uplift factor[115] and when updating to 2012 euros though the currency deflator adjustment, we arrive at **a DALY value of €$_{2012}$ 58,122**. This is applied across our human health damage calculations. This is within the range of DALY used in many studies.

Clearly the subject of valuing human life and health is quite sensitive and a variety of value judgements and methods can be applied. Income weighting of human health impacts in EU countries with relatively low per capita incomes would significantly reduce the values used there. While this is not uncommon in other studies, we have used a single value across all EU Member States. The most recent work in the EU thematic strategy for air pollution has used a much higher figures to value human health, and NEEDS also reports lower and upper bounds of €$_{2000}$ 25,000–100,000[116] to the central DALY estimate we used, both indicating the range of values that could be used.

A3.1.5 Ecosystems and Biodiversity: PDFs

Ecosystem and biodiversity impacts are typically valued at their endpoint damages as measured in the Potentially Disappeared Fraction or PDF/m^2(/yr) or species.yr. The PDF approach is based on the ReCiPe methodology and places a value on the difference in biodiversity between a particular land use and a reference natural state (extensive broadleaf, mixed and yew low woodland). The difference is measured in the average number of vascular plant species found in one square meter of the particular land type compared to the reference.

Values are attached on the basis of this difference, the PDF, using work by Kuik et al[117] for the Ecosense model and CASES, which used willingness to pay methodologies to place a value on biodiversity. This methodology is designed to be applicable at EU level as a whole. **A PDF value of €$_{2012}$ 0.07/m^2 is used**, which is based on the median values for a PDF reviewed by Kuik et al. A mean value of 0.55 €$_{2012}$/m^2 could also be selected, but a median value is generally more statistically sound and in this case the high mean value, compared to the median, shows that the mean has been skewed high by a handful of very high values. A mean value would be more consistent with a restoration cost approach, although in cases where restoration actually takes place the cost is typically internalised through producer set-aside funds or payments.

Species.yr is an alternate endpoint used to value three of the ecotoxicity impacts. The **species.yr values** are reached by multiplying the PDF m^2 value presented above by the species density in the appropriate environment. The species densities are taken from Recipe (2013), and final values used are as follows:

- € 1.04E-09 species.yr (terrestrial);
- € 2.95E-12 species.yr (freshwater);
- € 5.68E-17 species.yr (marine).

[115] The value for a DALY in NEEDS is based on Willingness to Pay (WTP) methods, it is assumed that the willingness to pay increases with income. Therefore the uplift factor is used to provide a DALY value for a particular point in time adjusted for an assumed increase in income, this effect is assumed in NEEDS as a 1.7% increase each year, we have halved this rate to 0.85%, partially to reflect lower income growth following the financial crisis.
[116] NEEDS (2008) 6.7 RS 1b Final report on the monetary valuation of mortality and morbidity risks from air pollution.
[117] Kuik et al. (2008) Deliverable D3.2 CASES project, Report on the monetary valuation of energy related impacts on land use changes, acidification, eutrophication, visual intrusion and climate change, O. Kuik, L. Brander, N. Nikitina, S. Navrud, K. Magnussen and E.H. Fall.

Resources

The resource endpoint unit is euros and this is intended to represent the marginal cost increase to society of the depletion of a resource. This method estimates the present value of a marginal cost increase of extraction over time, with a social discount rate of 3%. Values can be found in the text. For metals, depletion of the resource has the effect of decreasing the average ore grade. For energy resources the effect of depletion is to extend the types of fuels that must be extracted, as conventional resources are used, more unconventional resources must be called upon. We have included uranium in the energy resources category as unlike other metals there are very few substitution possibilities.

Key source documents

Our valuations are based on a variety of sources, but some key EU work underpins our method and findings, we briefly describe these key sources below. We also reviewed a wide range of other relevant documents.

Table A3-3 Key source documents for external costs

Document/ Project	Description	Key developments	External costs
ExternE (1991 – 2005) (External Costs of Energy)	A large-scale EU-funded and EU-wide research project. Pioneered an approaches to understanding and valuing external costs.	Developed the impact pathway approach used to frame analysis of a variety of externalities. Led to spin-off EcoSense tool.	Specified external costs of energy for the EU-15 Member States and the EU overall and 9 energy technologies. Values in the range 0-15 euro cents kWh. We include some impacts that were not included in this study e.g. resource depletion.
CASES (2005 - 2008) (Cost Assessment for Sustainable Energy Systems)	Supported by FP6. CASES intended to derive a consistent and comprehensive picture of the full cost of energy, including private and external costs, at present and into the future.	It further developed the methodologies developed in ExternE, particularly in the area of human health. Also developed external cost scenarios for energy technologies in 2020 and 2030.	Specified external costs for 33 different energy technologies and the EU-27. Values in the range of 0-5 euro cents kWh. We include some impacts that were not included in this study e.g. resource depletion
NEEDS (2006 - 2009) (New Energy Externalities Development for Sustainability)	Supported by FP6, focused on developing: • Life Cycle Assessment (LCA) of energy technologies; • Monetary valuation of externalities; • Policy integration of LCA and externalities information; and • Multi-criteria decision analysis (MCDA).	Updated external cost estimates of ExternE. Particular developments in the areas of valuation for biodiversity and ecosystems, climate change and human health. Continued development of Ecosense tool.	Specified external costs for at least 7 different energy technologies and the EU-25. Values in the range of 0-3 euro cents kWh and average 0.7% of GDP in total. We include some impacts that were not included in this study e.g. resource depletion
ReCiPe (2008 - 2013) life cycle impact assessment method which comprises harmonised category indicators at the midpoint and the endpoint	Commissioned in the Netherlands. This project and report provided an integration of LCA methods within a framework that linked midpoint and endpoint impacts for a set of 18 standard environmental impacts.	Defined and updated midpoint and endpoint characterisations of 18 environmental themes, including resource depletion. Enabling a standardised but flexible approach to LCA.	Provided a framework to analyse environmental externalities, to both measure and value their impacts.

Document/ Project	Description	Key developments	External costs
level. First edition (version 1.08) Report I: Characterisation			
CE Delft (2010) Shadow Prices Handbook: Valuation and weighting of emissions and environmental impacts	This project applied abatement, damage and direct valuation approaches to estimate monetisation values for the impact of environmental damages in the Netherlands and the EU27.	Combined the work from various methodologies, including NEEDS, CASES and ReCiPe to estimate unit values to monetise a set of environmental impacts.	Provides an important synthesis reference source for monetisation values for environmental externalities in the EU.

A3.1.6 Monetisation values across the EU28

To monetise a specific impact, we use the same value across all Member States. The most important reason to do this is because of the uncertainty associated with the location at which the impact actually occurs. Although some impacts may be local, many more, particularly those associated with upstream activities such as fuel extraction and processing, could occur anywhere globally. For example we value the impact of power generated in a nuclear power plant in a particular country, but this also includes the impacts from uranium extraction and processing, which typically occurs outside the EU. Additionally, for human health damages it is further the case that we prefer to treat each human life in the EU, or globally, in the same way and at the same value.

Climate change

Our approach to valuation of climate damages is based on literature review and expert judgement. Work by CE Delft[118] developed estimates of the damage costs of climate change based upon a literature review and projections from the ExternE, NEEDS and CASES projects. Their values were €$_{2008}$ 25/tonne CO_2 eq for 2010, increasing over time, i.e., € 40 in 2020 as a central value, and for a high value estimate € 45 in 2010, and € 70 in 2020.

The Stern Review[119] was among the literature reviewed by CE but is worth individual consideration. It recommended SCC values equivalent to €$_{2012}$ 25, €$_{2012}$ 30 and €$_{2012}$ 85/tonne CO_2 eq, depending on the climate scenario, with a business as usual scenario attracting the highest values and a rapid mitigation scenario to 450ppm CO_2 the lowest, the central value representing 550ppm CO_2. A paper by Dietz and Stern published in June 2014[120] recommended the use of a current price of \$US$_{2012}$ 32-103/tonne CO_2 or €$_{2012}$ 25-80/tonne.

[118] CE Delft: Sander de Bruyn, Marisa Korteland, Agnieszka Markowska, Marc Davidson, Femke de Jong, Mart Bles, Maartje Sevenster (2010) Shadow Prices Handbook: Valuation and weighting of emissions and environmental impacts.

[119] Stern, N. et al for HM Treasury (2006) The Economics of Climate Change.

[120] Dietz and Stern (2014) Endogenous growth, convexity of damages and climate risk: how Nordhaus' framework supports deep cuts in carbon emissions, Simon Dietz and Nicholas Stern, June 2014, Centre for Climate Change Economics and Policy Working Paper No. 180, Grantham Research Institute on Climate Change and the Environment Working Paper No. 159.

Government bodies have been among the most active in deriving Social Costs of Carbon (SCC) to include a value for greenhouse gas emissions in their policy assessments to ensure socially responsible decisions are taken. The UK and US Governments have been among the forerunners in applying this in practice, particularly work by the US Government on the Social Cost of Carbon[121] (2010 & 2013). The US Government produced estimates of the SCC in 2010, which placed values on carbon based on discount rates of 5, 3 and 2.5 per cent, and also a 3% value at the 95% percentile (high end of estimate), these ranged from $\$_{2007}$ 4.7-64.9 in 2010, and also increasing values in 5 year intervals. The central 3% estimate was $\$_{2007}$ 21.4 in 2010, $26.30 in 2020. This work was updated in 2013 and the values revised upwards, resulting in a range of $\$_{2007}$11-90 in 2010, with the central 3% estimate of $33 (€2$_{012}$28), rising to $43 in 2020. These values have proved somewhat controversial, as may be expected, with industry groups claiming they are too high, environmental and civil society groups claiming they are too low. This US work represents the most authoritative recent revision of the SCC.

The European Environment Agency also commissioned a paper in 2011[122] that investigated the damage costs of various air pollutants, including greenhouse gases. It estimated damage costs equivalent to €$_{2005}$ 33.6, or €$_{2012}$ 38.1.

A variety of other work has been carried out on Social Cost of Carbon, some through the use of integrated models of which only a handful exist. Meta-studies such as those by Tol[123] on the 'Economic effects of Climate Change' have reviewed estimates to evaluate the values that are derived in other studies. These meta-studies find that there are very high levels of uncertainty in the estimates, based on the assumptions that are used.

The meta studies also find that averages of estimates tend to be higher than the median, as average values tend to be skewed by very high cost estimates, indeed a large range of estimates was profiled by Tol, from those that estimate a social benefit, at least in the short term under certain conditions, to those with costs of over 1500 €s/tonne.

This is a key point in any social cost of carbon (damage) cost estimate, that there are significant uncertainties and assumptions included. It also clear that different valuations include or exclude different potential impacts, with only partial coverage of all possible climate damages included in any estimate.

Taking this into account, alongside continuing growth in global emissions and the most recent work such as that by Dietz and Stern, we use a base value of EUR 50/tonne CO_2 equivalent – this is subsequently adjusted for internalised externalities for the final value we use. This base estimate is consistent with the expectation of being on a mid-high global warming pathway at present.

We carry out a sensitivity analysis around this value, testing the impact of a higher value, i.e. EUR 100/tonne and also a lower value of EUR 30/tonne.

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[121] United States Government, Working Group on Social Cost of Carbon (2013) Technical Support Document: Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866 Interagency.

[122] EEA (2011) Revealing the costs of air pollution from industrial facilities in Europe.

[123] Tol, R. (2009) The Economic effects of Climate Change, Journal of Economic Perspectives—Volume 23, Number 2—Spring 2009—Pages 29–51.

Particulate matter formation

We draw upon the ReCiPe method and characterisation, and work by CE Delft[124] and NEEDS[125] for our monetisation value for particulate matter formation.

The impact of particulate matter is characterised using the ReCiPe method in PM_{10} equivalents, with the contributions of PM_{10}, NH_3, SO_2 and NO_x included. Endpoint damages in DALYs/PM_{10} are taken from the ReCiPe method.

The value we propose is updated from the CE Delft work and is based on direct valuation of the endpoint impacts on human health, in DALYs. Following the method and value for DALYs described in section 3.1.4.

We reviewed work from other studies, including the LC-IMPACT project under FP7[126] which has improved impact characterisation but the data is not yet compatible for use in this assessment.

A value of $€_{2008}$ 14.30/kg PM_{10} for the EU27 was identified in the work by CE Delft. We then use an updated value **$€_{2012}$ 15/kg PM_{10}** for this work, based on the DALY valuation method. This incorporates an adjusted uplift factor as per NEEDS of 0.85%/year between 2008 - 2012 to update the CE Delft value.

This will not ideally represent damages at national level, as differences in population density, topography, climate, economy and various other factors can highly influence the actual damage caused. In future it may also be more appropriate to move to a method based on $PM_{2.5}$ rather than PM_{10}, but PM_{10} remains the unit of the ReCiPe framework of the External-E tool we use and therefore we use this for consistency and for the availability of values.

Ionising radiation

The value for ionising radiation is intended to represent the damage to human health caused by emissions to air and water of radionuclide substances.

In the monetisation approach, first the radionuclide emissions are expressed in kg U235 equivalent kBq[127]. Ionising radiation is an aspect assessed not only in the life cycle of nuclear power plants, but is also relevant in other life cycles, i.e. ionising radiation as a result of the combustion of coal.

To apply a monetisation value to the impact unit of kg U235 eq. kBq we apply a direct valuation of the ReCiPe endpoint impacts based on work by NEEDS and ReCiPe. In this case the method calculates the human health damage caused by different radionuclides, using emission/dose factors for different illnesses[128]. These impacts can then be converted to their kg U-235 eq. kBq values, and the endpoint damages characterised and measured in DALYs. An average of these values is taken, as the actual emission distribution of the individual radionuclides is unknown, to provide a DALY/kg U-235 eq. kBq, to which a DALY valuation is applied.

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[124] CE Delft: Sander de Bruyn, Marisa Korteland, Agnieszka Markowska, Marc Davidson, Femke de Jong, Mart Bles, Maartje Sevenster (2010) Shadow Prices Handbook: Valuation and weighting of emissions and environmental impacts.
[125] NEEDS – the New Energy Externalities Development for Sustainability project (2005 - 2009) http://www.needs-project.org/
[126] LC-IMPACT - Life Cycle Impact assessment Methods for imProved sustAinability Characterisation of Technologies (2009 - 2013). http://www.lc-impact.eu/
[127] Kilo Becquerel.
[128] Fatal and non-fatal cancers, hereditary defects.

The DALY valuation is based upon a VOLY of €2_{000} 40 000 from the NEEDS work which is updated to 2012 values using the uplift factor and the deflator to express in 2012 euros. As a result we calculate a value of **€0.001 kg U-235 eq. kBq** to apply EU-wide in our external cost valuation.

For further context, and on the basis that the majority of the impact in this category is from nuclear power, we refer to work carried out within the NEEDS project[129]. This analysed and estimated the external costs of nuclear energy based on case studies of a set of nuclear plants in central and Eastern EU countries. This estimated external costs of radiation from nuclear energy at a total of €$_{2000}$ 0.3/MWh.

Agricultural land occupation

The value for agricultural land occupation represents the cost to ecosystems of continued occupation of the land, preventing its return to an (assumed) more biodiverse state, measured in m^2 of land occupied.

The values used for agricultural land occupation are based on the PDF approach developed within ReCiPe and the valuation method of Kuik et al[130]. The value we use is calculated on the basis of the known PDF/m^2/yr of the three key agricultural land types in the CORINE (ReCiPe) set: Monoculture crops/weeds, Intensive crops/weeds, Extensive crops/weeds. These PDF values were multiplied by the value per PDF of €$_{2012}$0.071m^2 (from €$_{2004}$0.060m^2), and an average taken of the three values to represent the damage cost. Therefore a value of **€ 0.1/m^2/year is used for agricultural land occupation**.

While updating this value we also reviewed work from other studies, including those carried out for the LC-IMPACT project under FP7, but the land use work on this project used a different land type and impact categorisation and also focused on characterisation factors rather than monetisation.

Depletion of energy resources

The value placed on energy resource depletion reflects the increased marginal cost to society of the consumption of finite (fossil and nuclear) fuel resources now, rather than in the future. As this externality reflects the cost surplus caused by the increased marginal cost of extraction, this could also be argued to represent the difference in time preference between the market price and what would be a more generation-equitable societal price.

The indicator is based on the approach in the ReCiPe set. The fossil fuel depletion indicator from ReCiPe has been extended to include nuclear energy resources to form a new indicator 'Depletion of energy resources'. This indicator aims to capture the external costs based on a discounted surplus cost of the production of energy resources. It is based on the following calculation. The marginal cost increase[131] of depleting a kg of oil is calculated based on production cost-supply curves published by the IEA. The marginal production costs are assumed to increase as more unconventional sources have to be used.

To estimate the cost of fossil depletion the cost-supply curve is simplified into two steps. The first step shows average marginal cost increase of US$ 25 per barrel for every billion barrels produced.

[129] NEEDS (2009) Paper n° 5.2 - RS 1d: Assessment of externalities of nuclear fuel cycle in Central-East-European countries.
[130] Kuik et al. (2008) Deliverable D3.2 CASES project, Report on the monetary valuation of energy related impacts on land use changes, acidification, eutrophication, visual intrusion and climate change, O. Kuik, L. Brander, N. Nikitina, S. Navrud, K. Magnussen and E.H. Fall.
[131] Note that marginal cost increase is used as this is assumed not be yet included in current market prices, hence only non-internalised costs are used to estimate the external costs.

This increase holds for the first 3000 billion barrels produced. For the following 1,500 billion barrels the marginal cost increase per produced barrel of oil increases. The total cost increase by producing this 1,500 billion additional barrels sums to US$ 40 per barrel. The methodology then calculates what the consequences are for societal costs of producing one barrel of oil now.

The rationale behind the methodology is that the marginal cost increase governs that producing a barrel of oil now has the consequence of making all the next barrels of oil more expensive to produce. This so called cost surplus per barrel of oil is then multiplied by a fixed annual production rate for the next decades. Using a discount factor of 3% this total cost surplus is translated into the societal cost of producing a barrel of oil now. This results in a value of €2$_{012}$ 0.05 per kg oil equivalent. Equivalents for other energy carriers - e.g. coal, gas, uranium - are calculated using the energy content of the primary energy carrier (i.e. MJ/kg). This is obviously an oversimplification as resources and cost-supply curves show very different trends for these other primary energy resources. By using the cost-supply curves of oil – limited in resources and relative high production cost - for the entire non-renewable energy resource sector we probably overestimate the societal costs. This is why we select the lower (individualist) value as suggested in the ReCiPe method as the default value for the external cost calculation.

Establishing a well-accepted methodology to estimate the societal cost of finite energy resource depletion has proven to be a very challenging research endeavour. Since the ExternE research programme various efforts have been attempted, the ReCiPe method being one of them. We reviewed work from other studies, but found no significant new updates, with the ReCiPe method still forming the basis of the recommended approach, therefore the ReCiPe methodology is used. However, this should be considered as an area still in development and indicators used to measure these external costs should be interpreted carefully.

A value of **€$_{2012}$ 0.05 kg oil eq**. is used to value depletion of energy resources.

However, strong conclusions cannot be drawn based on the indicator used here, mainly because:

- The indicator is biased towards the marginal cost increase of oil. Resources for gas, coal and uranium are not separately dealt with, but are inferred. This is an oversimplification of reality.
- It can be argued that marginal cost increase of production is already partially included in (future) market prices and therefore companies take this into account when developing and financing resource extraction. Whether this private cost is equivalent to societal cost is debatable, particularly as globally there are still significant subsidies to energy resources.
- Developments in resource potential and technological development (e.g. shale gas and oil developments) that have downward pressure on future prices are not taken into account in detail.

Other impact categories

For the following themes, whose impact and cost was judged to be low we have typically drawn upon the sources described above, and updated the values to €$_{2012}$. Please refer to the source documents as stated for further discussion and explanation of the valuation methods.

Table A3-4: Monetary values used for other impacts

Impact categories	Unit	External costs (€2012 /unit)
Ozone depletion	kg CFC-11 eq	107
Terrestrial acidification	kg SO_2 eq	0.2
Freshwater eutrophication	kg P eq	0.2
Marine eutrophication	kg N eq	1.8
Human toxicity	kg 1.4-DB eq	0.04
Photochemical oxidant formation	kg NMVOC	0.0023
Terrestrial ecotoxicity	species.yr	1.04E-09
Freshwater ecotoxicity	species.yr	2.95E-12
Marine ecotoxicity	species.yr	5.68E-17
Urban land occupation	m^2a	0.1
Natural land transformation	m^2	3.6
Water depletion	m^3	0.2
Metal depletion	kg Fe eq	0.07

Specific points of interest relevant to the values in the table include:

- **Use of valuation methods for Human health and Ecosystem damages:** for all impact categories for which the damage to human health and ecosystems and biodiversity is calculated, unless otherwise stated below, we have updated values from CE Delft (2010) based on endpoint characterisation from ReCiPe and valuation with adjustments as described the Section above.
- **Ozone depletion:** includes damages caused by various substances, including CFCs, Halons and HCFCs. The value represents the human health damage of increased exposure to UV radiation, using the ReCiPe characterisation approach. The PROSUITE[132] project reviewed ozone depletion impact methods and continues to recommend the ReCiPe approach.
- **Terrestrial acidification:** damages caused by various acidifying substances, including SO_2, NH_3, NO_x, represented in SO_2 acidification potential equivalents. Damages to crops and buildings are also included with an assumption that damage costs in the Netherlands are applicable EU-wide. We reviewed work from other studies, including those carried out for the LC-IMPACT project under FP7, but found that while improved impact characterisation has been produced it is not fully compatible for use in this assessment.
- **Freshwater eutrophication:** evaluates the emission of eutrophying substances to freshwater as characterised in kg of Phosphorus equivalents. We reviewed work from other studies, including the PROSUITE project which concluded that the ReCiPe midpoint approach is still valid.

[132] PRO-SUITE Development and application of a standardized methodology for the PROspective SUstaInability assessment of TEchnologies (2013) Recommended assessment framework, characterisation models and factors for environmental impacts and resource use. See also www.prosuite.org

- **Marine eutrophication:** evaluates the emission of eutrophying substances to the marine environment as characterised in kg of Nitrogen equivalents. This value is based on terrestrial eutrophication impacts in the Netherlands, but with modified estimates of species abundance and loss, to give the impact in marine environments. We reviewed work from other studies, including the PROSUITE project which concluded that the ReCiPe midpoint approach is still valid.
- **Human toxicity:** method and value to be confirmed.
- **Photochemical oxidant formation:** places a value on the emissions of non-methane volatile organic compounds (NMVOCs) and NO_x, measured in NMVOC equivalents, which can combine to form Ozone and lead to negative effects on human health. We use the ReCiPe endpoint characterisation of impacts in DALYs to place a value on these impacts.
- **Terrestrial, freshwater and marine ecotoxicity:** the values for these three impacts are estimated on the basis of the damage endpoints in ReCiPe as measured in species.yr. The values that are attached are based on the ReCiPe 2013 updated species density values for each ecosystem type multiplied by the standard PDF value, please also see Section 2.5 in the main report.
- **Urban land occupation:** the valuation approach is the same as for agricultural land occupation (see Section 0) but for the urban land types.
- **Natural land transformation:** we derive a value based on the ReCiPe methodology, which estimates that land transformation from an unknown land type has an impact equivalent to an average PDF loss of $51/m^2/yr$, based on an assumption of ecosystem recovery time consistent with the hierarchist[133] perspective, of approximately 100 years.
- **Water depletion:** we derive a value for water which represents the indirect use value of water consumption, i.e. the value we attach to water not being available for ecosystems and other uses. The method does not value changes in water quality that are not covered under the other impact categories (e.g. temperature). It is based on a modelled relationship between water scarcity and willingness to pay for the benefits that water provides as described in the PUMA Environmental Profit and Loss Account[134]. We used this modelled relationship and applied it to known water scarcities in the EU28 using data from FAOSTAT. The median value for the EU28 (of freshwater withdrawal as a % of actual renewable water resources of around 11%) was used to generate the value figure. This value is based on an experimental approach (PUMA), and therefore any results should be treated with caution. We use an EU28 average as we anticipate much of the water depletion occurs in the EU28. The differences between this average and the local depletion effects could be quite significant.
- **Metal depletion:** follows the ReCiPe approach used for energy resource depletion to develop a value for the marginal cost increase. This figure represents the cost to society of the depletion of minerals and metal deposits and was based on the characterisation of 20 key resources.

  We reviewed work from other studies, including those carried out for the LC-IMPACT projects under FP7, which has carried out further work into characterisation factors for metals and minerals, and marginal and surplus costs, but from which no new valuation method is available.

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[133] In order to deal with uncertainties at the end point level, ReCiPe makes use of the cultural perspectives theory of Thompson 1990. According to this theory consistent sets of subjective choices on time horizon, assumed manageability etc. can be grouped around three perspectives, identified by the names: individualist (I), hierarchist (H) and egalitarian (E).The hierarchist perspective is the middle perspective and is most often used as default option.

[134] PUMA (2011) PUMA's Environmental Profit and Loss Account for the year ended 31 December 2010.

Internalising externalities
Section 3.1 of the main report and Annex 2 address the main policy interventions which directly or indirectly influence the costs of energy production and consumption to achieve social welfare goals. These policies are 'internalising' the externality costs of energy.

Part of the aim of this analysis is to enable comparison of policy interventions with estimated external costs to discuss to what extent interventions are at an appropriate level. It should also point to particular external costs that are most problematic, which technologies have higher or lower external costs and the extent to which this is a problem in the different Member States.

It is important therefore to avoid double counting of costs, for example stating both the external cost and including within the public interventions the costs of a tax or intervention that directly addresses the externality costs. The clearest example of this within the EU is the EU-ETS, which already attaches a cost to the climate change externality, which represents a level of (partial) internalisation.

We only internalise externalities where there is a clear and direct link to interventions, and we do this by calculating a net monetisation value as follows:

- **EU-ETS:** this policy internalises the climate change cost of power generation. It is valued per tonne of CO_2 and we have taken the average EU-ETS price of €$_{2012}$ 6.67 tCO_2 in 2012 as the value[135]. This therefore mitigates our value of climate change of €$_{2012}$ 50 tCO_2e by the same amount, to €$_{2012}$ 43.33 tCO_2e for all technologies, except domestic heating technologies where EU-ETS does not apply and therefore the full value of €$_{2012}$ 50 was applied.
- **Climate taxes:** direct climate taxes were identified in a handful of Member States (DK, IE, LU, UK) and their revenues, as reported in Eurostat in 2011, were subtracted from the national total for climate change impact, this was allocated to electricity. These taxes total approximately 2 billion euros.

Taxes on air pollution, water use and other impacts may also represent some level of internalisation but for a variety of reasons such as data incompatibility, purpose of tax and sector allocation (i.e. tax applies to energy and other sectors without distinction) we have been unable to include these.

A3.1.7 Summary of final values

Table A3-5 summarises the values we have used to monetise the environmental impacts to estimate the external costs of energy.

[135] EC (2014), Impact Assessment Carbon Leakage list 2015 – 2019.

Table A3-5: Summary of monetisation values and approaches

Impact categories	Unit	External costs (€2012/ unit)	Approach/Method
Climate change	kg CO_2 eq	0.043	Literature
Ozone depletion	kg CFC-11 eq	107	NEEDS-based, ReCiPe endpoint, CE Delft
Terrestrial acidification	kg SO_2 eq	0.2	NEEDS-based, ReCiPe endpoint, CE Delft
Freshwater eutrophication	kg P eq	0.2	NEEDS-based, ReCiPe endpoint, CE Delft
Marine eutrophication	kg N eq	1.8	NEEDS-based, ReCiPe endpoint, CE Delft
Human toxicity	kg 1.4-DB eq	0.04	NEEDS-based, ReCiPe endpoint, CE Delft
Photochemical oxidant formation	kg NMVOC	0.0023	NEEDS-based, ReCiPe endpoint, CE Delft
Particulate matter formation	kg PM_{10} eq	15	NEEDS-based, ReCiPe endpoint, CE Delft
Terrestrial ecotoxicity	species.yr.m^2	1.04E-09	NEEDS-based, ReCiPe endpoint
Freshwater ecotoxicity	species.yr.m^3	2.95E-12	NEEDS-based, ReCiPe endpoint
Marine ecotoxicity	species.yr.m^3	5.68E-17	NEEDS-based, ReCiPe endpoint
Ionising radiation	kg U235 eq kBq	0.001	NEEDS-based, ReCiPe endpoint, CE Delft
Agricultural land occupation	m^2a	0.09	NEEDS-based, ReCiPe endpoint
Urban land occupation	m^2a	0.1	NEEDS-based, ReCiPe endpoint
Natural land transformation	m^2	3.6	NEEDS-based, ReCiPe endpoint
Water depletion	m^3	0.2	Derived method from literature
Metal depletion	kg Fe eq	0.07	ReCiPe endpoint (adapted)
Depletion of energy resources	kg oil eq	0.05	ReCiPe endpoint (adapted)

A3.1.8 Calculation approach

The different input data described in the sections above are combined to yield external costs per unit of energy as well as the total external costs per Member State. The calculations consist of the following steps:

1. The LCIA input data are summed across lifecycle steps to arrive at the total lifetime environmental impacts per MWh for all 18 impact categories for each reference technology and reference country.
2. These environmental impact data are mapped to each Member State using the scaling factors described previously.
3. The scaled environmental impact data are multiplied by the 2012 production data described previously to calculate the total impacts per Member State and for the EU. An EU weighted average per technology is also calculated.
4. These total environmental impact values are multiplied by the monetisation values described previously to determine the external costs per technology and Member State.

As described in Box A3-1 two different sets of LCIA data are used as input to the tool; one including as upstream electricity use and a second one excluding all upstream electricity use occurring within the EU. To ensure a fair comparison between technologies, the first LCIA dataset is used for all results per MWh (i.e. impacts per technology). To prevent double counting of impact, the second LCIA dataset is used for all aggregated results (i.e. total impacts across all technologies per Member State).

A3.1.9 Other key methodological assumptions and notes

The tool is underpinned by many different assumptions and decisions, some of the key points are listed below.

- All final values are in 2012 euros, with standard deflators and exchange rates used;
- External costs are only calculated for the year 2012;
- Only the listed environmental externalities are calculated as impacts and then valued, other potential externality impacts such as noise, erosion or salination, etc.; are excluded;
- Total external costs are not calculated for domestic heat pumps or domestic solar thermal systems as production data is unavailable and/or incompatible. External costs per MWh of heat are calculated for these technologies;
- The impact of energy distribution is not included in the analysis;
- In the case of CHP systems environmental impacts are allocated to electricity and heat production on an exergy basis (see box A3.2 below);
- In the case of waste CHP, 50% of the environmental impacts are allocated to energy generation (heat and electricity combined), while the other 50% are allocated to the waste treatment function of the CHP;
- For industrial heat an efficiency of 85% is assumed;
- For the direct electricity use of domestic heating technologies either the calculated EU energy mix impact, or a generic Ecoinvent electricity production mix for average European conditions is applied;
- Data for coal-fired CHP is not available in Ecoinvent. Therefore, a hard coal-fired power plant was used as a proxy. Similarly, data for a biomass CHP was used as a proxy for a dedicated biomass power plant;
- Ecoinvent assumptions for Biomass CHP for particulate matter and NOx pollution control were considered to be very conservative, even considering that the data relates to 2000.
  Therefore, the values were changed in Ecoinvent from 90% to 97% for the particulate matter reduction efficiency and from 50% to 75% for NO_x pollution control.
  Ammonia and urea use and ammonia emissions were also changed with the NO_x reduction efficiency (a linear relationship was assumed).

- We assumed wood pellets are made of residue wood and did not allocate agricultural land occupation to the production of this wood (i.e. all agricultural land occupation is allocated to the main wood product). The agricultural land occupation impact of the growing of the wood used for wood pellet production (used in dedicated biomass plant, biomass CHP and wood pellet boiler) was excluded. While this may not reflect all biomass use in the EU, we understand it reflects the majority sources in 2012[136];
- We excluded the impact from uranium used in nuclear power production from the metal depletion category as this category includes elements of substitutability of different metals which does not apply to uranium. Instead, we added uranium to the depletion of energy resources impact category (i.e. the energy content of the fuel input was converted to kg oil eq and added to the indicator Depletion of energy resources);
- We exclude arsenic and manganese emissions relevant to human toxicity impacts, from activities in the EU as we assume that regulation prevents or minimises their release[137]. This excludes these emissions from lignite altogether as it is both mined and used in the EU. For hard coal, there may be emissions from internationally mined coal so therefore it is included in upstream emissions.

[136] Lamers, P., M. Junginger, C. Hamelinck and A. Faaij (2012). Developments in international solid biofuel trade – an analysis of volumes, policies, and market factors. Renewable & Sustainable Energy Reviews. DOI: 10.1016/j.rser.2012.02.027.

[137] We explored this issue further as initial findings gave very high impacts, and found that a large part of this was that the impact was calculated based on a global dataset, while in reality in the EU lignite is largely produced and used close to source. In contact with the lignite association in Germany we were provided with assurances that regulation in Europe is stronger than the global average and strongly mitigates the most important pollutants from mining activities. The explanation, briefly summarised as follows:
In order to get permission of lignite mining, high environmental standards have to be met. If negative impacts on the water are expected because of geological conditions, countermeasures have to be taken in advance. These countermeasures are therefore part of the initial investment when opening mines, their costs are included in the costs of the resource lignite. The success of the countermeasures have to be reported continuously to the regulating authority. Mining operators have to build financial reserves to finance follow-up measures after the excavation process is finished. These financial reserves are obligatory and are included in the costs of the resource lignite.
To stabilise machines in open lignite mines, the ground water level has to be reduced. The lignite and the soil and rocks beside it have to be dry before you can start to cut the lignite layers. Additionally, the water pressure level has to be reduced to a point below the deepest point of the lignite layer you want to extract. By reducing the water level and especially by opening the ground, air gets in contact with pyrite. The mineral partly oxidises. While the lignite is extracted, pyrites are in contact with oxygen at the mining site itself and at the disposal area. In general it is exposed for weeks to months. Clay and pyrite free excavation material around the pyrite containing excavation material reduces the oxidisation processes. The oxidation rate of pyrites depends on the mining technique. In Germany, it is about 15 – 20%.
In Germany, currently active open mines for lignite, the average concentration of pyrite is 0.1 to 0.8%. Pyrite includes traces of zinc, nickel, cobalt and arsenic. Manganese is bound in oxides, carbonates and silicates and might be mobilised in the pyrite oxidation process. Because of chemical reactions due to the pyrite oxidation process, the main parts of the arising iron is bound in siderite.
The residuals of the pyrite oxidisation process stay to a large extent in the dewatered disposal site. When the excavation process has been finished, the returning ground water might wash out some of the residuals. Manganese and arsenic play an inferior role in this process. Concentration of manganese is mostly below 10 mg/l. The threshold of 0.1 mg/l of arsenic concentration is only crossed in exceptional cases. These values are only found in the excavation disposal area itself. This water is not taken into account for drinking water or similar usage. It rarely gets into contact with underground streams which takes away much less concentrations of the residuals.

Box A3-2: Allocation of impacts for CHP

For CHP the environmental impact values for heat and power were derived by splitting the total CHP environmental impact between power and heat using an exergy based split with a beta factor of 0.3. This is summarised by the following formulae[138]:

$$Impact\ power\ = \left[\frac{E}{E + ß * H}\right] * I$$

$$Impact\ heat = \left[\frac{ß * H}{E + ß * H}\right] * I$$

where:

E = net electricity production of the CHP plant
H = net heat production of the CHP plant
I = total environmental impact of the CHP plant
F_H = the amount of fuel that is allocated to heat production
F_E = the amount of fuel that is allocated to electricity production.
ß = the ratio between the exergy and the energy content of the heat produced

The ratio of 0.3 was selected as reflective of an actual average, noting that typical values could be as low as 0.2 in the case of some district heating systems and around 0.35 for industrial heat.

Actual results vs technically possible results

The actual impacts of the CHP plants as calculated by our approach show impacts similar to that achieved by their dedicated counterparts. This is counterintuitive when it is known that a new highly efficient CHP should deliver much lower impacts than their dedicated counterparts, due to overall fuel efficiencies in the range of 75-90%.

Adjusting efficiencies in the tool to this optimum range, i.e. 85% total; we find reduced per MWh impacts of 15-30% compared to those from our calculated efficiencies from reported production data. In each case the CHP then also has more favourable impacts than its dedicated equivalent.

The reasons for the actual results being higher relate closely to the statistics and also the actual implementation and definition of CHP, with many older, less efficient CHP plants included in the statistics we use. There is also a size-efficiency aspect with gas, as our gas CHP reference is a smaller (1MWe) unit.

A3.2 Results tables

In this section detailed results tables are presented.

A3.2.1 Results per Member State

Table A3-6 and Table A3-7 show the total external costs per Member State. Upstream electricity use within the EU is excluded from these figures. These figures are not shown per unit of energy use so the higher impacts relate to a large extent to higher energy use in a Member State. The costs for France are relatively lower because of the higher use of relatively low-external cost nuclear power than for example Germany and the UK.

[138] Blok, K. (2007): Introduction to Energy Analysis. Teche Press, pp.138f.

Table A3-6: External costs per Member State for electricity (power) technologies [billion €2012]

Member State	Climate change	Depletion of energy resources	Particulate matter formation	Human toxicity	Agricultural land occupation	Other	Total (billion €2012/a)	€2012 per MWhe
EU28 Total	**53.93**	**27.91**	**20.74**	**12.39**	**1.50**	**5.72**	**122.19**	**38.3**
Austria	0.59	0.19	0.11	0.06	0.02	0.04	1.01	14.3
Belgium	0.87	0.82	0.25	0.20	0.01	0.05	2.28	28.6
Bulgaria	1.25	0.54	0.33	0.22	0.02	0.12	2.48	53.8
Croatia	0.17	0.06	0.06	0.02	0.01	0.01	0.33	31.9
Cyprus	0.17	0.06	0.13	0.01	0.00	0.02	0.39	83.7
Czech Republic	2.28	0.91	0.59	0.33	0.06	0.20	4.36	50.9
Denmark	-0.29	0.14	0.09	0.09	0.02	0.03	0.09	2.9
Estonia	0.41	0.14	0.30	0.03	0.00	0.05	0.93	79.3
Finland	0.63	0.47	0.14	0.14	0.02	0.07	1.47	21.4
France	1.80	5.81	1.18	1.12	0.04	0.90	10.85	20.1
Germany	14.55	5.40	2.20	2.37	0.33	1.15	26.00	42.3
Greece	2.13	0.78	1.21	0.37	0.03	0.22	4.73	79.9
Hungary	0.61	0.39	0.14	0.08	0.00	0.06	1.28	38.3
Ireland	0.30	0.19	0.10	0.11	0.01	0.04	0.76	27.5
Italy	5.32	1.78	2.01	1.10	0.08	0.42	10.71	38.1
Latvia	0.05	0.02	0.01	0.00	0.00	0.00	0.09	15.2
Lithuania	0.08	0.03	0.01	0.00	0.00	0.00	0.13	28.0
Luxembourg	-0.01	0.02	0.01	0.00	0.00	0.00	0.02	6.1
Malta	0.10	0.04	0.08	0.01	0.00	0.01	0.24	102.9
Netherlands	2.01	0.75	0.39	0.41	0.03	0.12	3.71	36.7
Poland	6.03	1.77	3.03	0.88	0.42	0.40	12.53	78.3
Portugal	0.83	0.26	0.49	0.24	0.01	0.08	1.90	42.1
Romania	1.41	0.56	0.38	0.21	0.03	0.12	2.71	47.3
Slovakia	0.28	0.28	0.26	0.07	0.01	0.05	0.95	35.6
Slovenia	0.25	0.14	0.14	0.05	0.01	0.03	0.63	40.7
Spain	4.60	2.23	3.10	0.93	0.13	0.56	11.55	40.3
Sweden	0.19	0.83	0.11	0.16	0.01	0.14	1.44	8.9
United Kingdom	7.31	3.31	3.86	3.17	0.20	0.76	18.61	52.6

*Denmark has a negative climate impact as we have subtracted the revenues from their carbon tax and allocated them to electricity to represent the internalisation – this is not a perfect alignment.

Table A3-7: External costs per Member State for heat technologies (excluding domestic heat pumps and solar thermal) [billion €2012]

Member State	Climate change	Depletion of energy resources	Particulate matter formation	Human toxicity	Agricultural land occupation	Other	Total (billion $€_{2012}$/ a)	$€_{2012}$ per MWh_{th}
EU28 Total	**44.77**	**15.61**	**9.00**	**4.65**	**0.37**	**2.24**	**76.65**	**19.5**
Austria	0.90	0.32	0.20	0.07	0.00	0.05	1.55	18.5
Belgium	1.35	0.51	0.15	0.09	0.00	0.06	2.16	17.5
Bulgaria	0.35	0.12	0.13	0.04	0.01	0.02	0.66	20.0
Croatia	0.25	0.09	0.06	0.02	0.00	0.01	0.44	19.2
Cyprus	0.02	0.01	0.01	0.01	0.00	0.00	0.05	37.6
Czech Republic	1.64	0.52	0.45	0.39	0.03	0.09	3.11	25.4
Denmark	0.46	0.14	0.11	0.06	0.01	0.03	0.81	13.8
Estonia	0.07	0.02	0.03	0.02	0.00	0.01	0.16	16.7
Finland	0.66	0.21	0.23	0.17	0.01	0.05	1.32	17.7
France	5.12	1.75	1.10	0.58	0.02	0.28	8.84	19.8
Germany	9.02	3.26	1.58	0.84	0.07	0.41	15.18	19.8
Greece	0.39	0.13	0.16	0.08	0.00	0.03	0.79	25.2
Hungary	1.08	0.37	0.17	0.04	0.00	0.04	1.70	20.4
Ireland	0.30	0.10	0.05	0.02	0.00	0.01	0.48	20.0
Italy	6.28	2.13	1.15	0.70	0.02	0.26	10.55	20.0
Latvia	0.11	0.04	0.04	0.01	0.00	0.01	0.21	12.8
Lithuania	0.13	0.05	0.04	0.01	0.00	0.01	0.24	14.3
Luxembourg	0.10	0.04	0.01	0.01	0.00	0.00	0.16	19.1
Malta	0.00	0.00	0.00	0.00	0.00	0.00	0.00	16.9
Netherlands	2.68	1.04	0.24	0.08	0.00	0.12	4.16	16.6
Poland	2.75	0.90	1.00	0.37	0.09	0.16	5.27	23.2
Portugal	0.41	0.15	0.12	0.04	0.00	0.02	0.75	19.5
Romania	1.30	0.46	0.33	0.13	0.01	0.07	2.31	17.8
Slovakia	0.59	0.20	0.16	0.06	0.01	0.03	1.04	24.5
Slovenia	0.12	0.04	0.04	0.02	0.00	0.01	0.23	17.1
Spain	2.64	0.92	0.67	0.32	0.03	0.13	4.71	21.9
Sweden	0.52	0.16	0.21	0.16	0.01	0.04	1.10	15.4
United Kingdom	5.55	1.94	0.56	0.31	0.01	0.30	8.67	17.9

A3.2.2 Technology specific results

Table A3-8 and Table A3-9 show the external cost in the EU28 per technology. Please note that upstream electricity use within the EU is included in these figures. Therefore, the values cannot be directly compared with the EU28 aggregated total.

Domestic heating technologies, especially the heat pump, use electricity during operation. Within this analysis, due to data and process complexities, this electricity demand was not adjusted to the electricity mixes in the specific Member States. Instead, we used our calculated EU average impacts per MWh, or the generic EU average dataset from Ecoinvent was applied. Therefore, the results should therefore be seen as an indication of the average external costs of these technologies.

Table A3-8: EU28 external costs per technology for electricity (power) technologies [billion €2012]

Technology	Climate change	Depletion of energy resources	Parti-culate matter formation	Human toxicity	Agri-cultural land occupation	Other	Total (billion €2012/a)	€2012 per MWhe
Hard coal-fired power plant	18.44	5.15	9.59	6.69	0.75	1.36	41.99	95.3
Lignite-fired power plant	12.00	3.22	2.56	1.77	0.02	0.92	20.48	81.7
Natural gas-fired power plant	6.10	2.50	0.60	0.03	0.00	0.32	9.56	34.3
Oil-fired power plant	1.87	0.66	1.36	0.13	0.00	0.21	4.23	87.6
Nuclear power plant	0.26	10.94	0.76	1.36	0.03	1.48	14.85	17.8
Biomass †	0.34	0.06	0.21	0.27	0.01	0.06	0.96	17.7
Solar PV, rooftop *	0.13	0.04	0.12	0.22	0.02	0.12	0.65	14.2
Solar PV, ground (utility) *	0.06	0.02	0.06	0.06	0.01	0.10	0.31	14.1
Wind, offshore	0.00	0.00	0.00	0.01	0.00	0.01	0.02	2.4
Wind, onshore	0.16	0.05	0.17	0.19	0.01	0.25	0.83	4.2
Hydro, reservoir	0.06	0.01	0.04	0.01	0.00	0.04	0.16	1.0
Hydro, run-of river	0.05	0.01	0.09	0.02	0.00	0.04	0.20	1.0
Geo-thermal power	0.01	0.00	0.02	0.01	0.00	0.01	0.05	9.4
CHP-Bio (Power) †	0.47	0.09	0.29	0.37	0.01	0.09	1.31	13.8
CHP-Natural gas (Power)	7.15	2.70	1.15	0.06	0.00	0.26	11.33	37.4
CHP-Hard coal (Power)	9.81	2.85	4.27	1.71	0.67	0.61	19.91	85.0
CHP-Waste (Power)	0.20	0.00	0.02	0.13	0.00	0.01	0.36	35.3

*Note: The values presented here for costs per unit of production for solar PV are likely to be an overestimation of the current situation, because of the high pace of technological development for this technology improving efficiencies and reducing upstream impacts.

†Note: biomass is assumed to be sourced from agricultural/waste wood residues only, i.e. biomass from dedicated energy crops is not included (see also Annex 3).

Table A3-9: EU28 external costs per technology for heat technologies [billion €2012]

Technology	Climate change	Depletion of energy resources	Parti-culate matter formation	Human toxicity	Agri-cultural land occupation	Other	Total (billion €2012/ a)	€2012 per MWhth
CHP-Bio (Heat) †	0.14	0.03	0.08	0.11	0.00	0.03	0.39	4.3
CHP-Natural gas (Heat)	1.43	0.54	0.23	0.01	0.00	0.05	2.27	11.7
CHP-Hard coal (Heat)	2.01	0.58	0.65	0.35	0.13	0.11	3.83	24.1
CHP-Waste (Heat)	0.11	0.00	0.01	0.07	0.00	0.00	0.20	10.1
Dom. natural gas-fired boiler	21.07	7.22	1.23	0.29	0.03	0.78	30.61	17.9
Dom. wood pellet boiler †	1.11	0.27	1.51	0.72	0.00	0.33	3.95	11.2
Domestic heat pump	n/a	n/a	n/a	n/a	n/a	n/a	n/a	12.5
Domestic solar thermal	n/a	n/a	n/a	n/a	n/a	n/a	n/a	9.6
Industrial fuels for heat	20.08	7.29	5.71	3.71	0.22	1.08	38.08	27.2

†Note: biomass is assumed to be sourced from agricultural/waste wood residues only, i.e. biomass from dedicated energy crops is not included.

A3.2.3 Detailed EU28 aggregated results

The table below shows the total impacts and external costs in the EU28 per impact category.

Table A3-10: Total EU28 impacts and external costs [bn EUR]

Impact	Unit (x million)	Total impact in impact unit	Unit value (€2012/x)	Total Value (€2012 billion)
Climate change	kg CO_2 eq	2 256 658	0.043	98.7
Ozone depletion	kg CFC-11 eq	0.2	107	0.0
Terrestrial acidification	kg SO_2 eq	6 154	0.2	1.4
Freshwater eutrophication	kg P eq	1 139	0.2	0.3
Marine eutrophication	kg N eq	381	1.8	0.7
Human toxicity	kg 1,4-DB eq	398 668	0.04	17.0
Photochemical oxidant formation	kg NMVOC	4 146	0.002	0.0
Particulate matter formation	kg PM^{10} eq	1 969	15	29.7
Terrestrial ecotoxicity	species.yr	0.0	1.04E-09	0.0
Freshwater ecotoxicity	species.yr	0	2.95E-12	0.0
Marine ecotoxicity	species.yr	0	5.68E-17	0.0
Ionising radiation	kBq U235 eq	1 147 586	0.001	1.1
Agricultural land occupation	m^2 a	19 997	0.09	1.9
Urban land occupation	m^2 a	8 275	0.10	0.8
Natural land transformation	m^2	378	3.6	1.4
Water depletion	m^3	5 391	0.18	1.0
Metal depletion	kg Fe eq	18 788	0.07	1.3
Depletion of energy resources	kg oil eq	912 769	0.05	43.5
TOTAL				**198.8**

A3.3 External cost of accidents

All forms of energy have an associated risk of an accident for example there have been high profile coal mining accidents (mostly outside the EU in recent years) and accidents during oil and gas extraction. In the case of nuclear, the cost and consequences of any accident has the potential to be very much higher than for other energy sources. In this section, we therefore present a review of literature on the external cost of a nuclear accident and provide estimates which should be added to the external costs described above – see also Box 3.2 in the main report.

Estimating the actual costs associated with a nuclear accident is not an easy task, because there is a lack of data and examples (not many accidents have occurred). In addition, there are indirect external costs, such as damage to a countries reputation and longer term costs such as increased cancer rates which further complicate nuclear accident cost estimates.

Naturally, the cost depends on the severity of the accident, which ranges from small accidents to nuclear meltdown and critical accidents. Furthermore, the frequency with which accidents happen also influences the estimated cost. Due to range of assumptions on frequency and severity alone, the external cost estimations vary by the order of a factor ten.

The few examples that exist show how large the external costs can be. Greenpeace estimates that the Fukushima disaster caused about € 130 billion of damage[139]. The costs of the accident in Chernobyl are also estimated to be of the order of several hundred billion euros. *Institut de Radioprotection et de Sûreté Nucléaire* in France estimated that the damage from a large nuclear accident in France would cost € 120-300 billion[140].

Various studies have estimated the external cost, expressed in euro per electricity production. This often results in a euro per MWh range, generally depending on inter alia type of accident, risk assumptions, frequency and location of the site. The German Institute for Energy Economics and the Rational Use of Energy [141] estimated the external cost of nuclear accidents is $€2_{012}$ 0.24 per MWh. The Nuclear Energy Agency[142] calculated that the *direct* external cost due to a nuclear accident to about $€2_{012}$ 0.0053 per MWh. When including indirect effects and correcting for risk aversion, the external cost is estimated at $€2_{012}$ 0.14 per MWh. Rabl et al[143] estimated that the external cost ranges from $€2_{012}$ 0.83 to 23.8 per MWh, with a central value of $€2_{012}$ 4.0 per MWh. **We estimate that the external cost due to a nuclear accident ranges from EUR 0.5 to 4 per MWh.** This range has been added to the external costs of nuclear power as presented in figure 3-5 in the main report. The range we use is comparable with D'haeseleer[144], who summarises that the external cost of nuclear accidents can be estimated in the order of 0.3-3 € per MWh.

A3.4 Uncertainties and assumptions

The sheer scale and complexity of each energy technology, its supply chain and national power system, combined with the different demographic, resource and geographic characteristics of Member States, means that the results produced by the External-E tool are an approximation based on a set of general assumptions rather than a precise estimate of actual external costs. Nevertheless the results provide an indication of the order of magnitude of specific impacts per technology and Member State.

In using the results of this analysis due consideration should be given to the following:

Uncertainties in key monetisation values: the two key values driving the results are the values applied to climate change impacts and fossil depletion. While we have selected on the basis of literature review there remain significant uncertainties and some element of value judgement attached to both of these values. Any changes in these values would significantly alter the total external cost, as is shown in the sensitivity analysis.

The tool only estimates the cost of specific environment externalities: and only for those impacts that are listed and for which methods and values to estimate their damages exist. While this gives a broad view of the external cost of energy it misses some environmental impacts, and does not include negative (or positive) social or economic externalities.

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[139] http://www.greenpeace.org/switzerland/Global/switzerland/de/stromzukunft_schweiz/atom/ageing2014/Lifetime-extension-of-ageing-nuclear-power-plants-Entering-a-new-era-of-risk.pdf
[140] http://www.irsn.fr/FR/Actualites_presse/Actualites/Documents/FR_Eurosafe-2012_Rejets-radioactifs-massifs-vs-rejets-controles_Cout_IRSN-Momal.pdf
[141] Institut für Energiewirtschaft und Rationelle Energieanwendung (IER; 2013) Die Risiken der Kernenergie in Deutschland im Vergleich mit Risiken anderer Stromerzeugungstechnologien.
[142] https://www.oecd-nea.org/ndd/reports/2003/nea4372-generation.pdf
[143] Rabl, A et al (2013). External costs of nuclear: Greater or less than the alternatives? Energy Policy Vol 57.
[144] D'Haeseleer, W. (2013) Synthesis on the economics of nuclear energy.

Latest technological and energy market developments are not all incorporated in values: some values, while the latest available, can be based on older work or data. In some cases simply the pace of technological change for a technology such as solar PV is faster than the life cycle inventory data.

Valuation of water depletion is based on an experimental method – results should be treated with caution: While extensive work has been carried out to value wetland, riverine, marine and coastal areas (m^2), i.e. 'The Economics of Ecosystems and Biodiversity for Water and Wetlands' (TEEB, 2013) little insight is given into the value of consumed water volume (m^3), as compared to the water available and its impact (as a cost) on ecosystems and biodiversity. As a result we selected a method for valuation which provides an estimate of external costs but which has some associated uncertainties.

Power-fleet efficiency modifier is a necessary simplification of reality: for simplicity and as a general rule we have assumed all impacts scale proportionally with power plant efficiency relative to the reference plant. This is not necessarily the case, for example a less efficient plant may have different (better/worse) air pollution mitigation technologies employed so that these do not scale positively or proportionally. We believe that in general most impacts do scale relatively closely with efficiency.

Ecosystem damage valuations are derived from a Swiss ecosystem ideal, but applicable across the Northern Hemisphere: the valuation of Ecosystem damages is based on the potentially disappeared fraction (PDF) relative to a characterised optimum of an 'Extensive broadleaf, mixed and yew LOW woodland' in Switzerland. The other land use types and their species diversity are ranked against this. The values are believed to be valid for use across the Northern Hemisphere.

Central perspectives, scenarios and values have been used: our impact analysis and valuation is based on the hierarchist perspective, with the exception of energy resource depletion as explained, with the overall assumption of a 100-year time horizon and 3% social discount rate, this is in contrast to individualist and egalitarian perspectives which reflect more extreme and opposite perspectives[145]. A number of the values, particularly for climate change, are also produced as part of a set of scenarios or options and this can make a significant difference to the values, in these cases we have selected the central scenario value, preferring for consistency with the hierarchist perspective on time-horizons and social discount rates.

[145] To deal with uncertainties at the end point level, ReCiPe makes use of the cultural perspectives theory of Thompson 1990. According to this theory consistent sets of subjective choices on time horizon, assumed manageability etc. can be grouped around three perspectives, identified by the names: individualist (I), hierarchist (H) and egalitarian (E).The hierarchist perspective is the middle perspective and is most often used as default option.