

1 Introduction

Each of the *World Energy Outlook* scenarios envisages growth in the use of renewable energy sources over the *Outlook* period. *World Energy Outlook 2011* includes estimates of the subsidies for renewable electricity and biofuels (renewable transport) for the historic years 2007-10 and projected subsidies for the period 2011-2035. This document describes how these numbers were derived.

Section 2 introduces the definition of ‘subsidies’ for the purposes of this analysis. Section 3 describes the calculation of subsidies for renewable electricity, and Section 0 details the methodology used to calculate biofuel subsidies.

2 Defining ‘subsidies’

The overall value of subsidies to renewables is calculated here as the price per unit of energy paid to renewable energy producers for their output over and above the prevailing market price (or reference price), multiplied by the volume of energy supported. This definition of subsidy excludes some forms of expenditure on renewables, including some direct funding of R&D.

The introduction of carbon pricing in energy markets improves the competitiveness of renewables relative to unabated fossil-fuel generators. Each of the *World Energy Outlook* scenarios is defined by a set of carbon constraints that reflect the each scenario’s assumptions relating to climate-change policy decisions. Because these carbon constraints are inherent to each scenario, carbon pricing is not considered to represent a support cost for renewables in this analysis.

3 Subsidies for renewable electricity

Most renewable technologies have experienced significant reductions in cost per unit of generation in recent decades, as technology has improved. Nevertheless, in most contexts the cost of generation from new renewable capacity today is higher than the cost of electricity from other generation technologies. As a result most of the renewable capacity built in recent years has received, or is receiving, economic support that is either provided directly by government expenditure or is in some way mandated by governments. The mechanisms for providing this support can take several different forms. Table 1 gives some examples of these.

Table 1: Example government support mechanisms for renewables-based electricity.

| Support scheme | Description |
|-----------------------------|--|
| Feed-in tariffs (FITs) | FITs are granted to operators for the renewable electricity they feed into the grid. They take the form of a fixed price per MWh, which reflects the cost of the technology. |
| Production tax credit (PTC) | Direct reduction in tax liability. |
| Investment tax credit (ITC) | Direct reduction in tax liability. |
| Green certificates (GC) | A green certificate is a tradable commodity proving the production and the use of a certain amount of renewable energy. |
| Premiums | Premiums are a type of bonus and are paid to the producers on top of the electricity price (market-driven or regulated). |

3.1 Technologies included in the analysis

A number of renewable electricity generation technologies are currently being developed and used in the power sector globally. The World Energy Model includes seven principal categories of renewable generation: biomass, geothermal, wind, hydro, solar photovoltaics, solar thermal, and marine. For most of these, the model includes further sub-divisions, e.g. onshore and offshore wind. The table also notes which technologies were included in this analysis, for the historic years 2007-2010 and for the *Outlook* period (2011-2035).

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In general it was assumed that a subsidy is being paid to all capacity installed since the year 2000 (inclusive), and that capacity built before this date was either economically competitive in its own right (for technologies such as geothermal) or is negligibly small compared to the total volume of renewable capacity installed since 2000 (in the case of onshore wind, for example).

Large hydro is not included in the analysis as it is generally competitive in those contexts in which it is deployed; biomass with CCS is not used in any of the scenarios during the period of the *Outlook* and therefore does not feature in this analysis either. Due to the considerable effort required to obtain data on historic subsidies for renewable technologies, the analysis for the period 2007-2010 excluded some of the technologies that are less significant in volume terms.

Table 2 provides a full listing of the renewable technology categories that appear in the power generation module of the World Energy Model. The table also notes which technologies were included in this analysis, for the historic years 2007-2010 and for the *Outlook* period (2011-2035).

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Table 2: Categories of renewable electricity generation technologies and inclusion in the analysis of subsidies

| Categories of renewable electricity generation in WEM | Included in the analysis for 2007-2010? | Included in the analysis for 2011-2035 |
|---|---|--|
| Hydro (Large) | No | No |
| Hydro (Small) | No | Yes, if built after 2000 |
| Biomass Power Plant | Yes, if built after 2000 | Yes, if built after 2000 |
| Biogas DG (Industry) | Yes, if built after 2000 | Yes, if built after 2000 |
| Biomass (Cofiring) | Yes, if built after 2000 | Yes, if built after 2000 |
| Biomass (IGCC with CCS) | No (not deployed) | No (not deployed in any scenario) |
| Biomass CHP (Medium) | Yes, if built after 2000 | Yes, if built after 2000 |
| Biomass CHP (Small) | Yes, if built after 2000 | Yes, if built after 2000 |
| Waste to Energy | No | Yes, if built after 2000 |
| Wind Onshore | Yes, if built after 2000 | Yes, if built after 2000 |
| Wind Offshore | Yes, if built after 2000 | Yes, if built after 2000 |
| Geothermal (Electricity-only) | Yes, if built after 2000 | Yes, if built after 2000 |
| Geothermal (CHP) | Yes, if built after 2000 | Yes, if built after 2000 |
| Solar PV (Grid-connected) | Yes, if built after 2000 | Yes, if built after 2000 |

| | | |
|---------------------------------------|--------------------------|--------------------------|
| Solar PV (Building-integrated) | Yes, if built after 2000 | Yes, if built after 2000 |
| Concentrating solar power | No | Yes, if built after 2000 |
| Tide/Wave | No | Yes, if built after 2000 |

3.2 Calculating historic subsidies costs for renewable electricity

3.2.1 Approach

The cost of renewable electricity support in the years 2007-10 was calculated based on the difference between the amount paid to renewable sources and the value of electricity for each of the countries included in the study.

As such, estimates of renewable subsidies in the years 2007-2010 reflect the *policy* costs of renewables support. That is to say that even if support mechanisms were under- or over-paying for renewable generation, compared to their economic cost, this under- or over-payment will be included in the subsidy cost calculated.

3.2.2 Methodology

In order to quantify the payments made to renewables, we conducted a country-by-country review of national support mechanisms, for four key technologies: wind, photovoltaics, geothermal and biomass.¹ This survey covered 26 countries, representing an estimated over 99% of global generation from these technologies. Electricity prices were derived from a combination of IEA data and other data for example from national power exchanges. The reference electricity price was assumed to be the wholesale electricity price for all technologies.²

For each country, and for each year 2007-2010, the difference between the total amount spent on renewable generation and the value of the electricity generated at the reference price was calculated. This difference was taken as the support costs for renewables in each of the three years. This calculation was performed separately for each technology and each country, and the results presented in the *World Energy Outlook* are a summation of the subsidy for each technology and in each country.

3.3 Calculating future subsidy costs for renewable electricity over the Outlook period

3.3.1 Approach

For future years, it is not possible to project the level or the mechanism of support for renewable energy that will exist in any country. In light of this, instead of calculating the *policy* costs of renewables support, we calculate instead the additional *economic* cost of renewable electricity over the *Outlook* period.

¹ The emphasis in this research was on national-level support mechanisms although some sub-national support was also considered in countries where this represents a significant proportion of the total.

² In *World Energy Outlook 2010*, the production costs of solar PV were compared to end-user prices for the purposes of calculating subsidies for solar PV in buildings. We have changed our approach after concluding that the difference between the wholesale price and the end-user price comprises several additional costs that are not affected by the presence of solar PV, such as metering and billing. Also, end-user prices in many regions include the cost of support to renewable technologies and it would not be appropriate to include this in the calculation of the subsidy required by solar PV.

The additional net economic cost of renewable generation can be calculated as the difference between the full unit cost of renewable generation in any period and the cost of providing a unit of energy from the mix of generation that would exist if there was no support for renewables.³

The full levelised cost of a renewable generator is the present value⁴ at the time of commissioning of its capital costs, any fuel it uses during its lifetime (e.g. biomass), plus operation and maintenance costs associated with running the plant, all divided by the volume of energy it generates over its lifetime.

The generation mix that would occur without subsidy for renewables is determined by several factors. These include the prices of fossil fuels; the pattern of within-day and within-year demand variation;⁵ the cost of capital; and the price on carbon emissions (if any). In order to maintain a sufficient level of generation capacity in a market, average wholesale electricity prices must in the long run be high enough to cover the levelised costs of new entrants. As a result, in a competitive electricity market the wholesale price will reflect the cost of new entrants, in the long run.

In practice this approach is very similar to the one used to calculate historic subsidies, the only difference being that it is the cost of renewable generation, rather than the unit revenue provided by a support mechanism, that is compared to the reference electricity price.

3.3.2 Methodology

In order to calculate the subsidies provided to renewables over the period of the *Outlook*, in each of the three scenarios, we used the following methodology.

For each renewable technology, and for the volume of that technology installed in any given year, we calculate the difference between its levelised costs per unit of generation (in \$/MWh) and the wholesale price of electricity (in \$/MWh) for each year of its economic lifetime. Because the wholesale electricity price changes from one year to the next, the difference between the levelised cost and the wholesale price also changes from year to year.

For example, for onshore wind turbines built in the US in 2011, with an assumed lifetime of 20 years, we calculate the difference between the levelised cost of new onshore wind built in the US in 2011 and the wholesale price for each of the years 2011-2030. Multiplying this difference by the annual volume of generation from onshore wind built in the US in 2011 gives the required support in each of these years for onshore wind capacity built in 2011. Repeating this for the volume of onshore wind built in each year and summing the results gives the total support required for onshore wind in the US over the *Outlook* period. Applying this to all technologies and in all regions gives the total subsidy required for renewables globally over the period.

In each scenario, we use the electricity price for that scenario, which reflects – among other things – the fuel and carbon prices assumed in each of these scenarios.

3.4 Factors determining the results

The total subsidy requirement for renewables in any year depends on three factors: the levelised cost of renewable technologies, the volume of renewable generation, and the reference price of electricity.

³ The World Energy Model determines the mix of non-renewable generation based on least-cost deployment of available generation technologies in each region.

⁴ In calculating the present value of a set of costs (or revenues), all future expenditure (income) is discounted to reflect the cost of capital.

⁵ The introduction of higher volumes of variable renewable sources changes the optimal mix of fossil-fuel generation as it affects the characteristics of the profile of thermal generation that is required.

In the *World Energy Outlook* scenarios, the volume of renewable generation increases over time, as governments maintain or increase support for these technologies. At the same time, the levelised cost of new entrant renewable energy technologies falls, as the results of technological improvements that arise from learning. The wholesale price also grows in most regions in all scenarios. This is mainly due to changes in fuel prices and carbon prices, both of which tend to grow over time, making electricity from unabated fossil technologies more costly and increasing the electricity reference price. Figure 1 shows the effect of these competing factors in determining the way in which renewable support costs change over time, and in particular how reductions in technology costs and increases in fuel and carbon prices can offset the impact of growth in the volume of renewable deployment over time.

3.5 Limitations of the methodology

3.5.1 Additional system costs

The methodology used to calculate the additional costs of renewables, described in this document, incorporates only the direct additional costs of renewable generation arising from their levelised costs of generation.

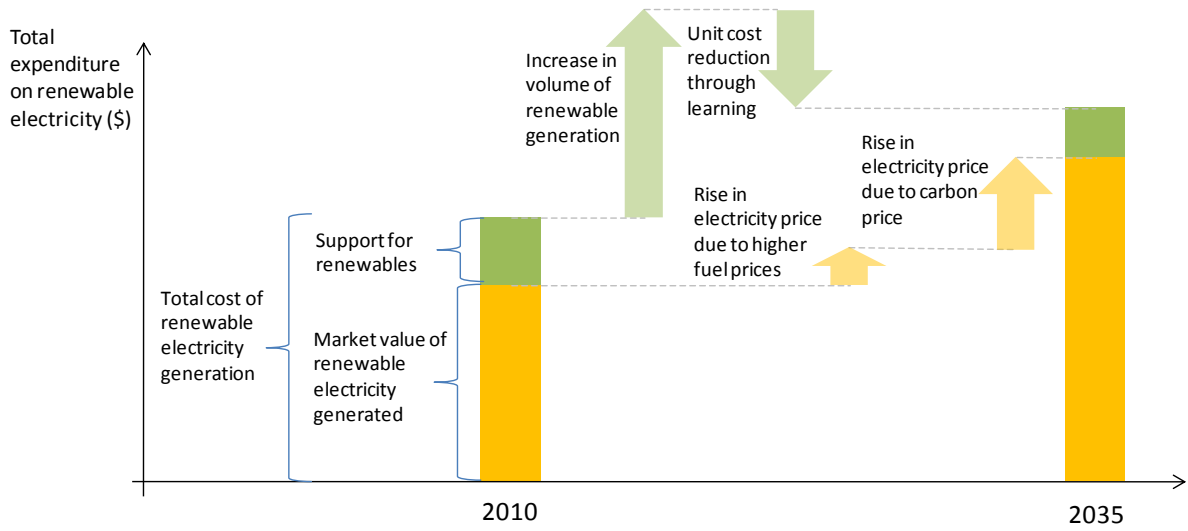
Renewable sources can also impose other costs on the electricity generation system in at least three ways. First, variable renewables – such as wind – may impose additional system operation costs as more resources are used to maintain a balance between system supply and system demand. Second, the stochastic nature of the output of variable renewables means that their capacity value is limited. As a result, other generators are required to provide capacity, which implies an additional cost per unit of generation. The WEM ensures that there is sufficient capacity to meet peak demand at all time, taking into consideration the lower capacity credit of variable renewables. Third, installation of renewable generation in geographically-remote areas or at low voltages can lead to a requirement for upgrades to transmission and distribution networks.

The additional costs associated with renewables are discussed in Chapter 5 of the *World Energy Outlook 2011*.

3.5.2 Impact of renewables on fossil fuel prices

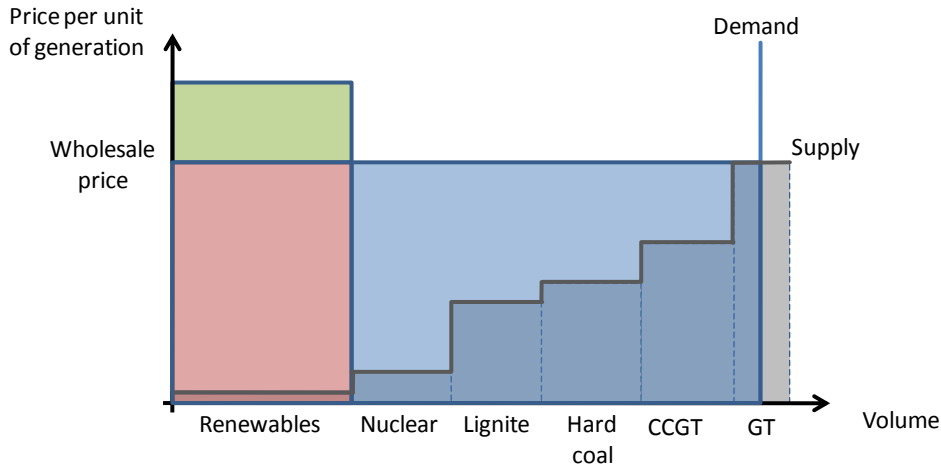
Fossil fuel prices in each scenario reflect the interaction between fossil-fuel supply and demand. As a result, for example, fossil-fuel prices are generally lower in the 450 Scenario than in the Current Policies Scenario as fossil-fuel demand is lower in the wake of tightening limits on carbon consumed. Renewable energy sources make a contribution to this weakening of fossil fuel prices by displacing demand for fossil fuels. The methodology described in this document to calculate the additional cost of renewables in each scenario takes account of the volume effect of displaced fossil fuels, but not the price effect. As a result the estimate of required support is a good reflection of the additional support required above the prevailing market price but does not reflect the full welfare gain to the economy arising from reduced fossil fuel use.

Figure 1 – Representation of changes in the costs of renewable generation and renewable support in the 450 Scenario



Box 1: The role of low-marginal-cost renewables in electricity price formation

The figure below represents supply and demand in an electricity market. The blue vertical line labelled 'Demand' is the instantaneous volume of demand for electricity. Instantaneous demand changes over the course of the day and throughout the year.



The grey line labelled 'Supply' represents the variable costs of the different plant types. These variable costs are determined mainly by the cost of a plant's fuel and its efficiency in converting the fuel to electricity. Most renewable technologies, such as wind or small hydro, have very low or no fuel costs and therefore have a low variable cost. Peaking plants, such as open-cycle gas turbines (GTs) use expensive fuel and have a lower conversion efficiency than other thermal generators, and therefore have the highest variable costs.

The wholesale price is set by the point at which the demand and the supply curve meet. As a result the wholesale price will vary within any day and over the course of the year. At the periods of highest demand the wholesale price will be set by peaking plants. When demand is low the price will be set by other technologies, such as coal.

All the non-renewable generators operating at any given time receive the wholesale price, so that the total revenue to non-renewable generators is represented by the blue area. This means that most of the plants are earning more than their variable costs. This allows them to recover their fixed costs, including their costs of construction. In a well-functioning electricity market, these revenues allow all generators to recover their full costs.

The red area represents the value of the renewable electricity on the wholesale market. Different types of support mechanisms pass this revenue to renewable generators by different means. In some systems renewable generators participate directly in the wholesale market and receive revenue from selling their electricity in the same way as a non-renewable generator. In other systems, renewable electricity is not sold explicitly into the wholesale market, but renewable generators are paid a tariff that includes this value.

For renewable plants that are not yet cost-competitive, the revenue they achieve from the wholesale price is not sufficient to meet their full costs. They require an additional level of support that is represented by the green area on the chart. This green area represents the additional economic costs of renewable electricity. By implication, the red and the green areas combined represent total expenditure on renewable electricity.

4 Subsidies for biofuels

Two steps were undertaken in identifying the additional costs of biofuels as a result of government support. First, the current level of subsidies was identified by looking into existing policy frameworks in support of biofuels. Second, a model was developed to project biofuels subsidies out to 2035.

4.1 Calculating historic support costs for biofuels

As the cost of biofuels outside Brazil are generally much higher than the price of importing oil, this almost inevitably means that any biofuels use is currently supported by some governmental policy, and a monetary value can be allocated to it. Numerous policies and measures exist to support the use of biofuels, and the exact monetary value is not always easy to quantify.

For the analysis in this year's *Outlook*, a full review of all existing policies and measures in support of biofuels was undertaken in the attempt to quantify their monetary value for the years 2007-2010. There were 20 countries investigated, covering about 90% of global biofuels consumption. The figure is then scaled up to derive a global estimate. The most common forms of support are tax credits and tax exemptions, import tariffs on foreign biofuels and blending mandates. Blending mandates have played an increasing role in recent biofuel support policies, many countries adding blending mandates to existing fiscal incentives or entirely replacing fiscal incentives by mandates. Some, but not all, of these measures can be considered subsidies.

In order to quantify the monetary value of government support to biofuels in this analysis, the tax advantage to biofuels, relative to the oil-based equivalent fuel, has been multiplied by the volume of biofuels consumed. Where blending mandates exist, tax reductions and biofuels prices were used for quantifying the implicit support through the blending mandate, which, in some cases is carried by the consumer (at least partially). Therefore, the value of what is called subsidy here represents a monetary value of all government interventions currently in place, whether the cost is finally carried by the *government* or the *consumer*.

4.2 Calculating future subsidies for biofuels over the Outlook period

For each region of the World Energy Model WEM, we calculate the difference between the costs of biofuels production for ethanol and biodiesel and the projected price of the liquid fossil fuel equivalent, i.e. gasoline and diesel, before taxes. This cost increment is then multiplied by the volume of ethanol and biodiesel used in each year, region by region.

Technology fundamentals and current and future biofuels conversion costs are adapted from the most recent version of the Mobility Model (MoMo) of the IEA, discounted over the lifetime of each biofuel conversion technology; biomass feedstock costs are derived from MoMo as well as from OECD (2010), projected out to 2035, and benchmarked against current and historical biofuel spot prices. Start year of the model is 2009, and the model is calibrated to reflect current biofuels subsidy levels as determined by the review of existing policies and measures.

The level of government subsidy to biofuels in the present analysis is therefore determined by the price level of the fossil fuel equivalent by scenario, and the pace of technology development in particular with regard to the market penetration of advanced biofuels. High fossil fuel prices can lower the cost / price gap between biofuels and the liquid fossil fuels, partly counterbalanced by an assumed 20% correlation of biomass feedstock and oil price developments. Increasing cost reductions for biofuels through technology learning and advanced biofuels deployment can also lead to lower overall biofuels costs and, thereby, to a smaller cost / price gap.

The result of the analysis of the prevailing cost increment across the different scenarios is multiplied by the volume of biofuels consumed in the specific year. Thereby, the amount of government support is determined both by the cost / price gap as well as by the volume of biofuels, and can therefore increase from one year to another with growing biofuels use, even if cost reductions are achieved on the technology side. This analysis of government subsidies does not differentiate as to whether the support is carried by the government directly, or indirectly by the consumer as possible e.g. in the case of blending mandates. It also represents an

optimal level of support, where policy-making closely monitors technology progress and avoids support above required levels. Biofuels subsidies can, thus, be even higher than the levels identified here.

4.3 Some observations on biofuels subsidies

Several observations were made when calculating the additional costs of biofuels, and limitations do exist. For the analysis of *current biofuels subsidy* levels, blending mandates are fully accounted for as government support. As blending mandates are often complemented by tax credits or tax exemptions, the level of subsidy through mandates can be quantified easily and corresponds to the level of the tax exemption or tax credit. While one could argue that the obtained monetary value corresponds to the impact of the tax exemption/credit rather than the blending mandate, it is the mandate that guarantees the market to producers and therefore provides the incentive for producing the observed amount of biofuels. There is no guarantee that the observed biofuels production levels would materialize if only taxation policy was in place. Therefore, there is unquestionably a monetary value to blending mandates.

Nevertheless, this leads to the somewhat problematic situation of Brazil, where no pure gasoline is available to the consumers, but only in blends with ethanol (commonly E-25, i.e. a 25% share of ethanol). The consumer then can choose between E-25 or pure ethanol, depending on the actual price at the refuelling station. The level of the blend (i.e. the 25% share) is mandated through a respective blending mandate by the Brazilian government, accompanied by a tax credit, and its monetary value can be calculated as above.

However, according to Brazilian government officials, the gasoline taxes that were used in this analysis were raised by the government in order to assure constant government revenues. As these tax increases were put into force before the analytical timeframe, our static analysis of government support is unable to capture such dynamic behaviour. Therefore, the monetary value of the blending mandate in Brazil calculated in *WEO-2011* is not necessarily being paid for by anyone, and if at all then by the consumers in the event of higher market prices for ethanol compared with gasoline. Nevertheless, it must be underlined again that the blending mandate guarantees a market to producers also in the case of Brazil. Thus, the blending mandate must be categorized as a subsidy, with a corresponding monetary value.

As for the analysis of *projected biofuels subsidy levels*, the limitation of the approach chosen lies in two aspects. Firstly, the analysis depends to a considerable extent on assumption regarding the pace of technology development and corresponding cost reductions, as well as on the precision of current biomass feedstock price levels and the ability to project them accurately. Data availability can be a problem especially in the case of biomass feedstock prices, and benchmarking them with current biofuels spot prices has proven to be a challenging exercise. In short: if biomass feedstock prices turn out to be lower, or technology development materializes faster than projected here, biofuels subsidies could be lower than projected, and *vice versa*. In addition, and as indicated above, the approach chosen reflects an optimal policy environment that closely monitors market development, which is rarely the case. Government support frequently exceeds required levels, as technology development sometimes takes effect much faster than expected, driven by the prevailing policy framework, and the pace of policy adaptation to the current market situation is lower. Besides, there have been cases in the past where policy support was too generous, thereby lowering the pace of technology development and increasing the monetary value of the government support. These policy imperfections cannot be reflected in our present analysis.