Methodologies for estimating Levelised Cost of Electricity (LCOE)

Implementing the best practice LCoE methodology of the guidance

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1 Introduction

The EC guidance for the design of renewable energy support schemes (SWD(2013) 439 final) discusses the process for setting support levels. Three steps are distinguished in the process of tariff setting, namely 1) selection of cost parameters and cost calculation methodology, 2) setting the cost and revenue projections and 3) transferring the levelised cost of electricity (LCoE) into an actual support level. The LCoE method is regarded as best practice.

Good knowledge and understanding of the costs of generating electricity is essential in policy design and analysis. In processes to set renewable energy support levels often the levelised cost of electricity are calculated as a basis for tariff calculation. Levelised costs of electricity generation correspond to the cost of an investor assuming the certainty of production costs and the stability of electricity prices (IEA/NEA, 2010). More precisely, it is defined as 'the ratio of the net present value of total capital and operating costs of a generic plant to the net present value of the net electricity generated by that plant over its operating life' (DECC, 2012). The level of detail in such calculations can differ widely. Sometimes a single formula is used, in other methods a full cash-flow analysis is applied, for instance to address the impact of fiscal regulations (IEA-RETD, 2008).

In the past, the LCoE method has been mainly used for price-based instruments, where developers receive a certain amount of EUR per MWh of electricity delivered to the grid e.g. feed-in tariffs, feed-in premiums/contract for difference or green certificates.

- Feed-in tariffs: power plant operators receive a fixed payment for each unit of electricity generated, independent of the market price. The level of the feed-in tariff is typically determined by an administrative procedure based on LCoE calculations. Alternatively to an administrative procedure, the support level can be estimated using an auctioning mechanism.
- Feed-in premiums/contract for difference: Plant operators have to market the electricity generated directly on the electricity market and receive an additional payment on top of the electricity market price. This way, part of the revenues for the electricity generator come from the wholesale market and an additional amount is granted to the generator in the form of a premium. LCoE or auctions are used to define the level of the premium.
- Green certificates: In green certificate schemes the level of support in EUR/MWh received by the electricity generator on top of the market price is also determined in a market and therefore variable. The level of support is variable and not set through an administrative process by a governmental body such as with FiTs and FiPs. However, some design elements of quota obligations also require knowledge of generation costs. Thus, setting minimum or maximum prices requires detailed knowledge of costs and in case of a banded quota, determining the multiplier for a technology-specific quota typically relies on generations costs of the different technologies.

- Auctioning schemes: For some implementation options, LCoE calculations are required. This includes the definition of the starting / ceiling price or when assessing the outcomes of the auction (in terms of efficiency).

The above shows that most support schemes – including volume-based based support schemes – include determining price elements and therefore require detailed knowledge of generation costs.

One of the advantages of using the simple LCoE method to calculate the costs of energy producing technologies is that all (fixed) costs that occur during the lifetime of a plant are aggregated in a single value that serves as a proxy. The LCoE method allows for cross technology comparison. Conventional plants can be compared to variable renewable sources like wind and solar power even though they have different cost structures.
The simple LCoE method also knows some drawbacks. First, the method does not provide insight in the financial performance of a specific project at all stages of its lifetime. Such a detailed financial assessment requires a full analysis of the cash flows at different stages of the project, where project costs and revenues may not be fixed over time. Second, the LCoE alone is not sufficient to conclude on a project's profitability or competitiveness. Investors need other parameters as input to investment decisions, such as Net Present Value (NPV), Internal Rate of Return (IRR), margins etc.. Further, levelised cost estimates are highly dependent on the underlying data and assumptions used for the different cost parameters. Sometimes ranges are used to address the uncertainties in key parameters such as capital costs, fuel and carbon costs and operating costs. Determining the value of all (market) parameters of a LCOE calculation, may require significant efforts and may hence have significant costs.

This report gives a reflection on the basic principles and requirements of LCoE calculations and includes four case studies that assess LCoE calculations used in tariff level setting processes.We consider LCoE calculation methodologies in The Netherlands, United Kingdom, Germany and Spain and compare these to the minimum requirements for such calculations as provided by the EC guidance (SWD(2013) 439 final). The added value of practical examples is to get an improved understanding of the differences between Member States' LCoE calculations and identify where LCOE calculation methodologies can be aligned.

2 Calculation of levelised costs of electricity – basic principle and requirements

The LCoE approach allows for a comparison between different energy technologies considering the costs occurring during the overall life cycle of a power plant (Kost et al. 2012; Prognos 2013). The LCoE is typically taken as basis for evaluating and comparing alternative options for investments into power plants. The LCoE reflect the minimum price at which electricity has to be sold to ensure that the investment made pays off. Similarly, the LCoE method can be taken as reference to determine a support level for renewable power plants in particular if the objective is to encourage investment without providing overcompensation. As shown in the following formula, the net present value of the investment is divided by the discounted electricity generation of the plant.

$$LCOE = \frac{\sum_{t=1}^{n} \frac{I_t + OM_t + F_t}{(1+DR)^t}}{\sum_{t=1}^{n} \frac{E_t}{(1+DR)^t}}$$

LCoE = Levelised cost of energy
I_t = Investment expenditures in the year t
OM_t = Operations and maintenance expenditures in the year t
F_t = Fuel expenditures in the year t
E_t = Electricity generation in the year t
DR = Discount rate
n = economic lifetime of the power plant

Note that this formula can be extended by incorporating construction interest costs. For combined heat and power technologies also modifications to this basic formula can be made.

Usually, the LCoE is calculated over 10 to 40 years lifetime of an installation and per unit of electricity generated (e.g. €/MWh). Depending on the planned duration of the support payments, the support level has to be adapted to the LCoE. The shorter the support period, the higher the support level in order to guarantee profitability.

According to Bauknecht et al. (2012) tariff determination based on LCoE can be divided into three steps:

- Definition of cost parameters;
- Revenue projection;

- Transfer of LCoE into actual support levels.

Regarding the *definition of cost parameters*, these can be differentiated in fixed and variable costs. Fixed costs do not depend on the actual electricity output of a power plant and include in particular costs related to the initial investment or fixed operation and maintenance (O&M) costs. Variable costs include O&M costs that depend on the electricity output and in particular fuel costs, if relevant. Figure 2-1 shows exemplarily cost components of power plants in the respective stage of an investment project.

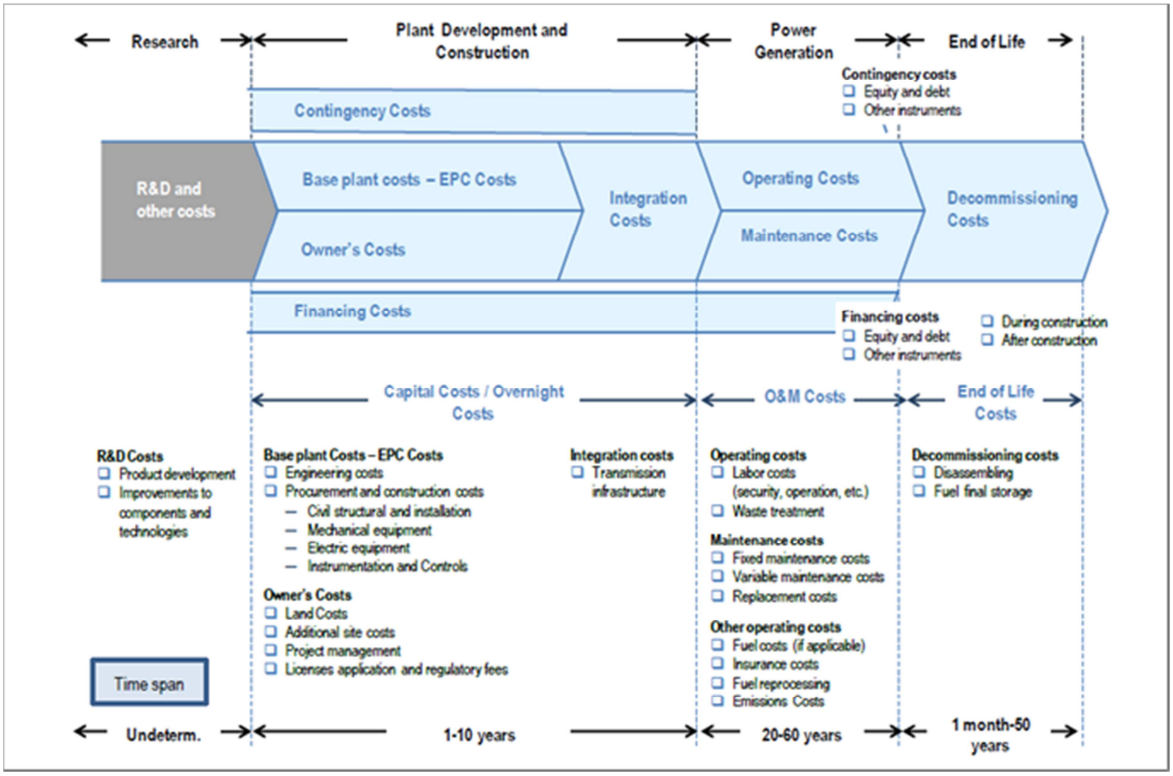

Figure 2-1 Cost components of power plants in the respective stage of an investment project. Source: IEA-RETD 2013

Compared to conventional energy technologies, the investment-related costs of renewable energy technology (RET) projects are often relatively high, whilst variable costs are often very low, especially for RET where no fuel costs occur. For biomass plants the share between fixed and variable costs is more similar to those of conventional power plants. Thereby, the level of detail regarding the LCoE calculation may vary significantly. In its guidance for the design of renewable energy support schemes (SWD(2013) 439 final) the EC proposes a minimum set of parameters that should be considered for calculating LCoE (see chapter **Error! Reference source not found.**).

The quality of LCoE estimations strongly depends on the quality and the level of detail of the input data. Ideally, detailed knowledge on resource conditions (wind speed, solar irradiation) as well as

data on technology costs is available. Real practice shows that potential estimations are typically characterised by uncertainty or show a broad range and investors are not interested in revealing the real cost elements of the actual investments. In addition, LCoE are highly sensitive to the assumed discount rate, typically reflected by the weighted average costs of capital (WACC), which again depend on the risk associated to a potential investment. Thus, obtaining good data quality for LCoE calculations is challenging and can be cumbersome and expensive. Moreover, a challenge in determining the LCoE is the dynamic development of technology costs. Some of the input parameters are characterised by uncertain development including the expected electricity output, which depends on the general developments on the electricity market. A common LCoE method should be practicable for all Member States and take into account these challenges and consider the differing data availability in MS as well as the differing economic potential to obtain the required data from studies.

In order to determine a price element, assumptions on the *expected revenues* have to be considered. Thus, avoided costs for electricity purchase due to auto-consumption should be considered as well as revenues from selling electricity in case of premium payments or certificate prices. Also other potential sources for revenues such as sales of guarantees of origin should be considered for estimating potential revenues.

Finally, the LCoE together with information from potential revenue projections have to be converted into a support level, which is supposed to provide an adequate profitability. The decision on the "adequate profitability" is not straightforward and depends on policy preferences. On the one hand, tariffs may be differentiated according to technologies, site qualities and plant sizes in order to account for heterogeneous generation costs. On the other hand, a more homogenous tariff leads to competition and the most cost-effective (in terms of generation costs) development of RES. Both approaches can be combined, so that small revenue differences remain and encourage cost-effective deployment, but also more expensive technologies or sites may be developed without generating

excessive windfall profits for the lower cost technologies.

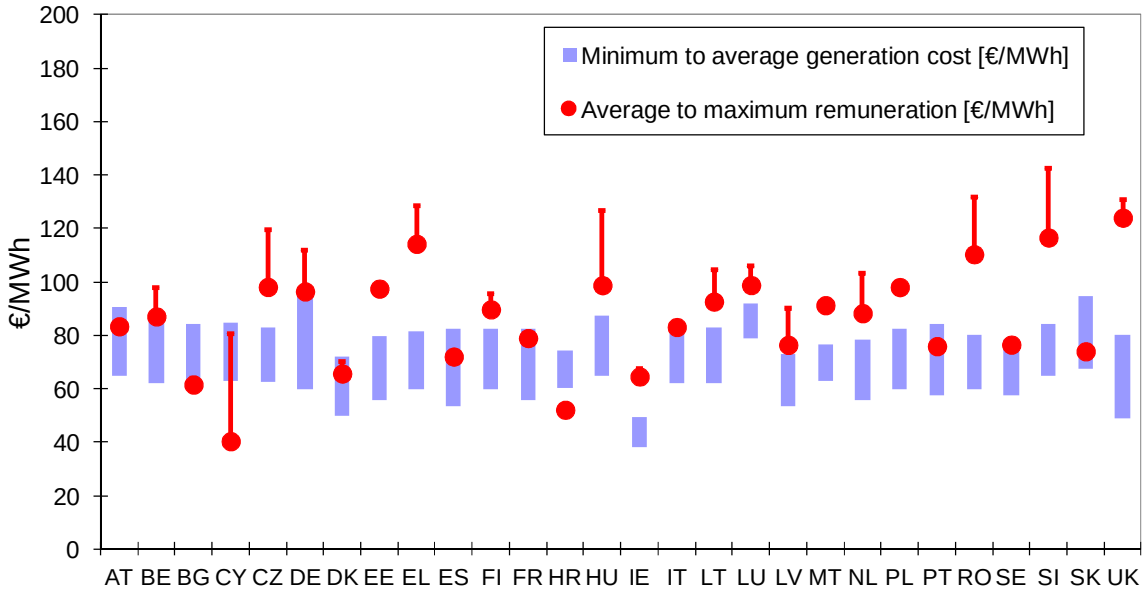

Figure 2-2 shows exemplarily the different spread between remuneration levels and costs for onshore wind power plants in 2011 in the EU Member States. It can be observed that costs vary considerably from country to country and that the cost range within one country is comparatively broad, taking into account that the overall cost range is shown.

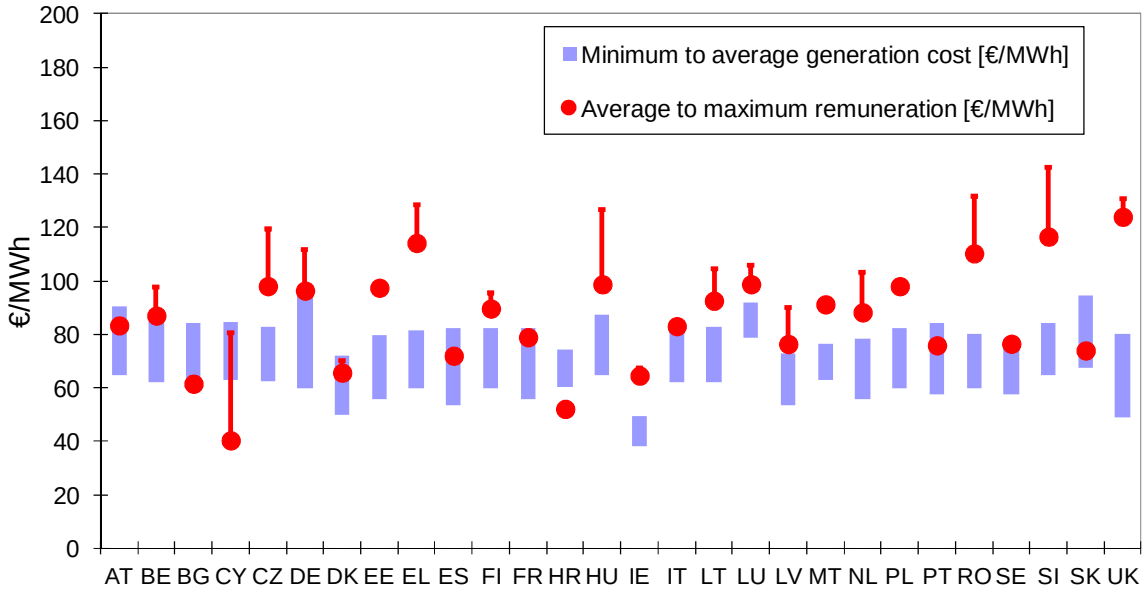

Figure 2-2 Comparison of remuneration level with generation costs for wind onshore energy in 2013
Source: Held et al. (2014)

3 Practical examples of LCoE calculations

The EC guidance for the design of renewable energy support schemes sets out a best practice process for setting support levels. One of the elements of this process is the calculation of the levelised costs of electricity. Following cost and revenue parameters are identified in the guidance that should be included as a minimum in LCoE calculations:

Cost parameters:

- Equipment cost (EU cost benchmark for technologies), e.g. turbines, control systems
- Other investment and planning costs (construction/installation costs, foundations)
- Land (access to land, purchase of land)
- Administrative costs included in support
- Capital cost (debt, equity)
- Operation and maintenance costs
- Decommissioning costs
- Fuel costs
- Common cost assessment for grid connection / grid reinforcement
- Network related costs (depending on the network access regime)

Electricity generation parameters:

- Calculated in advance
- Adjustments ex-post for differences between the agreed, expected and actual revenues, to avoid overcompensation
- Technology specific load hours

In addition to the cost parameters mentioned above, the capital costs for the investment during construction time is relevant in particular for larger projects with long construction times, such as offshore wind. Thus, financing costs during construction time could be added to the list for selected technologies, whilst the parameter can be neglected for technologies with short construction times.

In sections 3.1 to 3.4 we assess the LCoE calculation procedures that are part of tariff level setting processes. The objective of these assessments on Member State level is to identify to what extent the methodologies take into account the recommendations on minimum requirements as set out in the guidance (SWD(2013) 439 final). Per case study we include a table that evaluates the cost and revenue parameters on following aspects:

- Included in LCoE calculation: yes / no

- Data granularity: single value or range, or: simple, intermediate, complex (as used in NREL, 2011[1])
- Remarks: highlight any specifics of the parameter concerned

3.1 SDE+ in the Netherlands

The Dutch SDE+ is a feed-in premium scheme based on auctions. The SDE+ opens in a number of sequential auction rounds that represent increasing costs for the eligible technologies. Each year, the Dutch government defines the production costs (so-called base rates) per technology for each round and the bidders offer the respective volume. The SDE + provides a feed-in premium subsidy covering the difference between production costs (annually calculated per technology) and income (i.e. energy price, which is determined annually).

3.1.1 Organization of the LCoE setting procedure

ECN and DNV GL annually advise the Dutch ministry on the height of the base rates (the production costs of renewable electricity, renewable heat and green gas) for the categories prescribed by the Ministry. Each year, these institutes calculate the costs (the LCoE) of renewable energy projects in the Netherlands to be realised in the year ahead.
A consultation round and external review are part of the tariff setting process. The draft version of the advice on base rates is subject to a consultation round with market parties. There is consensus between the government and stakeholders for using the LCoE-model, which is based on a simplified cash-flow model. Discussions often relate to the estimation of techno-economic and financial parameters in the model.
An open consultation round with market parties and an external review of the draft advice are part of the tariff setting process. Market parties are invited to provide their written comments on the draft advice within three weeks. After addressing the comments of market parties, the final advice is sent out for an external review. Latest external reviews on the base rates were conducted by Fraunhofer ISI in 2012 and the Institut für Energie- und Umweltforschung in 2013. The external review focuses on the process, the advice and the way ECN and DNV GL have included the market responses.
The definitive base rates are sent to Parliament for adoption. Most times, the premium levels are adopted in line with the advice. After approval, the Ministry decides on the opening of the scheme, on the categories to be opened and on the base rates for new allowances for the year ahead.

3.1.2 Cost calculation methodology

The tariffs of the SDE+ scheme are based on LCOE calculations. Base rates are calculated using the OT-model (Onrendabele Top / 'financial gap') of ECN. The OT-model is a spreadsheet-based cash flow model and used for doing the financial gap calculations. The cash-flow model provides for the annual estimation of all project expenses, revenues, tax obligations or benefits and payments to capital

[1] NREL (2011) Renewable Energy Cost Modeling: A Toolkit for Establishing Cost-Based Incentives in the United States, March 2010 – March 2011, Sustainable Energy Advantage, LLC & Meister Consultants Group, Inc., May 2011.

providers. The individual annual cash flows are discounted to a single net present value (NPV). LCOEs (Euro/kWh (electricity), Euro/GJ (heat) or Euro/Nm^3 (biogas)) are calculated from the discounted cash flows (Euro) and the discounted energy production. Unlike conventional cash-flow models the OT-model does not calculate the internal rate of return (IRR) of a project, but it calculates the LCoE as a function of the cash flows and a minimum required return on capital resulting in the IRR being equal to this required return on capital (ECN, 2002)[2,3].
The model is designed to set the feed-in premium levels of the SDE+ scheme and is publicly available on the website of ECN[4].

Degree of technology differentiation

The SDE+ has some degree of technology differentiation, but size differentiation is limited. The SDE+ has five main categories (biomass, geothermal, hydro, wind and solar) and is further differentiated on technology level. In 2014, base rates were defined for 58 different technology subcategories (see OT-model).
One of the major changes of the SDE+ scheme was the introduction of wind differentiation as of 2013. The scheme differentiates according to the size of the wind turbines and the wind conditions at the project site. Table 3-1 shows the differentiation for wind for the 2014 SDE+ scheme. For onshore wind three subcategories are defined, namely onshore wind, onshore wind >6 MW and wind in lake. Further to this, onshore wind knows three different wind classes, characterized by different wind speeds. Wind turbines located at sites where wind conditions are les will be able to make less full load hours. For such wind projects the established base rates will be higher.

Table 3-1 Onshore wind differentiation (ECN, 2013)

Subcategory	Subdivision	Wind speed at 100 meters (m/s)
Onshore wind	Stage I	8.0
Onshore wind	Stage II	7.5
Onshore wind	Stage III	7.0
Onshore wind ≥ 6MW	-	8.0
Wind in lake	-	8.0

Financial assumptions

In projecting the subsidy base rates, a standard return on capital is presumed with a nominal weighted average cost of capital (WACC, post-tax) of 6-8% per year, based on an interest rate of 5-6%, a required return on equity of 15%, and a debt/equity ratio of 80%/20% (ECN, 2011)[5]. In 2013, the Ministry asked ECN and DNV GL to assume a total financial return of 7.8%. This return is considered to be a reasonable compensation for the total risk of the project. It should also capture the project preparation costs.

[2] ECN (2003) Onrendabele top berekeningsmethodiek, Augustus 2003, Petten, The Netherlands.
[3] Return on equity = 15%, return on debt = 6%
[4] Downloadable at https://www.ecn.nl/projects/sde/sde-2014/
[5] ECN (2011) Cost-benefit analysis of alternative support schemes for renewable electricity in the Netherlands

From 2014 onwards, projects that apply for the SDE+ subsidy will no longer be eligible for the Energy Investment Allowance (Energie Investeringsaftrek, EIA) tax relief programme. Therefore, possible benefits from the EIA scheme are not included in the calculations anymore (ECN, 2013; RVO, 2013). The benefits from the green soft-loan scheme are deducted from the base rates to the extent that these benefits apply generically to a category. The green soft-loan scheme assumes an interest benefit of 1% (ECN, 2013). The pre-set 6% interest on the loan changes to 5% in case green financing applies.

The duration of the loan and depreciation periods are assumed to be equal to the subsidy duration. For the biomass categories, the subsidy duration is set to 12 years, for all other categories the subsidy duration is 15 years.

Translation into support payment

LCoE calculations are used to set technology specific ceiling prices (base rates). The SDE+ opens in sequential auction rounds, with each round having higher base rates, where bidders offer the respective volume. The SDE+ premium covers the difference between the production costs of renewable electricity, renewable heat and green gas (base rate) and the market price of renewable electricity, renewable heat and green gas (correction rate). The premium that is paid will be equal to the difference between the base rate and the correction rate.
Base rates are calculated on an annual basis. For example, base rates calculated for the year 2013, apply to projects that are eligible for SDE+ in that year and can start construction in 2013 or early 2014. Base rates are fixed for the duration of the SDE+ decision.
Correction rates are established on basis of real revenues. Different price indices are used to calculate the correction rates, such as electricity prices for base and peak load, natural gas prices and derivatives (ECN, 2012).

3.1.3 Transparency and participatory elements

The data gathering and rate-setting process is highly transparent. Initial efforts to fill the OT-model with data are with ECN and DNV GL, but market parties are invited to come up with proposals to adjust the data that are in the public spreadsheet. The calculation method for the base rates is visible from the spreadsheets.

3.1.4 Assessment of the LCoE calculation methodology

Table 3-2 Evaluation table for the Dutch SDE+ scheme

Parameters	Included in LCoE calculation	Data granularity	Remarks
COST PARAMETERS			
Equipment cost	Yes	Capital costs are	

Parameters	Included in LCoE calculation	Data granularity	Remarks
		aggregated as a single input	
Other investment and planning cost	No (at least not as separate parameter)	-	Preparation costs are not included in the total investment amount, but need to be covered by the financial yield
Land	Yes	Integrated in costs	Only explicitly given for wind
Administrative costs included in support	No	-	
Capital cost (debt, equity)	Yes	80/20	
Operation and maintenance cost	Yes	Intermediate: differentiated in fixed and variable operation and maintenance costs	
Decommissioning costs	No	-	
Fuel costs (if relevant)	Yes	Single value	
Common cost assessment for grid connection / grid reinforcement	Yes		Includes costs that need to be covered by the project developer. Grid connection costs are included, costs for grid reinforcement are not
Network related costs	No	-	Cost assumptions for interconnection and for lines and transformers are built into FIT rate
Costs of market integration	Yes		
PRODUCTION PARAMETERS			
Technology specific load hours	Yes	FLH are given as a single value	

3.2 Determination of feed-in tariffs and premiums in Germany

After having supported renewable electricity with a fixed feed-in tariff until 2011, a floating premium was introduced as an optional support instrument for renewables in 2012. Renewable plants can choose between support under the fixed feed-in tariff and under the feed-in premium. From 2014

onwards, biogas and biomass plants with a capacity > 750 kW will only be eligible for the premium option. Plants under the premium scheme receive a market premium and a management premium on top of the market price (Klein et al. forthcoming; also: Klobasa et al. 2013). In its recent revision (EEG 2.0), that has been approved by parliament (Bundestag) end of June 2014 and is foreseen to come into force on August 1, 2014, requirements for LCOE calculations in the progress reports doesn't change. However, the obligatory participation for most of the RES power plants introduced in the new EEG makes the translation into support level more complicated. Additional income streams from selling heat or the consideration of own consumption make the translation into tariffs even more complex.

In principle, the same LCoE calculations are used for the determination of the fixed tariff and of the premium. The market premium is calculated ex post on a monthly basis. The average market prices are adjusted by technology-specific factors for wind and PV as the prices that these technologies receive in the market are structurally different from the average price. Regarding the market premium, additional tariff components are added to the base premium, which is calculated based on the difference between the fixed tariff and the average electricity market price in the respective month. The management premium is an additional premium meant to cover additional costs (e.g. IT infrastructure, personnel, forecasts and balancing costs) due to the direct marketing of electricity sold under the premium model. This additional payment is technology-differentiated. Furthermore, operators of biogas plants are entitled to a flexibility premium if they increase their installed capacity without producing more electricity and thus can react flexibly to market signals.

3.2.1 Organisation of the tariff setting procedure

In Germany, tariffs are based on the calculation of the LCoE. The tariffs are reviewed regularly by the Ministry for Environment (BMU, until 2013) and the Ministry for Economic Affairs and Energy (as of 2014). The LCoE calculation takes place within the general process of evaluating the experience gained with each amendment of the main German support scheme, the "EEG". The German Renewable Energy Act (§65) requires a periodic review that has to be presented to the German Parliament. In these evaluation reports ("Erfahrungsberichte"), which are due every four years, the Ministry of the Environment (until 2013) and the Ministry for Economic Affairs and Energy (as of 2014) assigns external experts to evaluate experiences made with the EEG in order to adapt the EEG to the dynamic development of technology costs, support costs, etc. The "Erfahrungsberichte" contain a review of the feed-in tariff rates and an analysis of cost development and serve as a basis for modification and amendments of the EEG.[6] Around eight research institutes have been contracted to conduct the detailed bottom-up analyses on technology level. For 2014, six reports with a focus on a specific technology category have been published[7]. This shows the considerable effort, Germany puts into the periodic review of its Renewable Energy Act.

[6] For the EEG 2011, evaluation reports for each technology can be found here: http://www.erneuerbare-energien.de/die-themen/gesetze-verordnungen/erneuerbare-energien-gesetz/eeg-erfahrungsbericht-2011/ (in German).
[7] Available at: http://www.bmwi.de/DE/Themen/Energie/Erneuerbare-Energien/eeg-reform,did=616706.html (in German).

Before being translated into tariff adaptations, the draft of amendments is discussed in and has to be approved by parliament. Tariffs in Germany are thus not defined purely administratively, but rather in a mix of an administrative and political process. There are concerns that this procedure opens up opportunities for lobbying through the respective industries, thereby weakening the initial approach of setting tariffs on a purely objective or scientific basis. This also means that tariffs can adequately adapted to political preferences, for instance, to distribute wind onshore installations over different regions in Germany or to give preference to one technology over another.

3.2.2 Cost calculation methodology

The determination of feed-in tariffs and premiums in Germany is based on cost calculations provided by the periodic evaluation reports. For calculating LCoE, the net present value (NPV) is calculated in a first step and then this NPV is converted to an annualised payment, as described in section **Error! Reference source not found.** (Staiß et al. 2007). Taxes and possible income from other support mechanisms than the feed-in scheme are not taken into account, since the estimation of the tax rates depends on the individual ownership structure and cannot easily be generalised (Staiß et al. 2007).

Degree of technology differentiation

In Germany the degree of technology differentiation is high in order to reflect the technology-specific generation costs and to avoid windfall profits for investors. Depending on the plant type and size and in case of onshore wind on the location, tariffs are further differentiated. In case of onshore wind this means that plant operators receive a fixed FIT (8.9 €c/kWh in 2012) during the first five years after the plant has started operating. The German Renewable Energy Act ("Erneuerbare-Energien-Gesetz", EEG) defines a *reference wind turbine*, which is located at a site with a wind speed of 5.5 m/s in an altitude of 30 meters. This reference turbine would generate a so-called *reference yield* in a five-year-period. If a wind turbine produces at least 150% of this reference yield within the first five years of operation, the tariff level will be reduced to a base tariff (4.87 €c/kWh for plants installed in 2012) for the remaining 15 years of support. However, for each 0.75% the generated electricity stays below the reference yield, the higher starting tariff will be paid for two further months. In theory, this means that the use of wind energy to generate electricity is not restricted to locations with very good wind conditions but that sites with less favourable conditions can also be exploited. In practice however, it was observed that the German system does not lead to a strong differentiation between locations as most locations are classified as low resource locations and thus receive a high tariff under the current scheme.

Revision of support level for new plants

The main revision mechanism of the German EEG is the periodic revision of tariffs every four years. For tariffs paid for PV power plants, this periodic revision has been supplemented with an automatic tariff digression procedure since 2009. This "breathing cap" links the tariff level to the capacity development occurred in the past. Tariffs paid for solar PV are automatically reduced by 1% per month and every three months the "breathing digression" is added to this monthly tariff reduction

since 2012. The automatic tariff reductions led to pull-forward effects of investments in Solar PV capacity, showing that the determination of the reduction parameters is highly sensitive. Therefore, detailed periodic reviews may still be needed in order to respond flexibly to unanticipated cost and market development of dynamic technologies such as Solar PV.

Evolution of support level for existing plants

In Germany, the FIT rate for RES remains constant in nominal terms over the lifetime of the power plants. Thus, there is no inflation correction, meaning that the tariff implies an indirect digression over lifetime corresponding to the inflation rate.

Financial assumptions

For calculating LCoE in the most recent progress reports from 2014, assumptions for working average costs of capital are differentiated according to combinations of the technology, plant sizes and the prevailing investor structure in order to reflect different risk profiles (see Table 3-3). The share of equity and debt has partially been identified based on surveys (sewage, landfill and mining gas, Solar PV).

Table 3-3 WACC assumptions for LCoE calculations in EEG progress reports 2014 Source: Interim progress reports 2014. Available at: http://www.bmwi.de/DE/Themen/Energie/Erneuerbare-Energien/eeg-reform.html

Technology	Sewage, landfill, mining gas	Biomass and biogases	Geothermal	Solar PV	Hydro	Onshore Wind	Offshore Wind
WACC	6.5%	6%	8.9%	4.3–4.4%	4.7–6.8%	4.6%	8.1%

Translation into support payment

There is no information available of how cost calculations are transformed into the tariff level. Provided that final tariffs have to pass the parliament, tariffs proposed based on cost calculations may be further modified. Tariffs in Germany are thus not defined purely administratively, but rather in a mix of an administrative and political process.

3.2.3 Data sources

Data sources for cost calculations in the German progress reports differ according to the respective technology. In general technical parameters and cost assumptions including investment, O&M costs, fuel costs, etc.) are based on expert knowledge and experiences of project partners and publicly available cost data (Staiß et al. 2007). For some technologies such as Solar PV, cost estimations rely mainly on public sources and analyses of raw material and component price development (e.g. silicon, wafer, modules, inverter) (Kelm et al. 2014). For other technologies the available data is supplemented with stakeholder surveys, as e.g. in the case of wind energy, where a survey on the

different cost components was realised among manufacturers, project developer and wind farm operators in spring 2013 (Falkenberg 2014). In total 155 companies and institutions have been consulted for the survey on wind energy costs (Falkenberg 2014). Results of this survey have been compared with previous studies and data from literature in order to guarantee plausibility of survey results.

3.2.4 Transparency and participatory elements

In its extensive progress reports, LCoE calculation methodology and assumptions are made transparent on a high level of detail. Although the actual tariff setting procedure is based on the LCoE calculations, the detailed methodology of converting costs into feed-in tariffs is not made publicly available. In addition, proposed tariffs have to pass the parliament and are therefore affected by political decisions. The progress reports include extensive surveys in order to estimate the cost elements as accurately as possible. In this way, industry is involved into the process to a certain extent, but there is no explicit stakeholder consultation process open to the public. The calculation models itself are not publicly available.

3.2.5 Assessment of the support level setting process

The German support level setting process partly serves as an example for best-practices in particular due to its high level of detail regarding the periodic analysis of generation costs and to the use of surveys in order to estimate cost components. However, this involves considerable efforts in terms of costs, which might not be possible for all Member States. Participatory elements are included, but restricted to the direct stakeholders. One main point of criticism is the lack of transparency regarding the translation into support payments. Opportunities for lobbying of tariffs through the respective industries during the political approval process may weaken the initial approach of setting tariffs on a purely objective or scientific basis. **Error! Reference source not found.** provides an overview of the parameters considered for the LCoE calculation in Germany.

Table 3-4 Evaluation table for the floating premium scheme in Germany

Parameters	Included in LCoE calculation	Data granularity	Remarks
Equipment cost	Yes	High level of detail. For example, prices of individual components are shown for PV. Wind separated in equipment (Turbine, rotor, hub) and subordinated investment (see other investment and planning costs)	
Other investment and planning cost	Yes	In general high, depends on technology PV: Planning, scaffold and assembly	

		Wind: Planning and authorisation, cabling, grid connection, fundament and other costs
Land		For wind part of other investment and planning cost.
Administrative costs included in support	No	No extra cost category
Capital cost (debt, equity)	Yes	Share of equity and debt as well as return on equity and interest rate of debt provided for most technologies.
Operation and maintenance cost	Yes	In general high, depends on technology Wind: 6 categories provided.
Decommissioning costs	No, except for landfill, sewage and mining gas	Low, not shown separately
Fuel costs (if relevant)	Yes	Medium
Common cost assessment for grid connection / grid reinforcement	Not part of LCoE calculation, only grid connection	
Network related costs	Not part of LCoE calculation, only grid connection	
Costs of market integration	Part of market premium option	
PRODUCTION PARAMETERS		
Technology specific load hours	Yes	Depends on the technology.

3.3 Feed-in Tariff with Contracts for Difference in the United Kingdom

In January 2014, the UK government introduced a sliding feed-in tariff with Contracts for Difference as a way of supporting investment in low-carbon electricity generation. CfDs are contracts that provide long-term electricity price stability to developers and investors in low-carbon generation. Generators will receive the price they achieve in the electricity market plus a "top up" from the market price to an agreed level (the "strike price"). This "top up" will be paid for by consumers. Where the market price is above the agreed level, the generator would be required to pay back and thus ensure value for money and greater price stability for consumers.
Agreements about the level at which the strike price is set will be based (in part) on the levelised cost of energy for the technology in question.

A technologies' strike price is different from its levelised cost. A strike price could be higher or lower compared to the levelised costs for a number of reasons. The elements that are incorporated in the strike price setting process are transmission losses (the strike price is increased to account for his), existing Power Purchase Agreements (the strike price is increased when generators are not able to sell their electricity at the reference price), CfD contract length (the strike price should be increased when the CfD is set at a shorter period than the operating life of a project) and other policies (the strike price is reduced to account for the Levy Exemption Certificates of 5 £/MWh) (DECC, 2013).

3.3.1 Organization of the tariff setting procedure

Draft strike prices have been published for the first time in the draft Energy Market Reform Delivery Plan of June 2013. This plan has been subject to a public consultation round from August to October 2013. Over hundred responses have been received from a wide range of individuals and organisations including generators, suppliers, consumer organisations and environmental groups. The responses have been analysed and some changes have been included on a number of key assumptions. Final decisions on strike prices for renewable technologies for the period 2014/15 to 2018/19 have been formally published by DECC in December 2013.
The UK system operator National Grid provided evidence and analysis to the government to inform its decisions on CfDs and the capacity market. The National Grid launched a Call for Evidence (CfD) that invited all stakeholders to come up with most recent and relevant technology costs and economic assumptions for setting strike prices. The results of the National Grid Call for Evidence were combined with the generation cost data collected by DECC (DECC, 2013) to produce the aggregated cost information utilised in the modelling.

3.3.2 LCoE calculation methodology

Levelised cost estimates for all cases have been calculated using the DECC Levelised Cost Model. Assumptions and results are published in the Electricity Generation Costs report of DECC (DECC, 2013). Levelised Costs estimates for a number of different cases are considered in the DECC report. These cases are presented in the table below.
In calculating electricity generation costs, DECC makes a distinction between First Of A Kind (FOAK) technologies and Nth Of A Kind (NOAK) technologies. FOAK technologies do not have the advantages of learning from earlier projects and correspondingly experience higher costs.

Table 3-5 Different project types included in LCoE calculations

Case No.		
1	Projects starting in 2013	All at 10% discount rate. Technologies are mixture of FOAK and NOAK
2	Projects starting in 2019	
3	Projects starting in 2014, 2016, 2020, 2025 and 2030	

Costs are calculated over the full lifetime of the plant. This includes pre-development, construction, operation and decommissioning. Decommissioning costs are treated as an additional cash flow charge, a so-called "provisioning fund" that is treated as an operational cost on output generated. The assumption is that the provisioning payments will accumulate over time to provide a fund that will be the appropriate (DECC 2013).

Levelised costs estimates are highly sensitive to the underlying data and assumptions used including those on capital costs, fuel and carbon costs, operating costs, load factor and discount rates. As such it is often more appropriate to consider a range of cost estimates rather than point estimates. Low, medium and high values are included for all project timings, some technical data, all capital costs, operating costs, CO_2 transport and storage costs, fuel prices, carbon price (DECC 2013).

Financial assumptions
Levelised cost estimates of technologies are compared at a 10% discount rate, which is considered neutral in terms of financing and risk (DECC 2013).

Translation into support payment
Levelised cost of electricity is only one input factor for the setting of strike prices. Other key assumptions include fossil fuel prices, effective tax rates, PPA discounts and maximum build assumptions. All are listed in the UK government report 'Electricity Generation Costs' (DECC 2012). The levelised costs are calculated by DECC's Levelised Cost Model.

The strike price setting process is informed by project specific cost discovery processes that are undertaken. These form the starting point of any process of setting a strike price, rather than relying on levelised cost data.
Strike prices of renewable energy technologies have been published in December 2013, based on evidence and analysis from the system operator, National Grid. The strike price for nuclear projects will be set through a process of bilateral negotiation with DECCS. This also applies to Carbon Capture and Storage projects.

3.3.3 Data sources

DECC used a number of different sources to compile the generation costs for renewable and non-renewable technologies. Cost data of non-renewable technologies have been derived from Parsons Brinkerhoff (2012). Cost data of renewable energy technologies have been drawn from nine different sources of information (DECC 2013). For both renewable and non-renewable technologies, the DECC report includes the data sources used.

3.3.4 Transparency and participatory elements

The United Kingdom stands in a long tradition of evidence-based and evidence-informed policymaking. There are sound opportunities for all stakeholders to provide input during the public consultation round.

3.3.5 Assessment of the LCoE methodology

The levelised cost estimates given are generic, rather than site specific. For instance land costs are not included in the estimations and although use of system charges are included, they are calculated on an average basis (DECC, 2013).
Some cost elements not explicitly mentioned in the EC guidance, but included in the DECC cost methodology include: insurance costs, connection and Use of System (UoS) charges and CO_2 transport and storage costs. Furthermore, costs of grid connection for increasing amounts of renewables and providing back up to a grid which relies more on intermittent power are not included in the levelised cost calculations.

Table 3-6 Evaluation table for the feed-in tariff with Contracts for Difference in United Kingdom

Parameters	Included in LCoE calculation	Data granularity	Remarks
COST PARAMETERS			
Equipment cost	Yes	High – Medium - Low	
Other investment and planning cost	Yes	High – Medium - Low	Pre-development costs are included in the capital costs
Land	No	-	The levelised costs analysis excludes land costs
Administrative costs included in support	No		
Capital cost (debt, equity)	No		
Operation and maintenance cost	Yes	Fixed and Variable High – Medium – Low	
Decommissioning costs	Yes		Decommissioning costs are part of the OPEX (included as decommissioning fund costs)
Fuel costs	Yes	High – Medium – Low	
Common cost assessment for grid connection / grid reinforcement	Yes		Connection costs are part of the OPEX
Network related costs	Yes		Costs of using networks beyond the station are only counted to

Parameters	Included in LCoE calculation	Data granularity	Remarks
			the extent that this is a charge upon the owners that is required to get energy to the station gate
Costs of market integration	No		The methodology does not take impacts on the wider electricity system into account
PRODUCTION PARAMETERS			
Technology specific load hours	Yes	Single value	For key technologies average lifetime load factors have been defined. All assumed base load

3.4 Remuneration based on the principle of reasonable profitability in Spain

Spain used a feed-in scheme including a fixed feed-in tariff and a premium to support RES-E until the system has been phased out for new plants in 2012 and for existing plants in 2013. The phase-out has been implemented in order to control strongly increasing policy costs. In Spain policy costs have not completely been via a levy on electricity prices due to the used cost sharing system, where only part of the occurring policy costs are paid by final consumers as part of regulated electricity tariffs. However, regulated tariffs for electricity have not been able to cover costs actually occurred. This difference between the system costs of electricity and the actual consumer charge adds up to the tariff deficit of the electricity sector. The cumulated tariff deficit amounted to around EUR 24 billion in 2012.

There has been already uncertainty on the policy framework starting with revisions of the scheme e.g. for PV tariffs as of 2008. The Royal Decree 413/2014 that specifies the legal and economic framework for RES-E support came into force in June 2014. This section describes the approach to calculate the remuneration based on the principle of enabling a "reasonable profitability" for RES power plants. It is the objective of the new framework to limit support costs and to ensure the financial sustainability of the electricity system.

3.4.1 Organization of the tariff setting procedure

It is planned to calculate the required remuneration by supplementing the income from electricity sales with additional payments in order to allow for a "reasonable profitability". The new remuneration therefore consists of the following components:

- Electricity sales at market price

- Additional remuneration for investment (RInv) and remuneration for operation (RO) that is not covered by the electricity price

For the calculation of the additional remuneration, the Royal Decree 413/2014 defines the parameters that are taken into account, but does not specify the value of the parameters. The criteria are the following:

- Remuneration for Investment (RInv)
- Remuneration for plant operation (RO)
- Regulatory lifetime
- Minimum limit of full-load hours in order to be entitled to receive additional remuneration. Plants with full-load hours below this limit do not receive any support.
- Minimum and maximum full-load hours to perceive remuneration
- Average market price of electricity (day-ahead and intra-day)
- Limits for electricity market prices

The calculation of these parameters requires the estimation of other parameter, the most relevant being:

- Standard initial investment of the installation
- Estimation of the day-ahead and intra-day market price
- Full-load hours of the installation
- Estimation of the future income from electricity sales and potential other income e.g. from heat generation of CHP power plants
- Estimation of future operation costs
- Discount rate based on the reasonable profitability
- Adjustment coefficient
- Net value of the assets

The Royal Decree states that criteria used to calculate the specific remuneration are based on efficient and well managed companies and that standard values for investment and utilisation should be taken as reference. Remuneration is paid for power plants on Spanish ground. Calculation methods for the remuneration of power plants located at the Spanish islands are different from those for the peninsula.

Degree of technology differentiation

The degree of technology differentiation in the new law corresponds to the former differentiation used under the "Special Regime" and is characterised by a high degree of technology differentiation.

Revision of support level

A revision of the remuneration level is possible and it is organised following a different timetable for revision depending on the remuneration component. Thus, an annual review of the remuneration for plant operation is foreseen for fuel-based renewable power plants. Every three years income estimations based on electricity market prices are revised and every six years all the other parameters except the value of the initial investment and the lifetime are subject to modifications.

Financial assumptions

The "reasonable profitability" for new plants before taxes shall be based on average rate of return of 10-year government bonds. For existing plants, 300 basic points are added to the government bonds leading to 7.398%.

Translation into support payment

There is not information available about the translation into support payment.

3.4.2 Cost calculation methodology

The detailed cost calculation methodology is based on Net Present Value calculations. Regarding the remuneration for investment, the annualised investment per unit of electric capacity installed is multiplied with a correction factor that represents the share of the investment that cannot be covered by income of electricity sales.

The remuneration related to the operation of a plant should in principle cover together with the income from electricity sales the variable cost components of a plant. Payments are restricted to certain amount of full-load hours which is to be determined by the Ministry of Industry, Energy and Tourism.

3.4.3 Data sources

There is a reference to 10-year government bonds in order to estimate the reasonable profitability and other parameters should be based on "standard" values. More detailed is not provided.

3.4.4 Transparency and participatory elements

Tariff determination of the previous feed-in tariff scheme was not made transparent. Only the final tariffs have been published in the corresponding Royal Decrees. These tariffs have been established based on LCOE calculation realised by consultants, but the corresponding reports are not publicly

available. Regarding the new calculation methodology and parameters, there was a long time of uncertainty where actual support conditions were not known. In addition, the new Royal Decree 413/2014 describes the methodology of how to calculate the specific remuneration for RES-E, but there is still no information on the value of the parameters used for the calculation. The only parameter known is that the profitability before taxes should be approximately 7.4%, corresponding to 10-year bonds plus 300 basic points. For new plants the profitability is yet to be determined.

3.4.5 Assessment of the LCOE calculation methodology

Since no information is provided on the determination of the parameters required to calculate the remuneration level, an assessment of the LCOE calculation methodology is not possible.

4 Identifying key parameters suitable for cross-border cooperation for calculating LCOE

A good knowledge of generation costs is required for the parameterisation of practically all support schemes, including volume-based support schemes such as quota obligations or auction schemes. Thus, determining price elements of quota obligations such as cap and floor prices or the multiplier for a technology-specific quota should rely on actual generation costs of power plants. The assessment of four LCOE methodologies realised in the context of this project reveals that there are quite some differences in the level of detail and transparency of the process of LCOE estimations.

The German support level setting process partly serves as an example for best-practices in particular due to its high level of detail regarding the periodic analysis of generation costs and to the use of surveys in order to estimate cost components. On the other hand, such level of detail involves considerable efforts in terms of costs, which might not be possible for smaller and economically weaker Member States. Regarding the level of detail of the LCOE calculation, a compromise between offering sufficient level of detail in order to reflect existing cost ranges and avoiding excessive efforts for the analysis at the same time should be intended.

The Netherlands process of establishing LCoE estimates is characterised by its high transparency. Stakeholders get the opportunity to comment on the LCoE estimates provided by ECN and DNV GL and are invited to provide cost information from real projects. Also the UK process of gathering the input data for the costs estimates involves a round of public consultations. These processes are much in line with the recommendation from the EC guidance that states that the analysis of cost parameters and expected generation should be based on country-specific studies that are transparent and validated through stakeholder consultations.

The translation of LCoE in support estimates is often less transparent, because other and often more political considerations come into play. For example, LCoE estimates in the United Kingdom cannot be translated on a one-by-one basis into strike prices. Also Germany is not transparent on how LCoE estimates are translated into tariffs. On the one hand, countries could be more transparent, on the other hand we realize that tariff setting processes allow for a pursuing different policy objectives.

Another challenge is the determination of a best estimate of costs. For the same technology and project configurations, different cost levels can be found across Europe (both for CAPEX and OPEX). In various cases these costs/prices reflect the level of support and do not reflect differences in real costs. Products and services sometimes are simply offered at higher prices to benefit from this support.

Based on the recommendation of the EC to use LCOE as best-practice method and the proposal of a list of basic parameters that should be included in the calculations, we provide a short evaluation of the suitability of each parameter for international cooperation. Some of the analysis required to determine these parameters could be realised in a joint effort of Member States in order to make a first step toward harmonising tariff setting methodology. These joint efforts can also save costs of the partially expensive data gathering process.

Provided that some parameters, such as the different shape of the cost-potential curves, are more difficult to determine commonly among Member States than others, we propose a step-by-step approach for cooperation. Thus, only some of the cost elements should be included into a joint effort in a first step.

Some cost elements still should be evaluated at national level (land, capital costs, issues related to the electricity markets), whilst estimating other cost elements such as the equipment costs or O&M costs is better suitable for cooperation between Member States. WACCs for example are more suitable for country evaluation, since they are a reflection of perceived risks and differ per country and technology.
In contrast, other investment and planning costs related to the installation of the power plant may deviate from country to country due to experience available for the installation process. Fuel costs may also deviate considerably from country to country, since there are rather local than global markets for biomass fuels and the range of different fuel types with different prices is broad.

Table 4-1 provides a brief evaluation of the suitability of the parameters proposed by the EC for cooperation between Member States[8]. Regarding production parameters resource conditions need to be estimated on country level, but harmonising the used approach is preferable.

Table 4-1 Short evaluation of parameters required for LCOE calculation regarding their suitability for international cooperation

Parameters	Data availability	Degree of uncertainty	Suitability for international cooperation
COST PARAMETERS			
Equipment cost	High degree of data availability, but it depends on the technology.	Uncertainty related to missing willingness of industry to reveal real costs	Well suitable
Other investment and planning cost	Medium degree of data availability, depends on the technology.	Similar to uncertainty for equipment costs.	Less suitable due to country-specific differences.
Land			Not suitable.

[8] Only parameters related directly to the electricity generation process and sales are taken into account. System-related parameters such as costs of market integration have not been taken into account.

Parameters	Data availability	Degree of uncertainty	Suitability for international cooperation
Administrative costs included in support	Low degree of data availability	High degree of uncertainty, since this cost component is difficult to estimate	Since administrative costs depend on the national regulation, it is less suitable for harmonisation.
Capital cost (debt, equity)	High degree of data availability		Application of common approach possible, but values have to be determined related to the MS
Operation and maintenance cost	High degree of data availability, but it depends on the technology.	Low level of uncertainty	Well suitable
Decommissioning costs			Well suitable. Regulations may deviate between countries.
Fuel costs	Due to partially local prices and a broad range of biomass fuel types, data availability can be difficult.	Uncertainty about future development of fuel costs.	Cost may deviate between countries, therefore harmonised estimation is difficult
PRODUCTION PARAMETERS			
Technology specific load hours	Data availability depends on country and technology.	High degree of uncertainty due to sensitivity of potential estimations to assumptions and due to uncertainty on expected electricity output (depending on developments in the electricity market and the number of hours during which RES power plants can sell their electricity).	Not suitable. A common approach could be applied.

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