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# Assessing the performance of renewable energy support policies with quantitative indicators – Update 2015

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# 1 Introduction

EU MS have been implementing heterogeneous policy instruments to promote the use of RES. Although there are already substantial experiences with the use of support schemes, the dynamic framework conditions have led to a continuous need for reforming the applied policies. Also policy priorities have changed in most MS. Whilst the policy effectiveness or the ability of support instruments to trigger new investments was a main policy target, when RES-share was still negligible, economic efficiency has become increasingly important in the light of higher shares of RES, rising support costs and the financial crisis. In particular the strong growth of Solar PV in some MS has enhanced this change of policy priorities. The stronger focus on cost control mechanisms has led to a revival of tender or auction mechanisms to control the additional RES-capacity eligible for support and to determine support levels in a competitive bidding procedure. Another highly relevant issue regarding renewables support is related to the increasing share of intermittent renewable energy sources (RES) leading to evolving requirements for effective electricity market design. While initially fair remuneration of RES power in the market should be a priority for market design, a more systemic focus on system flexibility should be adopted with a rising share of RES. This will likely comprise increasing shares of demand response and storage – but should also make use of the already existing flexibility in the integrated power system. This can be reflected in how the system matches temporal profiles of different generation and load types and how it accommodates the spatial profile of intermittent RES generation.

Evaluating the experiences made with policies for the support of renewable energy technologies (RET) in practice is crucial to continuously improve the design of renewable policies. Therefore, reliable evaluation criteria covering various aspects of renewable support policies have to be defined. These aspects include the effectiveness of the policies used to measure the degree of target achievement and the costs for society resulting from the support of renewable energies, expressed by the static efficiency. In addition, a comparison of the economic incentives provided for a certain RET and the average generation costs, helps to monitor whether financial support levels are well suited to the actual support requirements of a technology.

It is the objective of this report to update and extend the analyses realised to assess the performance of renewable energy support policies based on quantitative indicators in the context of the RE-SHAPING project (Steinhilber et al. 2011). Thus, we monitor the Member States' (MS) success or failure regarding the promotion of renewable energy sources (RES), considering additional factors such as the individual status of the market deployment of a technology and the openness of the power systems for integrating RES-E in the EU Member States.

To assess the described issues, this analysis relies on the policy performance indicators that have already been developed in the context of the EIE-funded research project OPTRES and applied for EC's monitoring process of renewable support schemes (European Commission 2005; European Commission 2008; Ragwitz et al. 2007, Steinhilber et al. 2011) as well as for an analysis of the International energy agency (International Energy Agency 2008, International Energy Agency 2011).

The 2014 edition of this report included some methodological additions, for instance changes in the definition of the policy effectiveness, where the time reference of available potential – denominator for the calculation of the indicator – has been extended from 2020 to 2030. The report also introduced an additional dimension to the analysis by assessing the policy performance in terms of a combined indicator set for wind and solar over time. The Market Preparedness Indicator was completely reviewed and extended in order to assess the openness of the power systems for RES in the EU Member States. This reflects the fact that the requirements for effective electricity market design are evolving with the increasing share of intermittent renewable energy sources (RES). In order to include a more systemic focus on system flexibility, several sub-indicators assessing the openness of the power system for RES in the EU Member States were developed.

This 2015 update follows up on the 2014 report, providing the latest available data for the previously presented indicators.

Complementary to the update and further development of the well established indicators for ex-post evaluation of RES support policies, we aim to perform an analysis of expected future RES deployment trajectories through the development of short-term forward looking indicators for RES diffusion in EU Member States. Thereby, the assessment focuses on the most dynamically developing RES-E technologies on EU level, namely onshore wind and PV. The analysis ultimately aims to provide estimations of the expected growth of the technology markets based on a comprehensive assessment of the regulatory framework conditions on country level. This short-term assessment allows for a refined estimation of the effects of individual policy measures or adaptations of the regulatory environment on the short-term RES market development on Member State level. The diffusion indicator can be used as a tool for monitoring the potential attainment of RES targets (i.e. the 2020 targets) as well for reviewing and improving the regulatory frameworks for RES on MS level to enhance their effectiveness and improve the cost-efficiency of measures promoting RES diffusion.

The report is structured as follows: Chapter 2 elaborates on the methodological aspects used to calculate the policy performance indicators. Chapter 3 follows with a short overview on recent developments in the electricity, heating & cooling and transport sector. The indicators have been updated and extended as part of the DIA-CORE project to increase their robustness and are presented in their new form in this report. The latest results - using data available in 2014 - are presented in chapter 4. Chapter 5 presents the approach and preliminary results for the forward looking diffusion indicator. Chapter 6 summarizes the key findings and policy recommendations.

# 2 Methodological aspects

In this chapter we outline the definition of the indicators developed to measure the performance of policies supporting the deployment of renewables in the EU: policy effectiveness, market deployment status, a comparison of economic incentives and conversion costs and the preparedness of the electricity market to integrate RES. Additionally, we introduce a forward looking indicator for evaluating the expected future RES diffusion under different framework conditions.

For the *Policy Effectiveness Indicator* we measure the impact of a policy on the deployment of renewables by setting the increase in renewable energy supply – normalized by weather-related fluctuation – in relation to a suitable reference quantity. The reference quantity chosen is the additional available resource potential considered to be realizable by 2030. This definition of the *Policy Effectiveness Indicator* has the advantage of giving an unbiased indicator with regard to the available potentials of a specific country for individual technologies. Member States need to develop specific renewable energy sources proportionally to the given potential to show comparable effectiveness of their instruments.

Information reflecting how advanced the renewables market is in each country for a certain technology will be provided in terms of the *Deployment Status Indicator* to take into account additional factors that may influence the attractiveness of RET investments.

The *Economic Incentives and Conversion Costs Indicator* reflects the economic incentives for investors and compares annualized support payments over the lifetime of a plant to the actual generation costs – levelised costs of electricity generation (LCOE). The objective of this indicator is to analyse whether payments are adequate to stimulate investments without providing excessive windfall profits for investors.

There is one additional indicator used only for the electricity sector measuring the preparedness of the electricity market to integrate RES-E. Thus, a market with an advanced liberalisation process may favour investments in renewable power plants, and this aspect is represented by the E*lectricity Market Preparedness Indicator.*

For the electricity sector we finally provide a *combined illustration of the Policy Effectiveness Indicator* and the potential profit provided by the economic incentives of the respective policy instrument. This combined illustration allows an analysis of whether a high profit level generally involves higher policy effectiveness.

The existing indicators have been developed and continuously improved and extended in the context of various projects supported by the Intelligent Energy Europe programme (OPTRES, RE-SHAPING). For a detailed description and definition of the indicators we refer to Steinhilber et al. (2011)[1]. The developed indicators have been applied broadly, including the EC's monitoring process for evaluating MS policies since 2005 (European Commission 2005 & 2008) and by the International Energy Agency for policies in OECD countries (International Energy Agency 2008 & 2011).

## 2.1 Effectiveness of renewables policies

### 2.1.1 Objective and rationale

In principle the effectiveness of a policy instrument serves as a measure for the degree to which a predefined goal can be achieved. However, this definition of effectiveness complicates a cross-country comparison of the effectiveness, as the setting of goals and their ambition level might vary significantly among countries. A less ambitious goal is easier to attain than a more ambitious one. In this case, the degree of achievement does not serve as an appropriate indication for the quality of a support scheme (Dijk 2003, p. 16). Consequently, the effectiveness of a policy scheme for the promotion of renewable electricity is understood as the increase in the supply of renewable final energy due to this policy compared to a suitable reference quantity. Such a reference quantity could be the additional available renewable electricity generation potential or the gross electricity consumption.

Renewable final energy provided may show some volatility from year to year which cannot be attributed to changes in policy support, but rather to weather- or climate-related factors. This means, that hydro or wind power electricity generation may vary from year to year as a result of changing precipitation or wind speed conditions.

In case of renewables-based heating systems, it we must consider that the space heating demand may also vary according to the average temperatures. To exclude the influence of changes in the supply of renewable final energy due to weather conditions and other external and unpredictable circumstances, the energy provided shall be corrected by these factors (see section 2.1.3 and 2.1.4). Using real generation figures would lead to a biased picture of policy effectiveness, as for instance a successful policy in the wind sector would be underestimated if the wind conditions were especially bad in the observed time frame.

### 2.1.2 Definition

The effectiveness of a MS policy is interpreted in the following as the ratio of the change in the normalised final energy generation during a given period of time and the additional realisable mid-term potential for a specific technology. In contrast to the indicators calculated in OPTRES and RE-SHAPING, we changed the definition of the effectiveness

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[1] Please note that the time horizon of the realisable potential for this analysis has been extended to 2030, as we are already approaching the period of 2020, time reference of the used reference potential in the RE-Shaping project.

indicator as follows. As we are already approaching the 2020 time horizon, we modified the reference potential by changing the reference year to 2030. The adaptation was required, since for some technologies the deployment gets already closed to a high potential exploitation. Provided that the denominator becomes very small, the effectiveness may be distorted if the 2020-potential is still taken as referece. One disadvantage of the change to the 2030-potential is that it cannot anymore be compared to indicators shown in previous analyses.

Thus, the exact definition of the *Policy Effectiveness Indicator* reads as follows:

$$E_n^i = \frac{Q_{n(norm)}^i - Q_{n-1(norm)}^i}{POT_{n-1}}$$

*where:*

$E_n^i$ := *Effectiveness indicator for RET i in year n;*

$Q_{n(norm)}^i$ := *Normalised renewable final energy of RET i in year n (corrected by weather-related influences);*

$POT_n$ := *Additional realisable mid-term potential in year n until* ***2030***

Figure 1 illustrates exemplarily the calculation of the *Policy Effectiveness Indicator* for biogas development in the UK in 2003. Please note, that the current definition takes the 2030 potential as denominator and not the 2020 potential as shown in Figure 1.

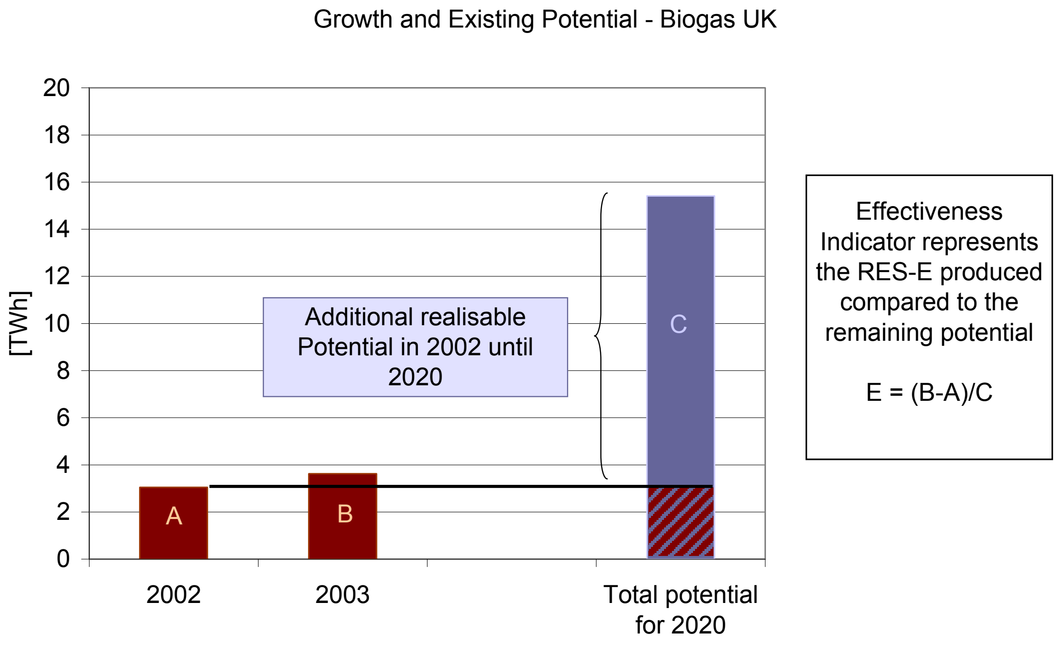

**Figure 1: Example: The effectiveness indicator for biogas electricity generation in the UK in 2003 (European Commission 2005)**

This definition of the *Policy Effectiveness Indicator* has the advantage of giving an unbiased indicator with regard to the available potentials of a specific country for individual technologies. Member States need to develop specific RES proportionally to the given potential to show comparable effectiveness of their instruments.

Solid and liquid biofuels can conveniently be transported and traded across country borders, which means that a country can easily consume more biofuels than it is able to produce domestically. Using the domestic generation potential as a reference quantity will not lead to meaningful indicator values in such a case.

The calculation methodology for electricity production as well as grid and non-grid heat production from biomass has been adapted to accommodate this fact. Originally, biomass potentials were based on a scenario with moderate imports, calculated in Green-X, the model generally used in the Re-Shaping project. Due to an increase in cross-border trade in recent years, the biomass potential used in the 2014 version of the indicators is based on a high-import scenario, which is consistent with the biomass trade reported by Member States in their national renewable energy action plans.

In the case of transport, a consumption-based approach has been chosen.

In the following paragraphs we explain how the correction of weather-related variations is realised first for the case of electricity generation technologies, namely wind and hydro power and then for renewables-based space heating systems. Finally, we describe how we deal with non-weather related fluctuations occurring in particular in the renewable heat and transport sector.

Despite the normalisation for weather-related variations and the non-weather related fluctuations, the policy effectiveness indicator can take negative values, if the renewable final energy provided decreases from one year to another. The reader should note that negative policy effectiveness does not actually exist and should therefore not be evaluated.

### 2.1.3 Normalisation of renewable electricity generation

In the power sector, we normalise electricity generation from hydropower and wind power plants according to the calculation formula stated in Directive 2009/28/EC (The European Parliament and the Council of the European Union 2009). Since annual variations are less crucial for the remaining RET, no normalisation appears to be required in these cases. In case of hydropower plants, the normalisation is based on the ratio between electricity generation and the installed capacity averaged over 15 years, as described in the following formula:

$$Q_{n(norm)} = C_n \cdot \left[ \sum_{i=n-14}^{n} \frac{Q_i}{C_i} \right] / 15$$

*where:*

$n$ := *Reference year;*

$Q_{n(norm)}$ := *Normalised electricity generated in year n by hydropower plants [GWh]*

$Q_i$ := *Actual electricity generation in year i by hydropower plants [GWh], (excluding electricity generation from pumped-storage units);*

$C_i$ := *Total installed capacity of hydropower plants at the end of year i [MW]*

Similarly, the normalisation procedure for electricity generated in wind power plants is realised based on electricity generation data averaged over several years. Since wind power plants are at present in an earlier stage of market development than hydropower, the average is calculated over up to four years, depending on whether the capacity and generation data is available in the respective MS. Therefore, the average full-load hours over the respective time horizon are calculated by dividing the sum of the electricity generation by the sum of the average capacity installed. Since renewables statistics do not provide information at which time during the year the additionally installed power plants have started operation, it is assumed that renewable power plants are commissioned evenly throughout the year. Consequently, the normalisation is calculated as follows:

$$Q_{n(norm)} = \frac{C_n + C_{n-1}}{2} \cdot \frac{\sum_{i=n-m}^{n} Q_i}{\sum_{j=n-m}^{n} \left( \frac{C_j + C_{j-1}}{2} \right)}$$

*where:*

$n$ := *Reference year;*

$Q_{n\ (norm)}$ := *Normalised electricity generated in year n by wind power plants [GWh];*

$Q_i$ := *Actual electricity generation in year i by wind power plants [GWh];*

$C_j$ := *Total installed capacity of hydropower plants at the end of year j [MW];*

$m$ := *The number of years preceding year n for which capacity and generation data is available (up to 4 years)*

### 2.1.4 Normalisation of renewable heat consumption

In contrast to the case of the electricity output, where annual variations are partly induced by the availability of the respective RES, annual heat consumption may vary according to the respective heating requirements of a year. The estimate for seasonal heating requirements is generally measured by 'heating degree days' (HDD) taking into account the outdoor temperature compared to the standard room temperature. In addition, a heating threshold specifies the temperature beyond which heating devices are supposed to be switched on[2]. To obtain a preferably unbiased effectiveness indicator for RET in the heating sector, a temperature-adjustment of the renewables-based space heating supply is undertaken based on the approach proposed by Ziesing et al. (1995) and Diekmann et al. (1997). In this context, one should take into account that heating requirements do not only depend on temperature effects, but also on building insulation and other weather-related factors such as solar irradiation, wind speed and precipitation patterns. To calculate the temperature adjustment, the share of space heating and water heating has to be estimated. In case of biomass, this information was provided by Eurostat, whilst we assumed 100 % of the geothermal heating capacity to be used for space heating purposes. In case of solar thermal heat, we assumed 100 % to be used for water heating and did not undertake any temperature adjustment. The adjustment is based on the following formula:

$$HC_{n(norm)} = HC_{n(eff)} \cdot \left( SH_n \cdot \frac{\overline{HD}}{HD_{n(eff)}} + (1 - SH_n) \right)$$

*where:*

$HC_{n(norm)}$ := *Temperature-adjusted heating consumption in year n;*

$HC_{n(eff)}$ := *Effective heating consumption in year n;*

$SH_n$ := *Share of space heating in heating consumption in year n;*

$\overline{HD}$ := *Long-term average of heating degree days;*

$HD_{n(eff)}$ := *Effective heating degree days in year n.*

Since the historic development of renewable-based heat consumption still shows considerable fluctuations after the temperature normalisation, the heating time series are further modified. To further smooth out the time series, we calculate moving averages over three years. The trend for recent developments shown in the figures reflects the average value over the last two years.

## 2.2 Deployment Status Indicator

The RET (Renewable Energy Technology) Deployment Status Indicator aims to quantify how advanced the market for a specific RET is in a specific Member State: the higher the value, the higher the maturity of that specific technology market in that country. The indicator shall be applicable to the 11 key RET in 28 EU Member States based on existing statistical data.

Based on earlier RET market surveys, we differentiate three types of deployment status, well aware that this categorization is somewhat rough and generalizing.

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[2] In this analysis we rely on annual heating degree days published by Eurostat assuming a heating threshold of 15°C and a standard room temperature of 18°C.

**Immature RET markets** are characterized by small market sizes, few market players and low growth rates. Local, regional and national administrations have little experience with the use and the promotion of the RET in question. Also, local banks needed for financing, energy companies and local project developers have little experience with that RET. This goes along with the typical market entry barriers for the RET, e.g. long and intransparent permitting procedures, grid access barriers, low or unreliable financial support etc.

**Intermediate RET markets** are characterized by increased market sizes, typically accompanied by strong market growth and the interest of many market players[3]. The increased market size reflects that the energy sector, the administration and parties involved in financing have gained experience with the RET. In case of fast market growth, growth related market barriers may occur, e.g. infrastructural (rather local) and supply chain bottlenecks (both local and global). Not all intermediate markets show fast market growth, however. In some countries this status reflects that the market has stopped growing at intermediate level, e.g. due to a stopped support policy (see example of Denmark below); in other countries the potential for a specific RET is so limited that the market cannot reach advanced deployment status.

**Advanced RET markets** are characterized by established market players and fully mature technology. Market growth may start to slow down at this advanced stage. Market players may encounter typical high-end barriers: competition for scarce sites and resources as the most cost-effective RES potential is increasingly exploited, power system limitations like curtailment, etc.

### Strengths of Deployment Status Indicator and contribution to the RET policy discussion

The Deployment Status Indicator allows more nuanced policy evaluation when doing macro-level comparisons of large groups of Member States and/or technologies.

- The effectiveness of a policy is influenced by the maturity of the respective RET market. The *Policy Effectiveness Indicator* has been criticized for not taking into account the diffusion curve of the RET. In conjunction with the *Deployment Status Indicator* it will be clearly visible in how far the deployment status of technologies and/or countries is comparable.

The *Deployment Status Indicator* allows better differentiation in generic policy advice, because the deployment status of a RET influences the further RET development options and thus also the effect of / options for RET policies:

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[3] Note that the actual market growth will not be measured by the Deployment Status Indicator; the indicator only measures the achieved market size; market growth is measured by the Policy Effectiveness Indicator.

- Depending on the maturity of a RET market, the RET support policy framework needs to overcome different types of barriers, e.g. market entry or high-end system barriers.

- For example the way risk is shared between market players and public may be adjusted to the maturity of the respective RET market, assuming that more mature markets can more efficiently cope with risk.

The *Deployment Status Indicator* is especially useful when discussing large groups of Member States and/or technologies as the same indicator set is available for 11 technologies and 28 Member States. It was designed with the purpose of having good input data availability and therefore broad coverage.

**Limitations of the Deployment Status Indicator**

The *Deployment Status Indicator* cannot replace a detailed assessment of a single technology across all Member States or all technologies within one Member State.

The RET *Deployment Status Indicator* does not express the global (technological or market) status of the RET or the combined status of all RET in a Member State.

The *Deployment Status Indicator* describes the status in a given year, but is not a forecast for future development, as it does not represent the actual existence of barriers, quality of policies or the speed of market growth in recent years. It is a static indicator that only reflects the cumulated development that occurred so far. It does not include any dynamic or forward looking element. Therefore, no conclusions can be drawn on current market dynamics or future market perspective. For example, a technology may be deployed to a significant extent, but without any further market growth. This is the case of wind onshore in Denmark, which showed steep market growth over several years until the support scheme was changed. After that, almost no further market growth occurred. Nevertheless, the status of wind onshore in Denmark can be considered advanced. Dynamic elements have been avoided on purpose: They are represented by the *Policy Effectiveness Indicator*.

### 2.2.1 Definition

**Sub-indicator A: Production of RES technology as share in total sector (electricity/heat) consumption**

This indicator reflects the relevance of a technology for its energy sector and in how far it is visible for policy makers.

To give an example: As long as the heat production of solar thermal installations accounts for less than 1% of the total heat consumption of a country, the public will not consider this technology as vital for heat supply. The low share also reflects that policy makers may have paid only limited attention to the support of this technology so far, or that their efforts have been unsuccessful. The importance of a technology is recognized once it gains a higher share in the domestic heat supply. This status also indicates that the typical market entry barriers are overcome. On the other hand, with increasing technology deployment, limitations of the energy system (e.g. missing heat networks and sinks) may occur as high-end barriers.

### Sub-indicator B: Production as share of 2030 realisable potential

The indicator reflects in how far the mid-term potential for a specific RE source is already exploited, or, in other words, to what extent the potential that can be realistically developed until 2030 is already tapped. The 2030 potential is taken from the Green-X model that is generally applied in the DIACORE project. As explained above, a high-import scenario is now the basis for the biomass potentials assumed in the effectiveness indicator. This is due to the fact that both solid and liquid biofuels are increasingly being traded across country borders. To ensure consistency with the effectiveness indicator, the 2030 biomass potentials used here are based on the same high-import scenario from Green-X.

For this indicator, too, higher shares indicate that low-end barriers have been over-come and high-end barriers may occur, in this case particularly supply chain bottle-necks and the competition for scarce resources.

### Sub-indicator C: Installed capacity of RET

This indicator serves as a minimum threshold and reflects whether a minimum capacity of this RET has been realized. In that case project developers, investors and banks have gained trust and experience in the national RET market. Even if technologies are proven abroad: Only domestic projects are a proof that barriers in permitting, grid integration, support scheme and energy market access can be overcome.

### Aggregation of sub-indicators to one overall indicator

Figure 2 below shows how the three sub-indicators are aggregated into one overall *Deployment Status Indicator*: This description applies to electricity technologies, the differences for heat technologies are presented afterwards. Defining thresholds and the weight of the sub-indicators is based on expert opinion. Depending on the technology one is looking at, one could argue to use other weighting and thresholds. However, as this indicator has to apply to various RET in a comparable way, a weighting and thresholds had to be defined that suit the whole RET portfolio.

1. The weight of the three sub-indicators in the overall *Deployment Status Indicator* is defined:

    a. The two sub-indicators *Production as share of sector consumption* and *production as share of 2030 potential* are considered to be most important: Each of them gets a weight of 40% in the overall *Deployment Status Indicator.*

    b. The sub-indicator *installed capacity* is relevant only during the first phases of market development. Therefore it has a weight of only 20% in the overall

*Deployment Status Indicator.* In the figures it is shown at the bottom of the stacked bar which makes it easy to recognize countries where the absolute amount of *installed capacity* is still very low. This may indicate that also the actual overall deployment status is lower than suggested by the overall *Deployment Status Indicator* if the *production as share of 2030 potential* is very high, which might occur in countries with a very low potential.

2. For each sub-indicator it is defined how it relates to Deployment Status:

a. If production as share of sector consumption reaches 10% a market is considered to be very advanced and the maximum amount of 40 points is attributed. 0% Production as share of sector consumption corresponds to a very immature market and the minimum amount of 0 points is attributed. For values in between the minimum and the maximum threshold a linear interpolation is applied.

b. If production as share of 2030 potential reaches 60% a market is considered to be very advanced and the maximum amount of 40 points is attributed. 0% Production as share of 2030 potential corresponds to a very immature market and the minimum amount of 0 points is attributed. For values in between the minimum and the maximum threshold a linear interpolation is applied.

c. If installed capacity reaches 100 MW the maximum amount of 20 points is attributed. Reaching the 100 MW threshold indicates that a significant number of projects have been realized in that market and thus that the technology can be considered to be proven to some extent in that market and that initial market entrance barriers have been overcome, which means the market is not completely immature anymore. In very large-scale technologies like wind offshore, grid-connected biomass heat or large hydro 100 MW can be reached with very few or just one project. Therefore for these technologies 500 MW is applied as a threshold. For technologies with rather small average project sizes like photovoltaics, biogas, solar thermal heat, heat pumps and non-grid connected biomass heat 50 MW is used as a threshold. For all other RET the default value of 100 MW is applied. Within this indicator set the sub-indicator Installed capacity is of no relevance in assessing markets whose deployment status is higher (intermediate or advanced), and therefore only a maximum of 20 points is attributed as compared to the 40 points for the other two sub-indicators. Receiving the maximum amount of 20 points for 100 MW installed capacity does not mean that 100 MW are considered to reflect an advanced deployment status – especially in larger countries this is certainly not the case. 0 MW In-stalled capacity corresponds to a very immature market and the minimum amount of 0 points is attributed. For values in between the minimum and the maximum threshold a linear interpolation is applied.

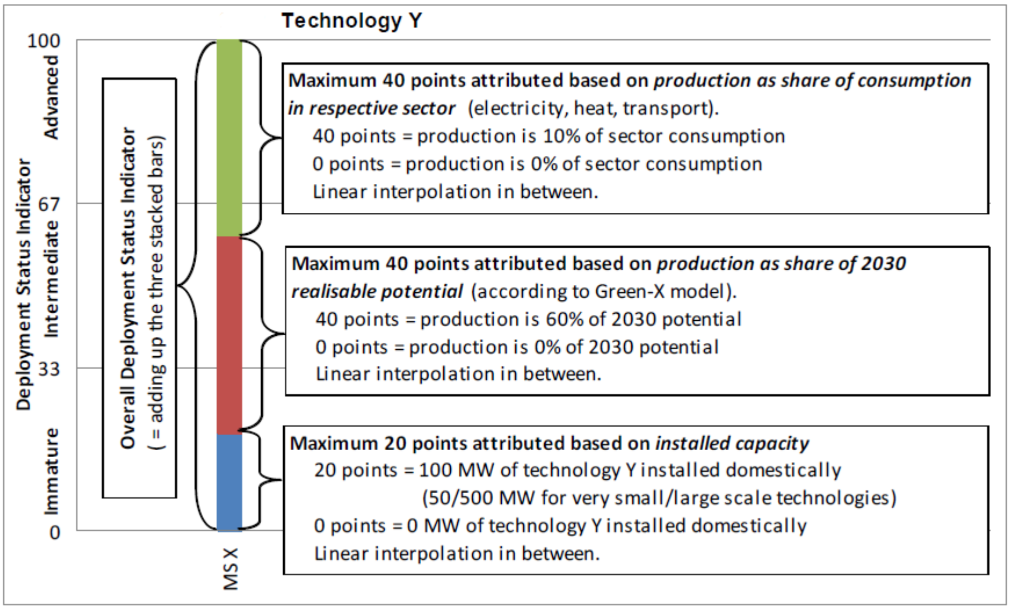

**Figure 2: Composition of the *Deployment Status Indicator***

In case the Member State potential for a technology is lower than 1% of the respective sector consumption, the Deployment Status Indicator is not considered to present meaningful results. Where this applies, the two-letter Member State abbreviation and the indicator are not shown in the figure for that technology. If a Member State abbreviation is shown but no bar is visible that means that the country has a significant potential which is not yet deployed.

The indicator is produced for both RES-E and RES-H technologies. Contribution of cogeneration to RES-E and RES-H is considered in the respective heat and electricity technologies. For RES-T the indicator is not calculated: Due to the fact that biofuels are a global commodity and are often imported to a large extent, the indicator - which is meant to reflect the status for domestic production - is considered to be less meaningful and is therefore not shown.

### 2.2.2 Data used

When designing the indicator, the aim was to be able to rely on existing and reliable data sources that cover all EU Member States and all RET. Wherever possible, Eurostat data have been used for the year 2012 which became available in May 2014. The following exceptions/adaptations apply:

- For wind onshore, wind offshore and photovoltaics, 2013 data from Eurobserver have been used – Eurostat does not yet provide 2013 data.
- For RES-H, 2012 Eurostat data had many gaps, especially concerning installed capacities. EurObserver provides data for some of these gaps, but the data do not

always seem to correspond perfectly. Therefore the following approach has been used:

- 2012 Eurostat data for solar thermal heat have been used.
- 2012 Eurostat production data for biomass grid and non-grid have been used, the respective capacities have been calculated based on the country-specific full load hour assumptions applied in Green-X.
- 2012 EurObserver data for geothermal heat and ground source heat pumps have been used.

## 2.3 Economic incentives and conversion costs

The level of financial support paid to the supplier of renewable final energy is a core characteristic of a support policy. Besides its direct influences on the policy cost, it also influences the policy effectiveness. In general, one can expect that a high support level induces more capacity growth than a lower support level, provided that the remaining framework conditions are equal. However, experience shows that a higher support level does not necessarily lead to an accelerated market development of RET, if e.g. the framework conditions for permitting procedures are not favourable or if risk considerations are taken into account. Nevertheless, a high support level involves higher policy costs to be borne by the society. Hence, the support level should be sufficient to stimulate capacity growth of RES by offering a certain profitability level to potential investors, but should also avoid windfall profits caused by high support levels exceeding the requirements of the RES technology.

Comparing the support level available for the different technologies in each MS contributes to the identification of best policy practices that have been the most successful in encouraging market growth at preferably low costs. However, the actual support levels are not comparable, since significant criteria including in particular the duration of support payments are not considered. For this reason the available remuneration level during the whole lifetime of a RET plant has to be taken into account. The remuneration level contains the final energy price if the support payments expire after a certain time horizon, but the RET plant continues in operation. To make the remuneration level comparable, time series of the expected support payments or final energy prices respectively are created and the net present value is calculated. The net present value represents the current value of the overall support payments discounted. Finally, the annualised remuneration level is calculated based on the net present value as shown subsequently:

$$NPV = \sum_{n}^{N} \frac{SL_t}{(1+z)^n}; \qquad A = \frac{z}{(1-(1+z)^{-N})} * NPV$$

*where:*

$NPV$ := *Net present value;*
$SL_t$ := *Support level available in year t;*
$A$ := *Annualised remuneration level;*
$z$ := *Interest rate;*
$n$ := *Reference year;*
$N$ := *Payback time*

The remuneration level under each instrument was normalised to a common duration of 20 years based on the assumption of a discount rate of 6.5 %. The discount rate is assumed to reflect weighted average costs of capital (WACC) consisting of costs for equity and debt.

Support payments with a duration of 20 years lead to a higher annualised remuneration level than the same payments available only for 15 years. In case of a certificate scheme, it was assumed that remuneration level is composed of the conventional electricity price and the average value of the tradable green certificate. It is supposed that the elements of the time series remain constant during the time certificate trading is allowed. The advantage of the presented indicator is that it allows a global picture of the financial remuneration offered by a certain support mechanism during the whole lifetime of a RET. The comparison will be carried out on an aggregated level per technology category, but the tariffs within one category might differ significantly. There might be a large range of tariffs available for the different biomass technologies as i.e. in Germany, where tariffs show a rather broad range. In addition, the complexity of support scheme combinations in some countries complicates the exact calculation of the indicator, which means that the comparison of the support level as it is calculated within this publication serves as an indication.

### 2.3.1 Electricity and heat generation costs

Electricity and heat generation costs, levelised over the whole lifetime of the renewable power or heat generation plant are calculated and compared to the respective financial support level available. Regarding the transport sector, since biofuels are assumed to be an internationally traded commodity, not the cost levels between Member States are compared with the remuneration levels in this case, but only the support levels have been assessed. In the context of electricity generation technologies, costs related to grid connection charging and balancing requirements are considered in more detail. For wind power plants, grid reinforcement and extension cost are included in the generation cost if these have to be covered by the project in the respective country (i.e. in case a shallowish/deep connection cost approach is applied).

In case of power plants producing only electricity, the calculation of the electricity generation costs reads as follows:

$$C_{tot,ele(level)} = \frac{\sum_{t=0}^{LT} \frac{p_{fuel,t}}{(1+z)^t}}{\eta_{ele}} + \frac{C_{O\&M}}{u_{ele}} + \frac{I}{u_{ele}} \cdot \frac{z}{(1-(1+z)^{-N})} + C_{System}$$

*where:*

$C_{tot,ele(level)}$ := *Total levelised electricity generation costs of a pure electricity generation plant;*
$p_{fuel,t}$ := *Price of fuel in year t;*
$\eta_{ele}$ := *Electric conversion efficiency;*
$C_{O\&M}$ := *Operation and maintanance costs;*
$u_{ele}$ := *Annual electric utilisation (Full-load hours);*
$I$ := *Investment;*
$C_{System}$ := *System integration costs in case of non-dispatchable RES;*
$z$ := *Interest rate;*
$LT$ := *Life time of plant;*
$N$ := *Payback time*

In case of CHP-generation, electricity generation costs are similar to the calculation for plants that only produce electricity. The only difference is that the potential revenue from selling the generated heat is rested from the electricity generation costs, as shown in the subsequent formula.

$$C_{tot,chp(level)} = \frac{C_{O\&M}}{u_{ele}} + \left( \frac{\sum_{t=0}^{LT} \frac{p_{fuel,t}}{(1+z)^t}}{\eta_{ele}} \cdot \frac{I}{u_{ele}} - \sum_{t=0}^{LT} \frac{p_{heat,t}}{(1+z_l)^t} \cdot \frac{\eta_{heat} \cdot u_{heat}}{\eta_{ele} \cdot u_{ele}} \right) \cdot \frac{z}{(1-(1+z)^{-N})}$$

*where:*

$C_{tot,chp(level)}$ := *Total levelised electricity generation costs of CHP-plants;*
$p_{fuel,t}$ := *Price of fuel in year t;*
$\eta_{ele}$ := *Electric conversion efficiency;*
$C_{O\&M}$ := *Operation and maintanance costs;*
$u_{ele}$ := *Annual electric utilisation (Full-load hours);*
$I$ := *Investment;*
$z$ := *Interest rate;*
$LT$ := *Life time of plant;*
$N$ := *Payback time*

Heat generation costs are calculated similarly to electricity generation costs of pure power generation plants, as shown in the subsequent formula.

$$C_{tot,heat(level)} = \frac{\sum_{t=0}^{LT} \frac{p_{fuel,t}}{(1+z)^{t}}}{\eta_{heat}} + \frac{C_{O\&M}}{u_{heat}} + \frac{I}{u_{heat}} \cdot \frac{z}{(1-(1+z)^{-N})}$$

*where:*

$C_{tot,heat(level)}$ := *Total levelised heat generation costs of a pure heat generation plant;*
$p_{fuel,t}$ := *Price of fuel in year t;*
$\eta_{heat}$ := *Heat conversion efficiency;*
$C_{O\&M}$ := *Operation and maintanance costs;*
$u_{heat}$ := *Annual heat utilisation (Full-load hours);*
$I$ := *Investment;*
$z$ := *Interest rate;*
$LT$ := *Life time of plant;*
$N$ := *Payback time*

In general, minimum to average generation costs are shown because this range typically contains presently realisable potentials which investors would normally deploy in order to generate electricity at minimum costs. Furthermore, the maximum generation costs can be very high in each country so that showing the upper cost range for the different RES-E would affect the readability of the graphs.

### 2.3.2 Potential profit for investors

Finally the economic incentives and the generation costs are translated into the total expected profit of an investment in RET. We assume the maximum profit available to correspond to the difference between the maximum support level and minimum generation costs. At the same time, the minimum profit shown is calculated by the difference between average support level and average generation costs. The generation costs have been calculated taking into account weighted average costs of capital consisting of costs for debt and equity. Therefore the potential profit ranges shown in the figures in chapter 4 indicate additional/lower profits compared to the assumed weighted average costs of capital.

Then, we compare the observed effectiveness with the level of financial support as seen from the perspective of an investor in order to clarify whether the success of a specific policy depends predominantly on the economic incentives or whether additional aspects influence the market development of RET. The potential profit for investors is calculated for the technologies in the electricity sector and shown in combination with the policy effectiveness.

Note that in this combined view, both profit and effectiveness refer to 2013 for wind and PV and to 2012 for the remaining technologies. As explained further above, when looking at the effectiveness indicator alone, we show the most recent result – 2013 for wind and PV, and 2012 for other technologies. When looking at financial incentives only, we depict the most recent data of 2013.

## 2.4 Electricity market preparedness for RES-E market integration

### 2.4.1 Objective and rationale

#### *2.4.1.1 Need to assess market preparedness for RES: systemic view*

The requirements for effective power market design are evolving with the share of intermittent RES in three stages.

For the initial small share of RES the focus lies on facilitating market entry for new technologies and new actors that can promote the technologies sometimes against the interest of incumbent utilities. This has been reflected in priority dispatch rules and feed-in tariff design and is not subject of this report.

In a second stage, as the share of RES is increasing, the cost of RES support mechanisms for final consumers can increase if RES is not recovering the value it contributes to the system. At this stage countries have been focusing on exposing RES producers to electricity price signals and on reducing gate closure times to support such direct marketing in the expectation that with full incentives to acquire good wind forecasts and clever strategies to sell in intraday markets they can increase the revenues (and thus reduce the need for support) from selling RES.

In a third stage, as the share of intermittent RES further increases, they turn into a central element of the power system. A power system with large shares of intermittent RES will be characterised by larger variations in generation patterns – as residual demand (market demand net of wind and solar electricity generation) will vary within days and across location and will be less predictable at day-ahead stage than traditionally. These variations increase the value of flexibility from load and all generation assets. As European power markets have historically not been designed for these requirements, it will be essential to assess and, where necessary, adjust the power market designs and operational paradigms to meet the emerging requirements so as to ensure intermittent RES provide full value to the power system to avoid unnecessary wind/solar spill (curtailment).

With the progression towards higher shares of intermittent RES, the previous objectives will remain valid, e.g. access for entrants and minimising costs for consumers by ensuring RES can recover the full value of their contribution. However, the solution towards achieving these objectives might evolve. For example, with small shares of intermittent renewables, investors will face multiple challenges of new technologies competing with incumbent technologies. Hence facilitating access and dispatch has priority. With increasing shares of renewables, the cost efficient solutions for integration of renewables are becoming more important to minimise costs for consumers. Direct marketing can incentivise private actors to develop strategies to maximise revenue from selling renewable energy sources. With further increases of renewables shares, the energy market design can no longer depend on strategic sales strategies of private actors to compensate for competitive outcomes or market incompleteness. Instead full internalisation of physical constraints of different generation assets in the market price and integration of markets for energy and system services is necessary to ensure a fair remuneration of any RES contribution and to capture synergies across all elements of the power system to minimise costs for consumers while ensring system security..

Across EU countries, the share of RES varies, and so does the importance of different measures in the integration of RES. For this reason we track indicators reflecting the different stages of RES penetration. Based on different electricity market requirements we identify suitable indicators, quantify selected indicators, and aggregate them to the Market Preparedness Indicator in order to gain a systemic perspective on market preparedness for renewables.

#### *2.4.1.2 Definition of market preparedness: openness of power system for RE*

This section will define requirements/provisions that a power system has to fulfil to be considered open/prepared to RES in the different stages: Ensuring fair remuneration of RES power in the market (I), matching temporal profiles of different generation and load types (II) and accommodating spatial profile of intermittent RES generation (III).

**Ensure fair remuneration of RES power in market (I)**

It needs to be ensured that intermittent RES can receive a fair remuneration in the market. Hence the emphasis is on liquid day-ahead markets and trading volume in the intraday market as well as the competitiveness of the market outcome. As forecasts in particular for wind improve significantly within the last hours before real time, emphasis was furthermore given on gate closure times. The later the gate closure time, the later wind producers can use the intraday market to adjust their power sales according to updates to wind forecasts.

**Match temporal profiles of different generation and load types (II)**

With increasing shares of intermittent generation, the contribution of RES to day-ahead and intraday markets no longer constitutes marginal adjustments to the generation schedule, but will alter the market outcome. However, the generation schedule is still determined according to the historic approach for conventional assets. This challenges the traditional approach of market design. Current market design is based on generation schedules structured along the daily demand profile and marginally adjusted in day-ahead and intraday markets according to the production of wind and solar energy brought to the market. With increasing shares of wind and solar energy, their production forecast will determine how conventional units are operated. Therefore the power market design has to:

- Allow for optimisation across time frames so as to allow conventional units to provide their full flexibility to the system while respecting ramping and part-load constraints.

Thus, ultimately maximising the value of both conventional and renewable assets can contribute to the system by minimising fuel and carbon costs,

- Allow for optimization across energy and system services at day-ahead and intraday stage, including for intermittent generation assets that cannot commit to energy or system service provisions on longer time frames,
- Facilitate the participation of all flexibility resources at TSO and DSO level and from generation, storage and load,
- Facilitate acquisition and sharing of system services across national/TSO boundaries,
- Be aligned across intraday and real time stage so as to avoid penalising unavoidable imbalances, exclusion of flexibility options or gaming opportunities.

### Accommodate spatial profile of intermittent RES generation (III)

Transmission networks across Europe have been designed to enhance supply security by sharing generation resources, to reduce costs by sharing system services, and in some instances to facilitate longer distance provision of power from or storage capacity linked to location specific resources. The resulting flow patterns were stable – or periodically repeating (day-night).

With increasing shares of intermittent renewable generation, the spatial profile of production and of power flows will vary with the wind and sun. To accommodate all weather situations and thus flow patterns would require large volumes of transmission capacity beyond current expansion plans. Such volumes might only be used in relatively few hours, and would thus not be economically warranted and politically accepted.

Therefore it will be important to use the transmission capacity that exists and is added to the network as effectively as possible across all time frames while maintaining full system security.

### Further considerations

The emerging power market design will have to ensure that various additional aspects are considered. As they are not necessarily focused on RES integration but more generic requirements for the operation of an effective market, we will subsequently not address these in more detail:

- Facilitate hedging of generation and load over periods exceeding one year to limit exposure to volatility of wholesale market prices linked to weather patterns, e.g. reflected in hydro storage. This requires clearly defined reference prices and transmission contracts of matching durations.
- Effective pricing of scarcity of generation also in intraday and real-time markets so as to fully remunerate the provision of capacity and flexibility. The introduction of corresponding concepts (e.g. operational reserve curve) might have to be aligned

with other improvements of market design (e.g. facilitating access of all flexibility resources) so as to avoid undue increases of cost for imbalance.

According to the categories of power market requirements identified above, we have identified a set of suitable indicators that are now briefly introduced and discussed in more detail in section 2. A selection of these indicators will be aggregated to the Market Preparedness Indicator. The Market Preparedness Indicator developed in the EU-funded RE-Shaping project (http://www.reshaping-res-policy.eu/) served as a basis, has however been refined to include a more system view of market preparedness.

#### *2.4.1.3 Identifying indicators for openness of power system for RE*

The requirements identified with respect to a fair remuneration of power from intermittent RES in electricity markets can be captured with indicators on the liquidity of day-ahead markets (energy traded spot) and the share of power traded at intraday stage. The level of competition in a market can – in one first instance – be approximated by the market concentration in the wholesale market. Finally, as the initial objective of market integration focuses on enhancing the revenue stream while limiting imbalance costs, both a late gate-closure time and balancing mechanisms without imbalance penalty are important.

**Table 1: Indicators for ensuring fair remuneration of renewable energy in electricity markets**

| Issue | Indicator | Selected for the Market Preparedness Indicator |
|---|---|---|
| Liquidity of markets | Volume of national demand traded spot | Selected |
| Liquidity through participation in intraday market | % of electricity traded in intraday market | Selected |
| Market concentration in generation | Number of companies with more than 5% share in generation capacity | Lack of current data availability |
| Gate closure time | Gate closure time | Selected |
| Avoiding penalty in mechanisms | Size of pooling units | Lack of data availability |

An effective power market needs to satisfy various criteria to match the temporal profiles of different generation and load types. Conventional assets need to be able to submit bids that reflect their start-up, part-load and ramping constraints. As requirements for system services are a function of the generation and load mix, their efficient provision needs to be responsive to energy market outcomes – but will equally influence their outcome. Hence an integrated approach to energy and ancillary service markets – including across national and TSO boundaries – will be of increasing value with increasing shares of intermittent RES. With increasing shares of intermittent RES, both flexibility requirements will increase and their provision primarily from conventional assets will be costly (part load cost of operating fossil assets). Hence increasing shares of flexibility through other resources will be important. It could be measured to what extent different bid formats allow for flexible participation, to what extent dedicated programs catalyse the deployment, or – as indicated in the table – to what extent progress has been achieved, for example with the provision of flexibility from demand side.

**Table 2: Indicators for matching generation and load profiles**

| Issue | Indicator | Selected for the Market Preparedness Indicator |
|---|---|---|
| Contribution of inflexible assets | Opportunity for complex bids | Difficulty to measure |
| Integrated energy, trans-mission and system services market | Qualitative expert review | Lack of data availability / Difficulty to measure |
| Utilization of demand response potential | Share of demand response | Lack of data availability |
| Information available to TSO | Qualitative expert review | Difficulty to measure |

A final set of indicators assesses to what extent the spatial profile of intermittent RES generation is accommodated in the power market design. Initial steps for flexible allocation at day-ahead stage are reflected in market coupling, initially based on pre-determined commercial capacities between individual countries (i.e. price zones), and gradually enhancing flexibility with a flow-based approach that allocates transmission capacity to the most valued use.

The concept of sharing transmission capacity across various potential users can also be reflected in – and measured with – the connection charges for generation assets to distribution or transmission grid. Sharing transmission capacity implies that historic users do not receive preferential treatment, but transmission capacity is used for the most valued use – and thus also expansion of transmission capacity to connect new users is tailored to the final transmission requirement and costs are shared across users.

With increasing uncertainty about realised flow patterns, TSOs need to reserve increasing shares of transmission capacity as security margin, thereby reducing the efficiency of their use. Hence early availability of corresponding data to TSOs will allow for precise determinations of flows and will reduce the required security margins. One option to assess the efficiency of the outcome is a comparison of the physical transmission capacity (PTC) with the share that is made available for commercial transactions (net transfer capacity, NTC).

A final indicator for market models with bidding zones covers re-dispatch costs. Re-dispatch costs result from transmission constraints within bidding zones. High re-dispatch efforts can create opportunities for gaming (inc-dec game) and system security constraints (uncertainty about flow-patterns and sufficient capacity to implement redispatch). High re-dispatch costs therefore create incentives for TSOs to limit further connection of renewables and indicate that bidding zones are too large. Therefore it would be optimal to have low or no re-dispatch costs.

However, it also needs to be monitored if a transmission constraint occurs in a meshed network between large bidding zones, but no re-dispatch costs are incurred within bidding zones. This has been at times the result of TSOs limiting transmission capacity nominated for international commercial transactions to reduce transmission flow and internal transmission constraints. Therefore clear rules on the volume of transmission capacity to be made available for international transfers are important – as is the monitoring of the transmission capacity that is made available over time.

**Table 3: Indicators for accommodating spatial profile of intermittent RES generation**

| **Issue** | **Indicator** | **Selected for the Market Preparedness Indicator** |
|---|---|---|
| Allocation of transmission capacity: Market coupling | % of interconnectors with market coupling (day-ahead & intraday) | Selected |
| Flexible transmission use / transmission sharing | Connection charges | Selected |
| TSO flow calculation | Unexpected loop flows | Lack of data availability |
| TSO system perspective | Time window before real time by which TSO knows about full flow pattern | Lack of data availability |
| Utilization of transmission capacity | Ratio between NTC and PTC | Selected |
| Integration energy and transmission markets | Redispatch costs | Lack of data availability |

In summary we have identified 15 indicators for the openness of the power system for RES integration, of which we have selected 6 for the initial coverage under the market preparedness indicator. Additional indicators could be added at later stage. This would either require a detailed review of the market design within individual countries or other data currently not publicly available.

Extending and developing the indicator further to represent electricity market preparedness may – due to data availability – not be possible for all 27 Member States. In this case the sub-indicators will be calculated for the countries where data is available and data collection requirements will be pointed out for the other countries.

Indicators that were identified as suitable to measure the openness of power system for RE, but where either sufficient data has not been available or where the assessment only makes sense once further reform towards the single European power market has occurred, are presented in the Annex I: Potential additional indicators.

### 2.4.2 Description of indicators

This section describes the selected six indicators in detail. As introduced in section 2.4.1, three indicators focus on a fair remuneration of intermittent renewable energy in power markets, by measuring the liquidity of day-ahead markets, the liquidity through participation in intraday markets and gate closure times. Three additional indicators analyse to what extent the power market design accommodates the spatial profile of intermittent renewable energy generation, by quantifying the share of interconnectors with market coupling, connection charges, and the utilisation of transmission capacity.

#### *2.4.2.1 Ensure fair remuneration of renewable energy in electricity markets*

**Liquidity of day-ahead markets**

**Indicator:** Share of national energy demand traded spot.

Synergies across the power system are unlocked and also small renewable energy players can fully benefit if all generation and load participates in the market ensuring liquid and deep markets. To approximate this effect, we measure the share of volume traded spot/year relative to the national demand/year.

**Liquidity through participation in intraday market**

**Indicator:** Share of electricity traded in intraday market.

Effective intraday markets allow all generation to accommodate for changing forecasts of intermittent and other generation at intraday stage. This indicator measures the trading volume in the intraday market against the national demand.

**Last update of wind forecast**

**Indicator:** Gate closure time or time of last auction/submission.

The value of intermittent renewable electricity increases with the accuracy of the projected energy provision. As wind forecasts improve in the last hours before real time, the value of wind power increases if the additional information can be used to adjust the volume of power sold. This avoids imbalance costs that would otherwise be incurred for deviations between power sold and delivered. Thus we measure how close to real time such adjustments are possible. In markets that only offer bilateral trading opportunities, this is in theory (if liquidity suffices) determined by the gate closure time. In markets with intraday auctions, this is the time of the last auction.

#### *2.4.2.2 Accommodate spatial profile of intermittent renewable energy generation*

### Allocation of transmission capacity: market coupling

**Indicator:** Share of interconnectors with market coupling (day-ahead and intraday).

The flexible allocation of transmission according to need is measured with this indicator – initially focusing at the day-ahead stage but with further progress of the target model also including the intraday stage.

So far four stages of improvement have been pursued, starting with non-market based allocation (grandfathering or first-come-first-serve approach). Where interconnection capacity between pricing zones was constrained, it has as a second stage been allocated with an auction approach. As the separate auction of commercial available transmission capacity and clearance of energy markets in bidding zones results in inefficiencies, market coupling, the implicit auctioning involving two or more power exchanges, of day-ahead markets was introduced (stage 3). The allocation of transmission capacity in the meshed network to commercial available capacity between individual bidding zones prior to day-ahead market clearing implies that the transmission capacity will not necessarily be used to the highest valued use. Hence in a flow based approach transmission capacity is jointly allocated with market clearing (stage 4).

We average the progress on transmission allocation across interfaces to neighbouring countries. To determine the allocation of transmission capacity for each country, the shares of interconnectors[4] with market coupling based on the entire number of interconnectors, were calculated.

### Flexible transmission use / transmission sharing

**Indicator:** Are connection charges deep or shallow

Connection charges for generators to connect to the distribution or transmission grid are also used to measure the sharing of transmission capacity across different users. Whereby "super-shallow" connection charges mean that all costs are socialized via the tariff and no costs are charged to the connecting entity, "deep" connection charges imply that grid users pay for the infrastructure connecting their installations to the transmission grid as well as all other required reinforcements/extensions in existing networks. Deep connection charges reflect a system philosophy that transmission capacity has to match generation capacity and thus needs to be expanded to match any addition in generation capacity. This can delay grid connection and increase costs. In contrast, transmission capacity can be shared, e.g. at high wind times less conventional generation is required

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[4] An interconnector is defined by the European Commission as a transmission line which crosses or spans a border between Member States and which connects the national transmission systems of the Member States.

and thus in turn requires less grid access and vice versa. This sharing implies that the expansion of transmission capacity is based on final requirements of users. It needs to be noted though that shallow connection charging might not always be cost-effective (e.g. if only one RES plant profits from the capacity extension).

#### Utilisation of transmission capacity

**Indicator:** Ratio between short-term net transfer capacity (NTC) and physical transfer capacity (PTC).

Effective use of transmission capacity allows to share and balance renewable energy across larger areas. To economically accommodate different weather situations and corresponding power flows of intermittent renewable generation plants, it is important to effectively use the existing transmission capacity. However, TSOs hold back increasing shares of transmission capacity for system security reasons. Good market design enables TSOs to obtain full and reliable information on the emerging generation and load pattern, based on which electricity flows can be accurately projected and where necessary response measures can be pursued in a timely manner. As a result, system security increases and uncertainty margins can be reduced. This is measured by comparing the physical transmission capacity (PTC) with the day-ahead net transfer capacity for commercial transactions (NTC). It however needs to be noted that between PTC and day-ahead NTC all nominated physical transmission rights (PTRs) are deducted, which reduces the availability of NTC and does not necessarily mean that inefficiencies increase.

### 2.4.3 Aggregation of sub-indicators

Figure 3 shows how the six sub-indicators are aggregated into one overall Electricity Market Preparedness Indicator:

- All six sub-indicators have the same weight in the overall Electricity Market Preparedness Indicator: All have a weight of 1/6th, and can contribute a maximum of 10 points to the maximum of 60 points for the overall indicator.
- For each sub-indicator at least one point is attributed in order to increase readability of the figure.

  a) If the ratio between NTC and PTC is 100%, 10 points are attributed. If the ratio is 0%, one point is attributed. It needs to be noted reaching 100% is not a realistic value, but it has be chosen as a consistent reference value.

  b) If the share of interconnectors with market coupling (weighted according to their PTC values) is 100%, 10 points are attributed. If the share of interconnectors with market coupling is 0%, one point is attributed.

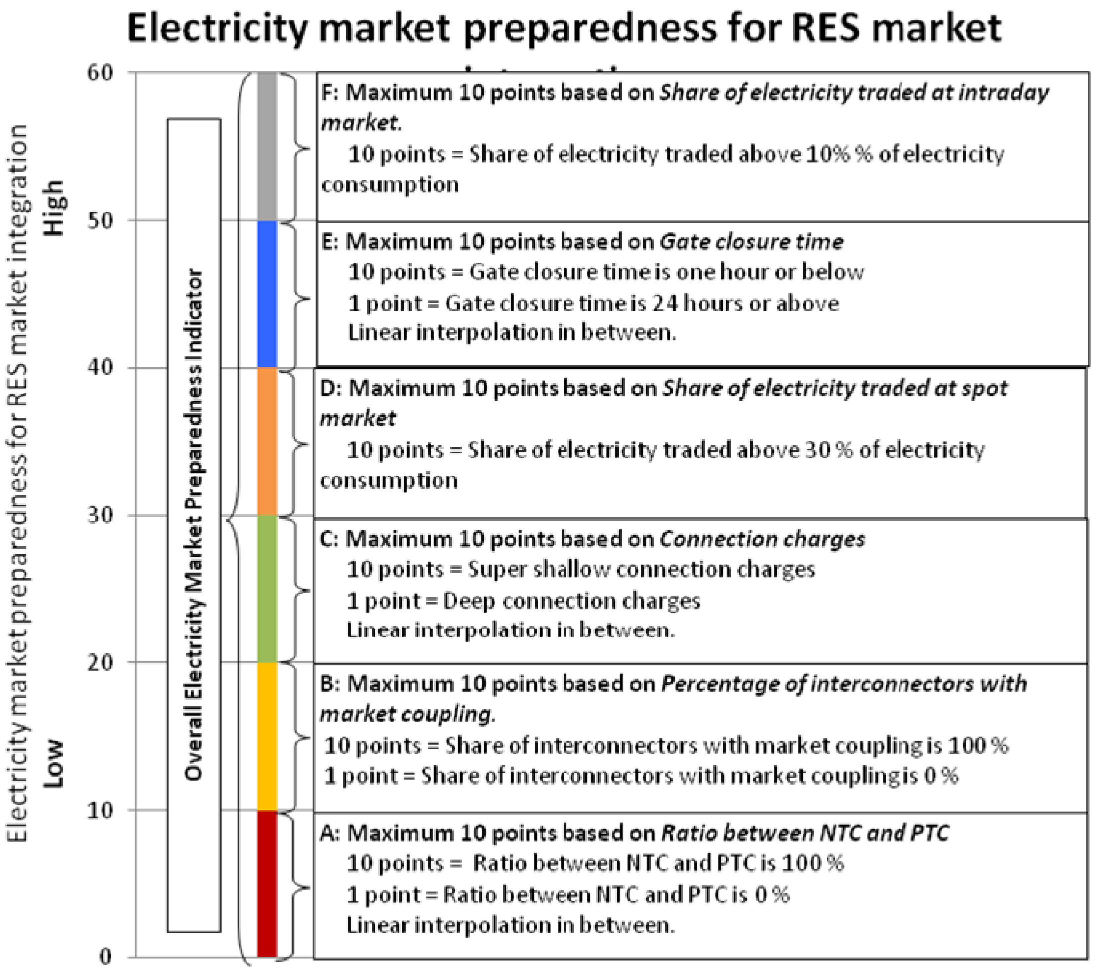
  c) If the connection charges are super shallow, 10 points are attributed, if the connection charges are deep, one point is attributed.

d) If the spot power exchange trade volume is above 30% of power consumption the market is considered to be liquid and therefore 10 points are attributed. If this value is below 5%, the market is considered to be illiquid and one point is attributed.

e) If gate closure time is one hour or below, 10 points are attributed. If gate closure time is 24 hours or above, one point is attributed.

f) If the intraday power exchange trade volume is above 10% of power consumption, 10 points are attributed. If this value is 0%, the market is considered to be illiquid and one point is attributed.

- For some Member States data is not available for all sub-indicators. In the results figure this is indicated by an asterisk (*) in front of the country name. In order to indicate the fact that the stacked bar is incomplete, a segment is added to the stacked bar titled Placeholder missing data points. The height of that segment is 5 points by default.



F: Maximum 10 points based on *Share of electricity traded at intraday market.*
10 points = Share of electricity traded above 10% % of electricity consumption

E: Maximum 10 points based on *Gate closure time*
10 points = Gate closure time is one hour or below
1 point = Gate closure time is 24 hours or above
Linear interpolation in between.

D: Maximum 10 points based on *Share of electricity traded at spot market*
10 points = Share of electricity traded above 30 % of electricity consumption

C: Maximum 10 points based on *Connection charges*
10 points = Super shallow connection charges
1 point = Deep connection charges
Linear interpolation in between.

B: Maximum 10 points based on *Percentage of interconnectors with market coupling.*
10 points = Share of interconnectors with market coupling is 100 %
1 point = Share of interconnectors with market coupling is 0 %

A: Maximum 10 points based on *Ratio between NTC and PTC*
10 points = Ratio between NTC and PTC is 100 %
1 point = Ratio between NTC and PTC is 0 %
Linear interpolation in between.

Figure 3: Aggregation of sub-indicators

## 2.5 Forward-looking RES diffusion indicator

### 2.5.1 Objective and rationale

Monitoring and forecasting expected RES diffusion trajectories in the short-term is central to be able to examine the attainment of RES deployment targets and – in case that the attainment of the objectives is at risk - to be capable of implementing required changes of the regulatory framework in time.

Especially for RES support schemes with a strong reliance on quantity caps (i.e. tender or quota schemes) it is crucial to be able to anticipate future market sizes and scarcity to allow for an adequate policy design. Particularly with regard to the design of RES auctions (i.e. tender volumes) or the definition of RES quota targets, prognoses for a realistic RES market growth for the near future constitute an important reference in order to safeguard a sufficient level of competition and adequate price levels.

However, a central requirement to be able to provide such accurate short-term market forecasts is a more comprehensive understanding of the relationship between the major drivers and barriers for RES deployment and the resulting impact on RES diffusion processes. Therefore, it is crucial to integrate economic factors (e.g. support levels, technology costs or access to financing) as well as non-economic factors in the assessment, as both influence the attractiveness of markets for RES developers and thus determine the actual deployment of RES technologies. Non-economic factors comprise, for example, the complexity and duration of administrative and planning processes for RES projects, the complexity, transparency and duration of grid connection procedures or the design of regulations affecting the access for RES producers to different electricity market segments.

Furthermore, it is crucial to integrate the perspective of the affected stakeholders, namely RES developers and investors, into the assessment, as these actors are the final decision makers when it comes to the realization of RES projects. Only an extensive dialogue with the primary decision makers makes sure that their view on the attractiveness of regulatory environments for RES projects is fully captured by the diffusion indicator.

### 2.5.2 General approach

As mentioned above, the assessment of the framework conditions for RES deployment requires a detailed understanding of the perspectives of the concerned stakeholders - in particular RES project developers and investors. Therefore, the design of the forward-looking diffusion indicator is based on a comprehensive survey and an assessment of the major determinants for RES diffusion on Member State level. To this end, a large number of stakeholders was contacted via an online questionnaire, a web-based platform and through in-depth interviews.

The approach can be structured in 4 major steps (see also Figure 4):

(1) The identification of the major framework factors (determinants) for RES diffusion and selection of suitable indicators and data sources to represent each of them. With this step, the conceptual framework of the forward looking indicator is developed (cf. Boie, Ragwitz, and Held 2015).

(2) The assessment of the relative relevance (weight) of each of the determinants through stakeholder consultation on a European level. For this step, contributions from more than 200 stakeholders across Europe were collected though questionnaires (cf. Annex III) and via an online platform (see section 5.1.2).

(3) The quantification of the indicator by assessing the manifestation of the determinants on country level. To this end, data was collected from several data sources, including in-depth expert interviews in three Member States (Germany, United Kingdom and Spain). Altogether 31 Interviews with an average duration of 1 hour were conducted. Further information for quantification of the individual components was collected from regulatory and legal documents and other publicly available data sources (see section 5.1.1).

(4) Finally, the information on the relevance and the manifestation of the determinants is combined and the composite framework indicator is derived on country level. On this basis, the diffusion analysis can be performed. The short-term diffusion forecast on country level is based on the review of past deployment trends (historical RES diffusion) and changes in relevant framework factors in recent years (for details see section 5.2.1).

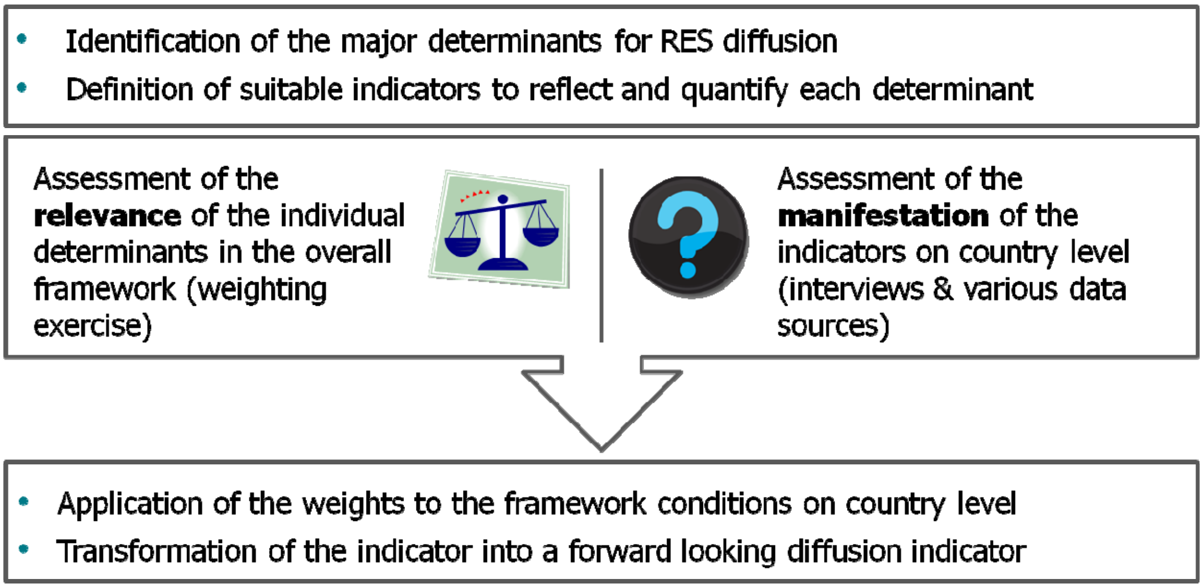


**Figure 4 Methodology overview for derivation of forward-looking RES diffusion indicator**

The quantitative information that is derived by the above described approach can be used for cross-country comparisons (benchmarking) as well as for detailed policy analyses and diffusion forecasts. Also, the underlying conceptual framework can be used for regular updates and further development of the indicator. It can thus serve as a transparent frame to compile an extensive database of indicators for the major determinants for RES diffusion on Member State level.

A more detailed description of the methodology is provided in chapter 5

# 3 Current status of renewable energy use in the EU

The overall share of RES in gross final energy consumption for the EU-28 has increased from 8.3% in 2004 to 14.95% in 2013 (see Figure 5). This puts it above the planned share resulting from Member States' individual trajectories as laid down in their NREAPs. Regarding RES shares in the three final sectors electricity, heat and transport (RES-E, RES-H, RES-T), , RES-E and RES-H are both above NREAP planned values, while the RES-T sector's development has been slower than planned. This is in part due to some Member States' delayed transposition of Directive 2009/28/EC Articles 17 and 18 on biofuel sustainability. EU-level discussions about biofuels sustainability and possible alterations of the transport target also created insecurity within the industry. In absolute numbers, the RES-88,292 ktoe consumed in 2013. The RES-E sector follows with 70,760 ktoe, and the RES-T sector with 15,427 ktoe.

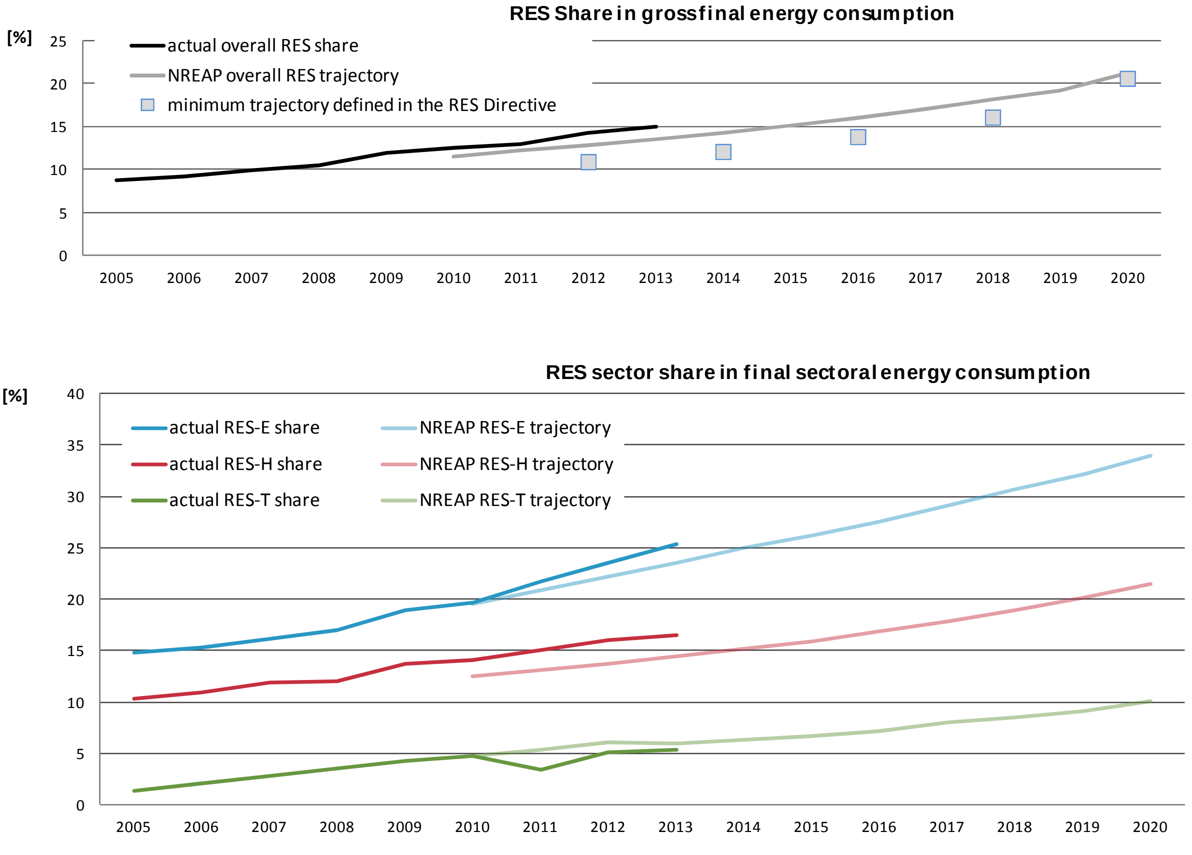


**Figure 5: Actual and planned RES shares (EU-28)**

## 3.1 Electricity

The development of RES-E generation in the EU shows a rising trend between 1990 and 2013 (see Figure 6). Hydropower is still the dominating technology, but there has been a strong development of emerging RETS such as wind and biomass. While hydropower accounted for 94 % of RES-E generation in 1990, this has decreased to below 45 % by 2013. Figure 6 depicts the varying electricity output from hydropower due to annual changes in precipitation. Hydropower production figures reveal that there have been strong variations from 2001 to 2002 and from 2010 to 2011.

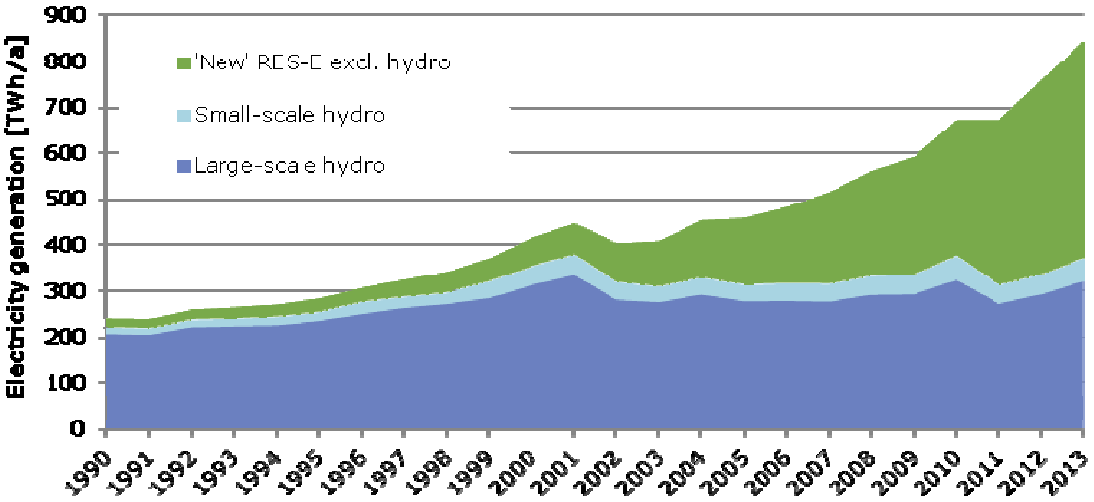


**Figure 6: Market development of RET in the electricity sector (EU-28)**

Figure 7 provides a more detailed picture of the development of 'new' RET including all RET with the exception of hydropower, amounting to 482 TWh in 2013. Compared to RES-E generation in 1990 of 19 TWh electricity generation from new RET has increased by a factor of more than 25 over the last 10-15 years as a consequence of policy efforts undertaken on European and on national level (cf. Figure 7). In particular onshore wind with 216 TWh generated in 2013, followed by solid biomass with 100 TWh and in recent years also photovoltaics with 80 TWh contributed significantly to this development.

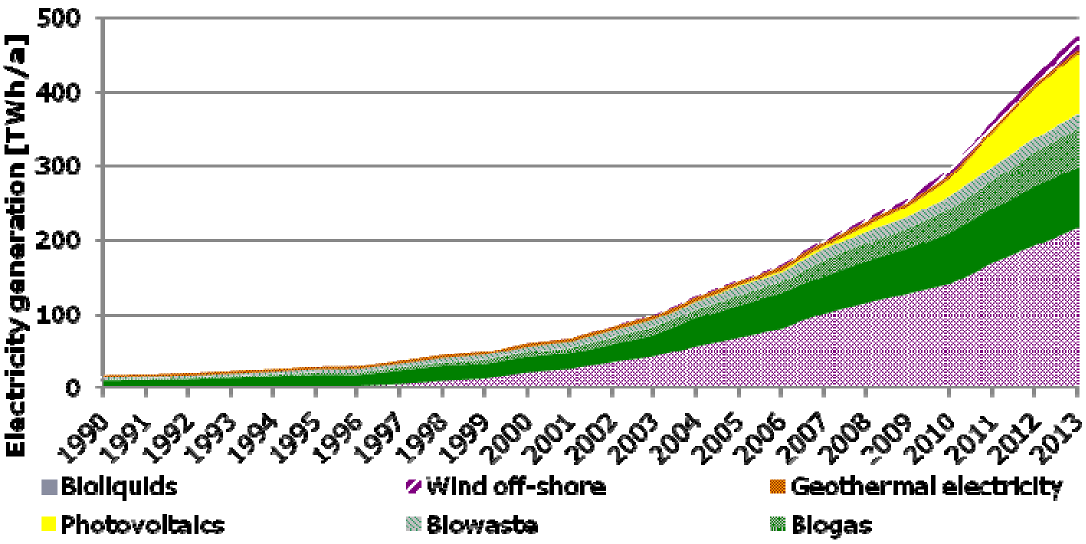


Figure 7: Market development of 'new' RET in the electricity sector (EU-28)

## 3.2 Heating and Cooling

Most of the renewable heat generated in the EU-28 comes from biomass-derived technologies. Regarding heat generation technologies, two different forms of heat supply can be differentiated. The first describes decentralised heating applications where the heat is produced on-site at the consumers' location whilst the second refers to centralised installations. In the latter case the heat is distributed to the final consumer via heating networks. Due to difficulties in measuring on-site heat production, data gathering in this sector is complicated and the final statistics involve a certain degree of uncertainty. Therefore, the data presented should be interpreted cautiously.

The RES-H market (see Figure 8) is clearly dominated by domestic decentralised heating appliances based on biomass. The use of biomass in centralised heating plants or CHP-plants plays an important role in Scandinavian countries, in the Baltic countries and Austria. Solar thermal heating technologies including glazed, non-glazed and vacuum collectors account only for a very small share of the total amount of RES-heat generated. Similarly, heat pumps and geothermal heating technologies represent only a marginal share of RES-heat production but are expected to experience further growth in the future.

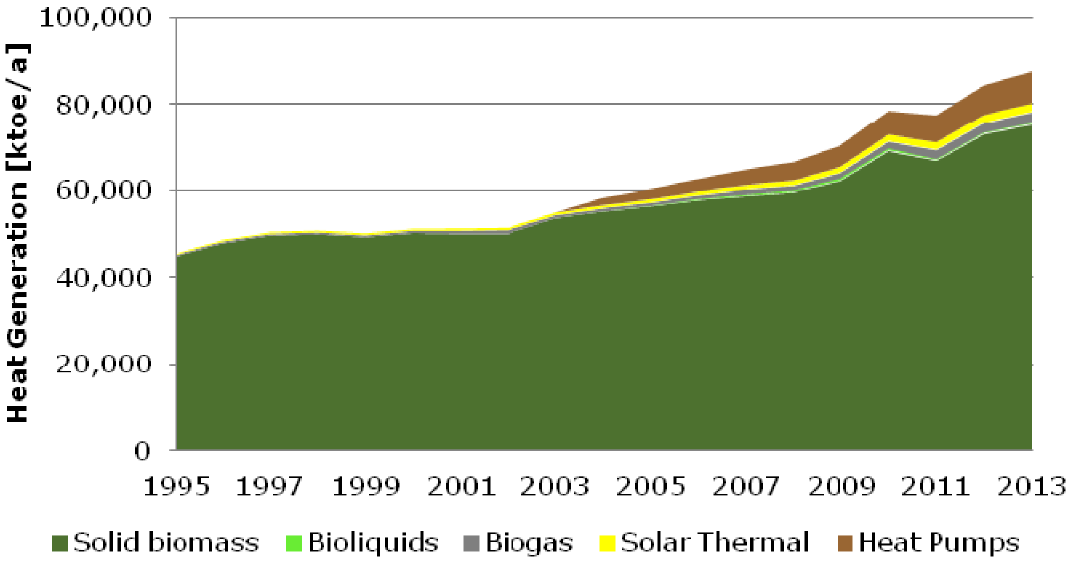


**Figure 8:** **Market development of RET in the heating and cooling sector (EU-28)**

In general, the market development of RET in the heating and cooling sector is characterised by a less rapid development than that of 'new' RES-E technologies, but renewable heat has already. Before the introduction of the RES-Directive (2009/28/EC) in 2009, the focus of RES-support was more on electricity, but support for RES-H&C has been strengthened in recent years.

## 3.3 Transport

Figure 9 shows the development of consumption of RES-E in transport as well as all biofuels, including the portion not compliant with EU sustainability criteria[5] and thus not accountable for the RES share. Market development shows a strong increase in the early 2000's up to 2012. However, a decrease in bioethanol/bio-ETBE and biodiesel consumption could be observed in 2013. This did not apply to that portion of biofuels complying to sustainability criteria, which in that same year showed a slight increase from 11,596 ktoe to 11,932 ktoe. The use of renewable electricity for transport has been initiated in the early 2000s and has been growing continuously, achieving a contribution of 1,196 ktoe ktoe in 2013. The vast majority of this can be attributed to non-road transport modes such as railways.

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[5] Directive 2009/28/EC, Articles 17 and 18

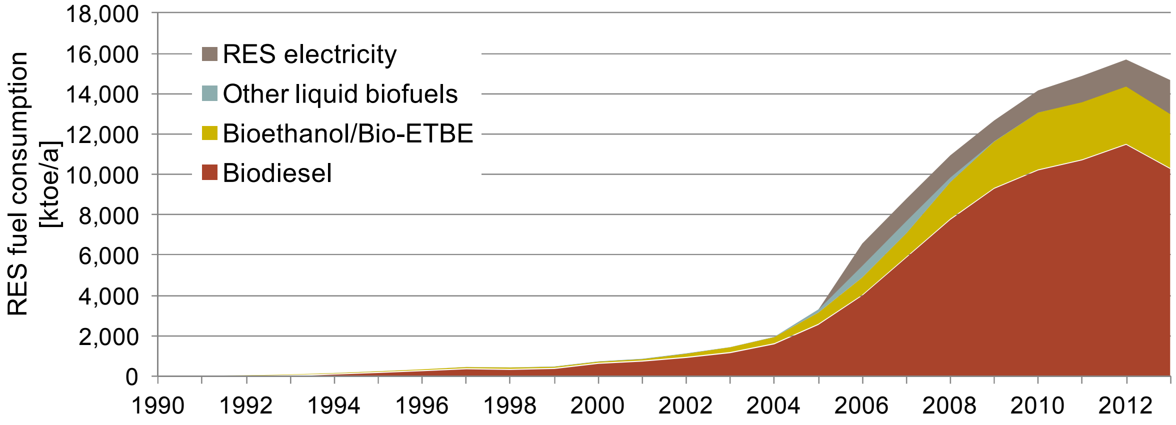


**Figure 9:** Market development of RET in the transport sector (EU-28)

# 4 Monitoring the success of renewable energy support in the EU (All, depending on indicator)

In this chapter we compare and analyse the results of the indicators that have been described in section 2. We calculate the *Policy Effectiveness Indicator* for electricity and the heating & cooling sector, whilst for biofuels we show the share of RES in the transport sector. The *Deployment Status Indicator* is calculated for the electricity as well as heating and cooling sector. The *Electricity Market Preparedness Indicator* is exclusively applied to the electricity sector.

## 4.1 Electricity

In this section we assess the success of RES-support policies by means of the indicator set, described in chapter 2, for the following technologies:

- Wind onshore and offshore power plants;
- Solar photovoltaics (PV);
- (Solid & liquid) biomass power plants;
- Biogas-based power plants;
- Small-scale hydropower plants.

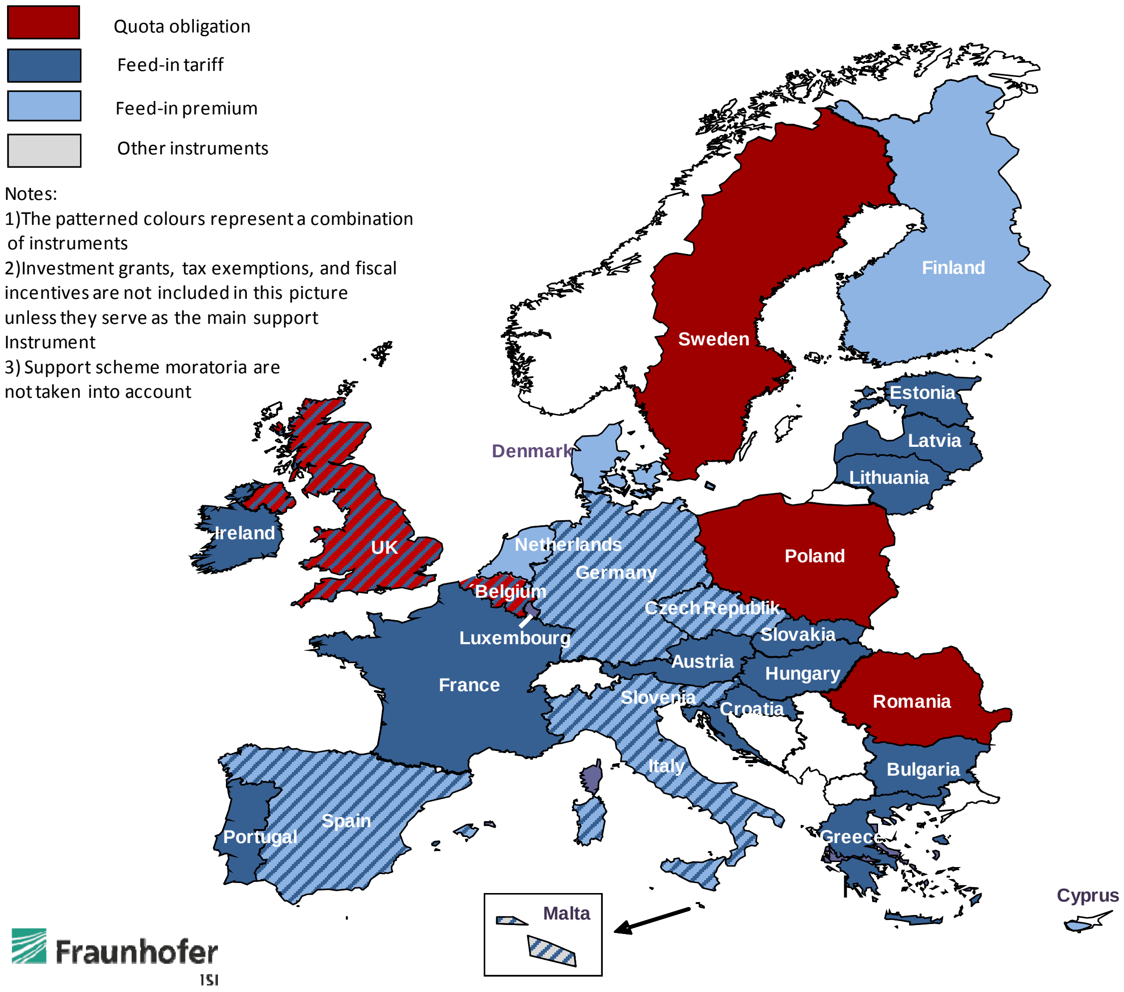
Other technologies have not been assessed either because little market development has taken place so far (geothermal, concentrating solar power) or the existing realisable potential is nearly exploited (large-scale hydropower). The observation period for the *Policy Effectiveness indicator* covers the time horizon from 2011 to 2013 for wind onshore, wind offshore and solar PV, whilst the Policy Effectiveness for the remaining technologies comprises the time horizon between 2010 and 2012.

### 4.1.1 Development of national support measures

In recent years Member States have undertaken considerable changes in their design of national support measures to promote renewable electricity as shown in Figure 11. The dynamic market environment including the quick maturing process of some renewable energy technologies such as Solar PV, the continuously rising share of RES in the electricity system and rising support costs have led to adaptations or even changes of support schemes in several Member States (cf. Figure 11).

Thus, accelerated and partly overheated growth of costly solar PV technologies in Germany, Italy and the Czech Republic have led to changing policy priorities with a stronger focus on policy cost control. Thus, support for Solar PV and other RET (except small-scale hydropower) in the Czech Republic has been abolished as of beginning of 2014, specific support for PV in Italy is no longer paid after the budget of the program “Conto Energia V” has been used up in summer 2013. Several MS including Spain, the Czech Republic and Bulgaria have recently suspended temporarily their support schemes or even abolished it. For example, Spain has replaced the former feed-in system for new and for existing plants by a system that determines the remuneration level based on the principle of a reasonable profitability.

In the context of rising support costs and the increasing relevance of RES in the electricity system, the European Commission (2013) recommends MS to introduce more market-based design elements in national RES support policies. More precisely, the European Commission (2014) requires MS in its State Aid Guidelines to base RES-support mainly on competitive bidding procedures, by foreseeing a continuous replacement of existing RES-support between 2015 and 2017. MS shall use auctions to determine the RES-support level for most of the RES as of 2017. The use of auctions for determining RES-support instead of administratively setting prices has been increasing in the EU in recent years. Thus, the Netherlands and Italy have recently replaced their feed-in system with an auction scheme, and also Portugal, France and Denmark use auctions to set tariffs or premiums for certain technologies. Germany has introduced auctions for large ground-mounted PV power plants.



Notes:
1)The patterned colours represent a combination of instruments
2)Investment grants, tax exemptions, and fiscal incentives are not included in this picture unless they serve as the main support Instrument
3) Support scheme moratoria are not taken into account

**Figure 10: Main support instruments applied in EU28 Member States at the end of 2013**

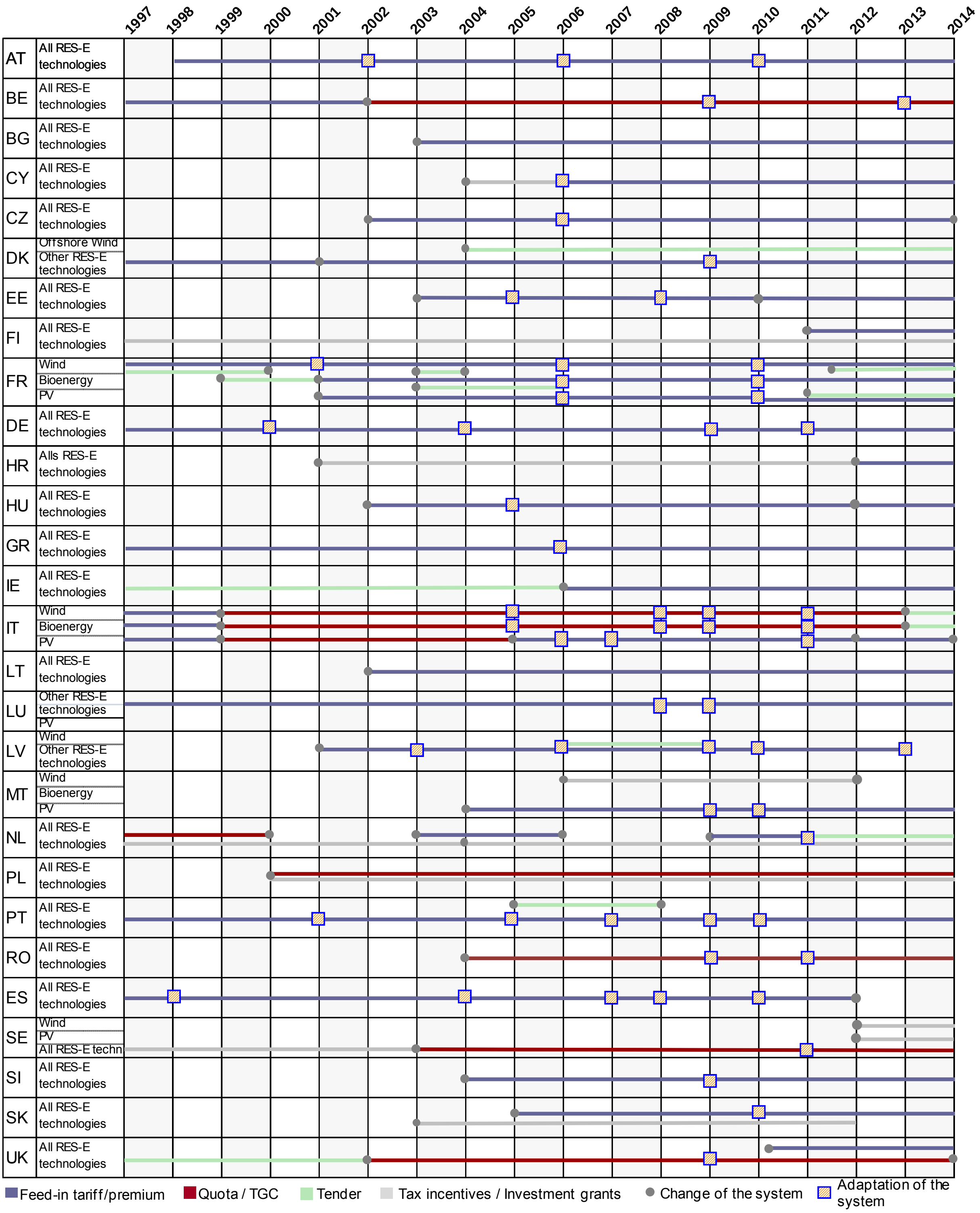


**Figure 11: Evolution of the main support instruments in EU28 Member States**

### 4.1.2 Onshore wind

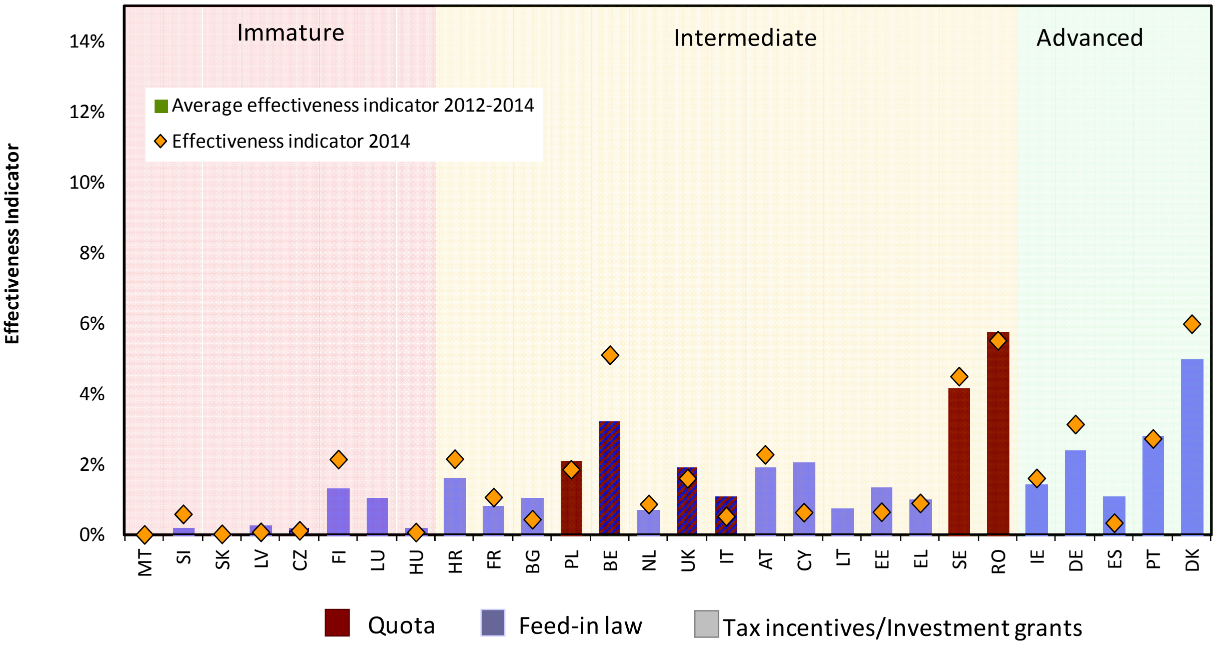


**Figure 12:** Policy Effectiveness Indicator for wind onshore power plants in the period 2012 – 2014. Countries are sorted according to deployment status indicator.

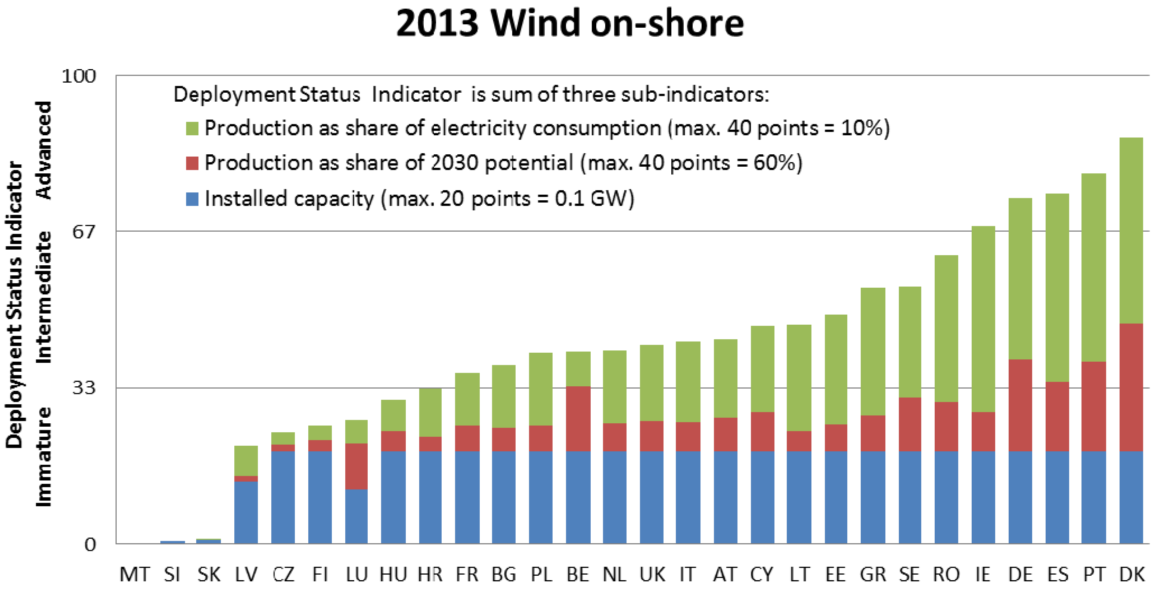


**Figure 13:** Deployment Status Indicator for wind onshore power plants in 2013

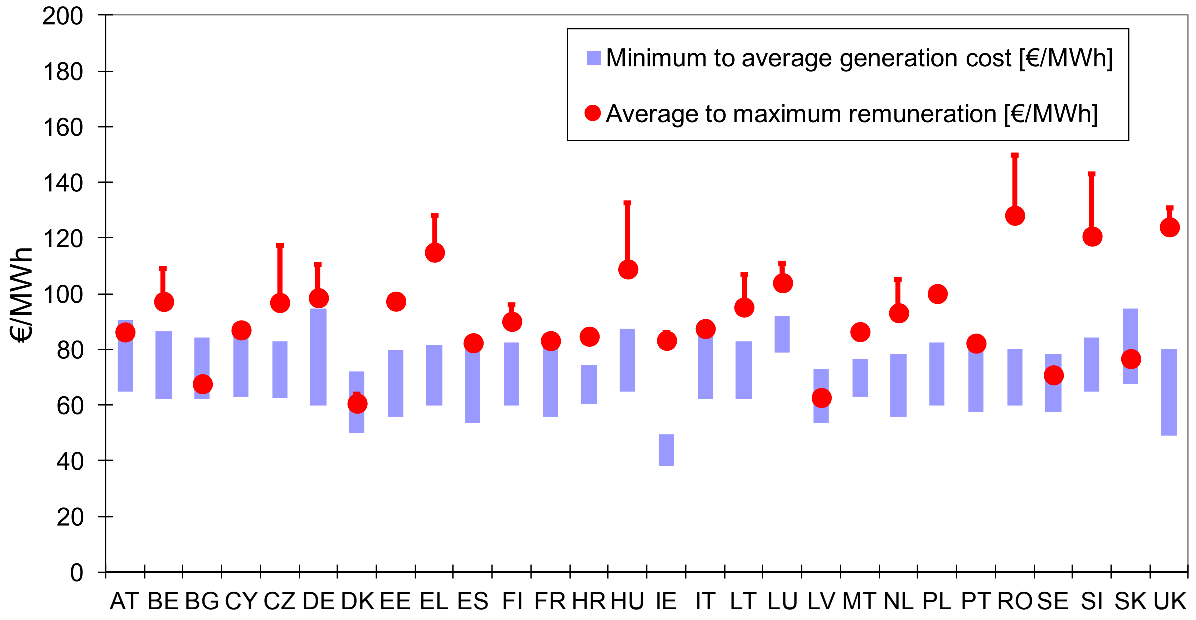


**Figure 14:** **Remuneration ranges (average to maximum remuneration) for Wind Onshore in the EU-28 MS in 2013 (average tariffs are indicative) compared to the long-term marginal generation costs (minimum to average costs)**

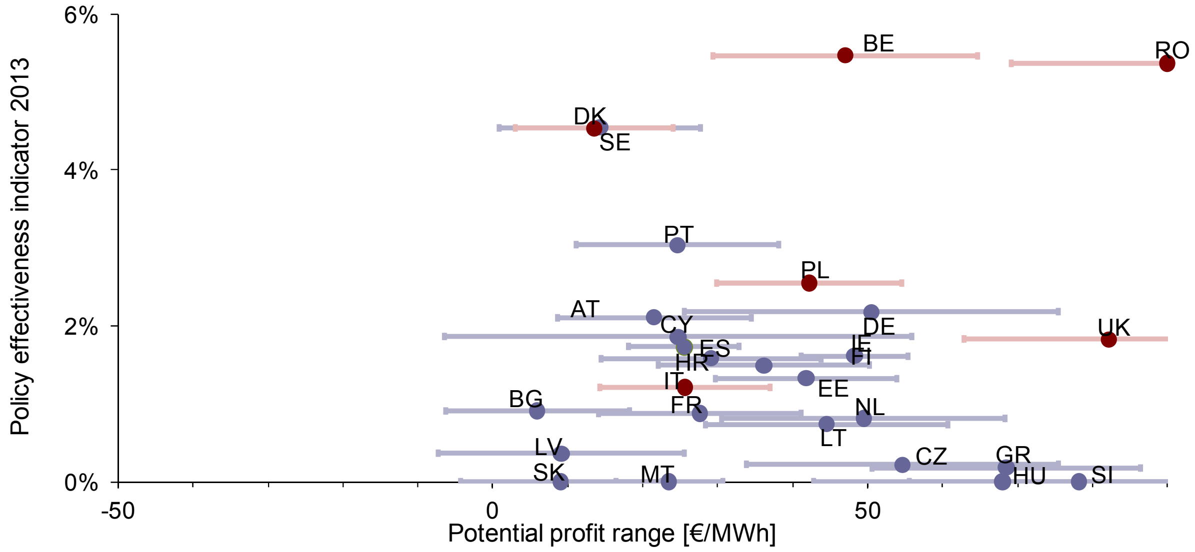


**Figure 15:** **Potential profit ranges (Average to maximum remuneration and minimum to average generation costs) available for investors in 2013 and Policy Effectiveness Indicator for wind onshore in 2013**

#### 4.1.2.1 Policy effectiveness

The average policy effectiveness between 2012 and 2014 shown in Figure 12 shows that some countries with a medium deployment status – labelled by the yellow background area - have been catching up with the forerunner countries – marked by the green background area. The MS with a medium deployment status featuring high effectiveness and the current trend of effectiveness in 2014 even above average levels are Belgium, Romania and Sweden. In contrast, some saturation of more developed markets including Spain and Portugal can be observed. Spain still a positive effectiveness as onshore wind capacities still showed a gross increase of 55GW in 2014 despite the support scheme moratorium and the recent change to substitute the feed-in system with the particularly unattractive new subsidies system. This compares to new onshore wind installations of 170GW in the previous year[6]. The effectiveness of Denmark seems high, as electricity production in 2014 was higher than in the previous year even after normalising for weather fluctuations. However, note that wind power, especially onshore, is currently facing serious public acceptability problems in Denmark, leading to only 68 MW of new installations in 2014, compared to 657 MW in the previous year[7]. Another interesting observation is that MS using quota obligation (BE, RO, SE) have gained momentum compared to MS supporting onshore wind power plants by means of feed-in laws. Onshore wind is one of the lower cost technologies and thus benefits more strongly from technology-neutral quota obligations as implemented in Romania and Sweden than do more costly technologies.

#### 4.1.2.2 Deployment Status

Wind onshore remains the most mature RES-E technology besides hydro; however, a slowdown in deployment is appreciated in the limited changes in the indicator since the latest (2012) update. Five Member States (Denmark, Portugal, Spain, Germany, Ireland) continue to have advanced deployment status and 15 Member States reach the deployment status intermediate. The majority of MS meets (or exceeds) the 100 MW threshold to achieve maximum score in the sub-indicator of installed capacity, with the exception of Luxemburg, Latvia, Slovakia, Slovenia and Malta. Only 8 Member States remain immature with regards to wind onshore deployment.

#### 4.1.2.3 Economic incentives and generation costs

Figure 14 compares the average to maximum remuneration – consisting in the feed-in tariff or in the sum of electricity prices and TGC or feed-in premium and remuneration from investment grants or tax incentives – with the minimum to average generation costs of onshore wind. It reveals that most MS offer sufficiently high remuneration in order to stimulate investment. Whilst the majority of the MS apparently provide an adequate level of remuneration, remuneration levels in the Czech Republic, Greece,

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[6] EurObserv'ER Wind Energy Barometers 2014 and 2015.
[7] EurObserv'ER Wind Energy Barometers 2014 and 2015.

Hungary, Romania, Slovenia and the UK allow for considerable windfall profits. Only support in Bulgaria covers only the lower cost-options of the existing onshore wind potential.

#### *4.1.2.4 Profitability of renewable investments in relation to the policy effectiveness*

Figure 14 illustrates the combination of the expected profit from an investment in wind onshore power plants and the Policy Effectiveness Indicator for the year 2013. Belgium and Romania clearly show the highest effectiveness in 2013, combined with rather high profit levels. In terms of effectiveness, Belgium and Romania are followed by Denmark and Sweden with only moderate and even low profit levels. In the United Kingdom, a high profit level available could not be transformed into high policy effectiveness.

### 4.1.3 Offshore wind

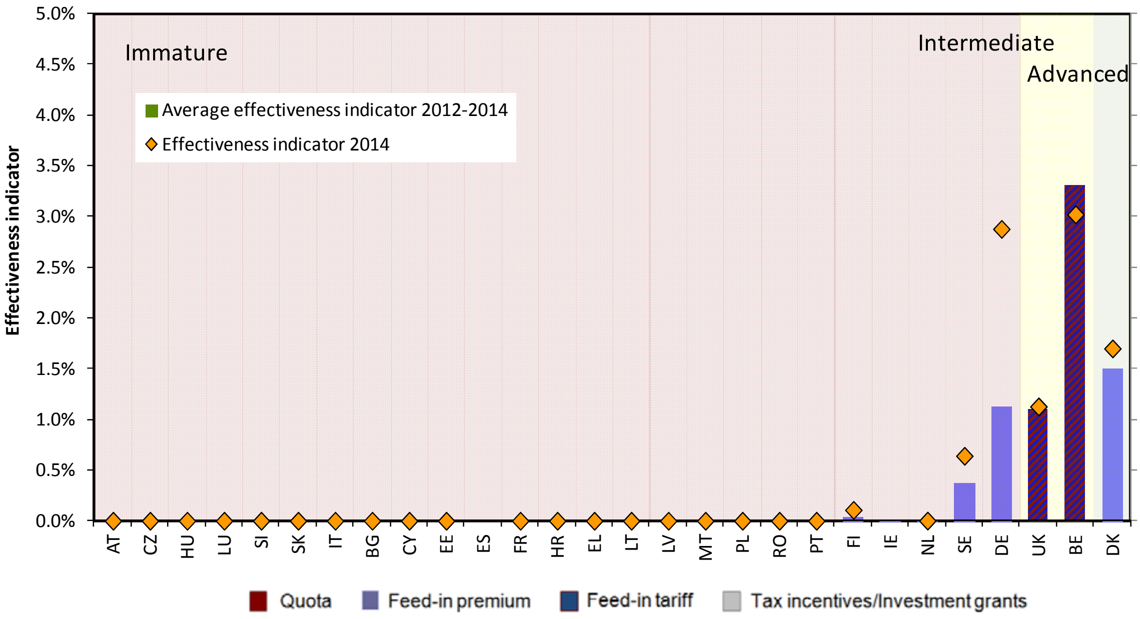


**Figure 16: Policy Effectiveness Indicator for wind offshore power plants in the period 2012 – 2014**

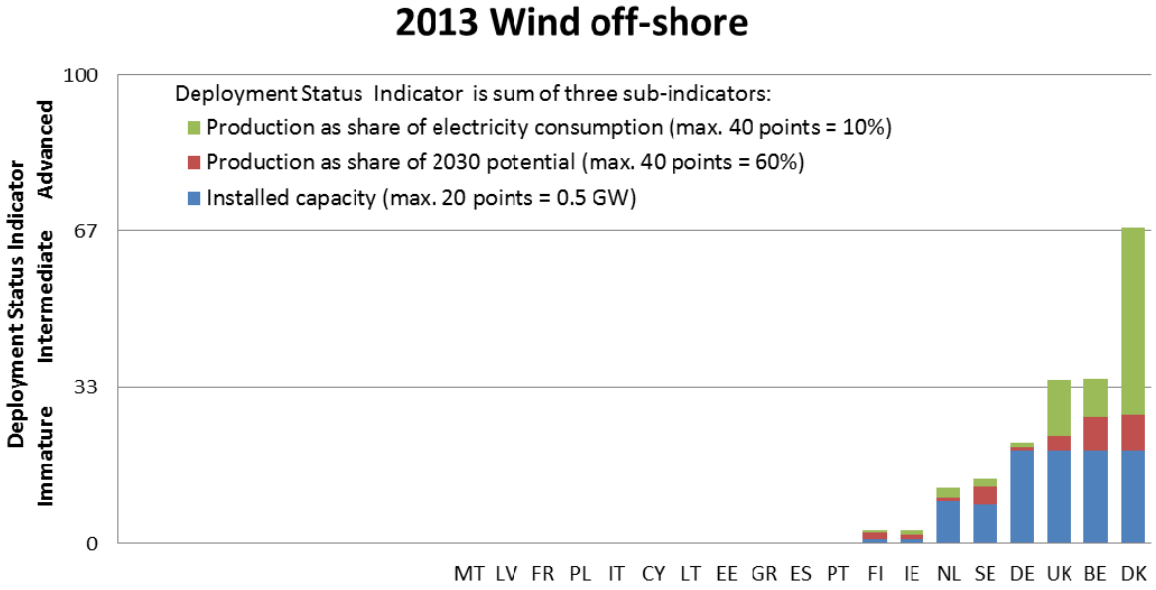


Figure 17: Deployment Status Indicator for wind offshore power plants in 2013

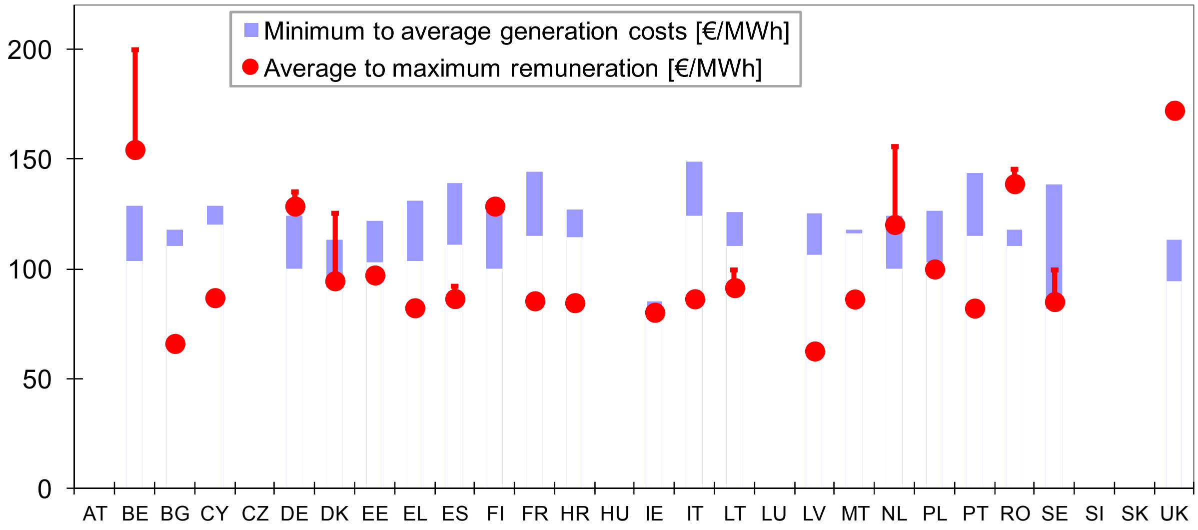


Figure 18: Remuneration ranges (average to maximum remuneration) for Wind Offshore in the EU-28 MS in 2013 (average tariffs are indicative) compared to the long-term marginal generation costs (minimum to average costs)

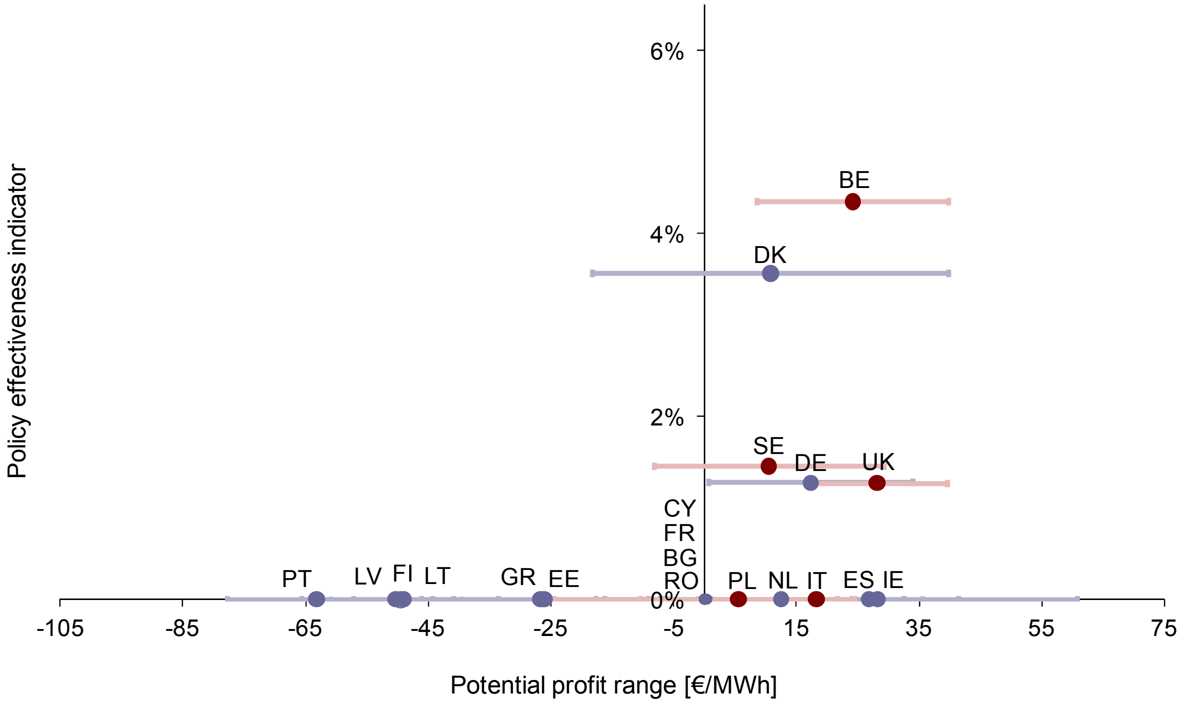


**Figure 19:** Potential profit ranges (Average to maximum remuneration and minimum to average generation costs) available for investors in 2013 and Policy Effectiveness Indicator for wind offshore in 2013

#### *4.1.3.1 Policy effectiveness*

Offshore wind development has been accelerating in recent years, almost doubling its installed capacity from 4.7 GW in 2012 to 9.2 GW in 2014. However, offshore wind development remains restricted to a few EU MS including the United Kingdom, Germany, Denmark, Belgium, the Netherlands, Sweden, Finland, Ireland, Spain, and Portugal. Although the United Kingdom is the top EU country in terms of installed offshore wind capacity amounting to 4.4 GW at the end of 2014, it is not a leading performer in terms of policy effectiveness. The reason for this is the abundant potential for offshore wind in the United Kingdom. After previous delays, German policies showed good results in 2014, as indicated by the steep increase of 0.9 GW installed capacity in 2013 to 2.3 GW in 2014. Denmark comes in third in terms of installed capacities, with 1.2 GW installed by 2014. Belgium also performs very well in the policy effectiveness indicator, as its comparatively small installed capacities (0.7 GW at the end of 2014) match the country’s limited offshore wind potential. In other EU MS there is little development in the area of offshore wind energy.

#### *4.1.3.2 Deployment Status*

The deployment status is still immature in most EU Member States with identified wind-offshore potential. Only 4 Member States have installed more than 500MW of capacity

(Denmark, Belgium, UK and Germany). Denmark is the only market that has reached advanced deployment status, with wind-offshore electricity already accounting for 10.1% of total electricity consumption. Germany, United Kingdom and Belgium have achieved significant increases in their deployment status compared to the last (2012) update of the indicator, and United Kingdom and Belgium have reached intermediate deployment status. 10 EU Member States have no off-shore capacity installed despite of available potentials.

#### *4.1.3.3 Economic incentives and generation costs*

Electricity generation costs of diverge considerably between and inside the MS due to differences in water depth, the distance to coast and by the local wind conditions. Offshore electricity generation cost data are characterised by higher uncertainties than onshore wind as less experience with commercial wind offshore installations is available.

Belgium, Romania and the United Kingdom apparently provide a support level which leads to remuneration clearly above average electricity generation costs. Remuneration in Germany, France, Denmark and the Netherlands also seems high enough to stimulate growth. In countries such as Sweden, Ireland and Poland the support granted for wind offshore appears to be sufficient for the lower cost potentials. In contrast, the support level available for wind offshore in most other countries is clearly below the economic requirements of the technology and the respective locations. This is mainly due to the fact that most MS disposing of a favourable offshore wind potential do not aim to stimulate development of the costly technology. Thus, in many of these countries offshore wind receives similar support as onshore wind leading to insufficient support levels to trigger investment.

#### *4.1.3.4 Profitability of renewable investments in relation to the policy effectiveness*

The comparison of profit ranges with policy effectiveness in 2013 shown in Figure 19 reveals that policy support was most effective in Belgium, Denmark, Sweden, Germany and the United Kingdom offering similar profit levels. Only in Denmark the range of the profit level is rather broad, whilst the Swedish support appears to cover only the lower cost range of the existing potential. Thus, one wind farm with comparatively low generation costs started operation in September 2013 in Sweden. The EON-owned Kårehamn with 48 MW of total capacity is located closed to the coast – only about 5 km of distance – and water depth are moderate, amounting to 6-20 m. The proximity to the coastline and the low tide imply comparatively low investments due to favourable conditions regarding logistics, foundation of the turbine and grid connection, involving an investment of roughly 2,500 €/kW (EON Climate & Renewables 2011). Assuming an annual utilisation of roughly 3600 hours per year and an interest rate of 7%, we estimate the average generation costs of the Kårehamn wind park to 82 €/MWh. It should be noted that support from the Swedisch quota system cannot cover costs of wind parks with longer distances to shore and higher water depths.

### 4.1.4 Solar photovoltaics

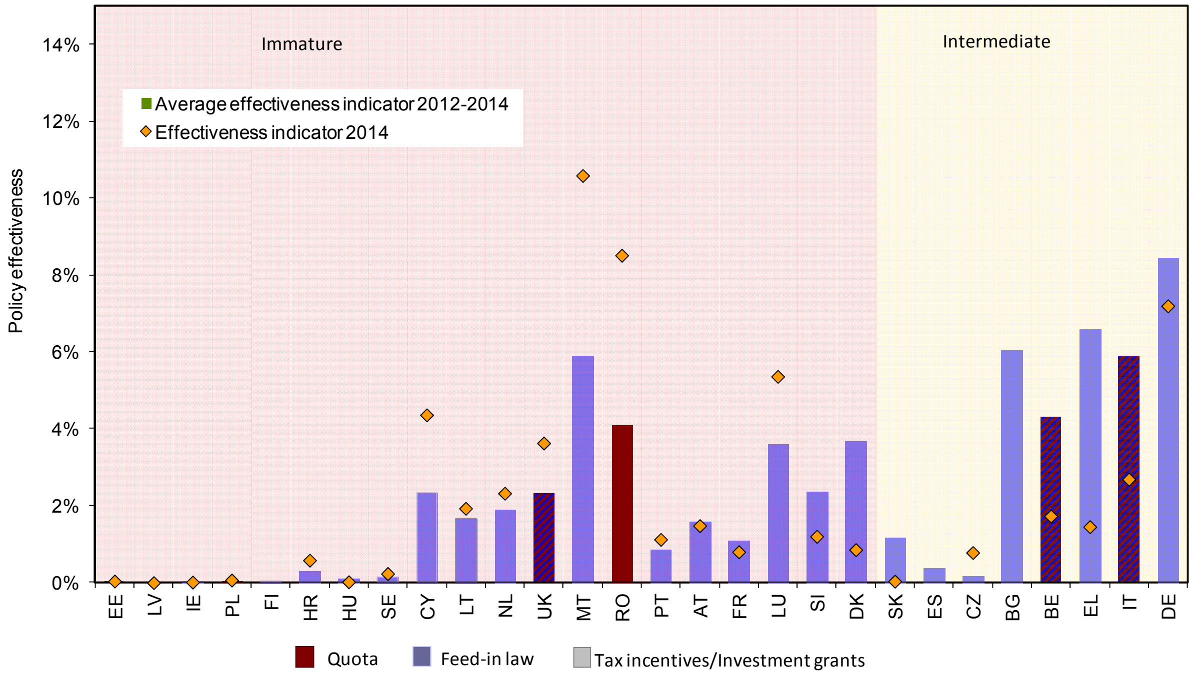


Figure 20: Policy Effectiveness Indicator for Solar PV power plants in the period 2012 – 2014

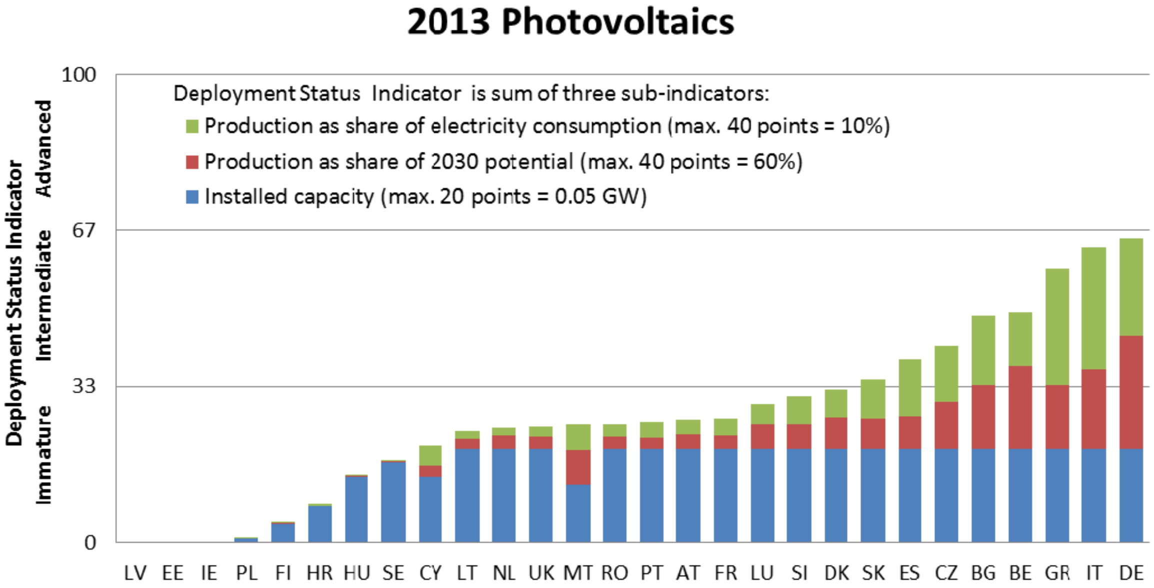


Figure 21: Deployment Status Indicator for Solar PV power plants in 2013

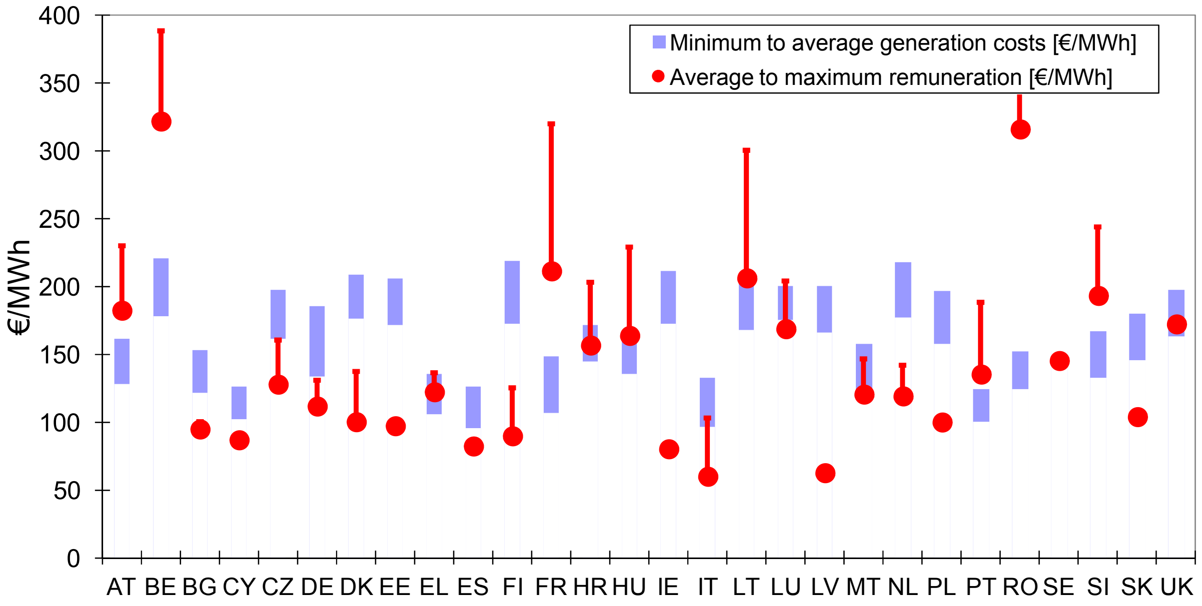


**Figure 22:** Remuneration ranges (average to maximum remuneration) for Solar PV in the EU-28 MS in 2013 (average tariffs are indicative) compared to the long-term marginal generation costs (minimum to average costs)

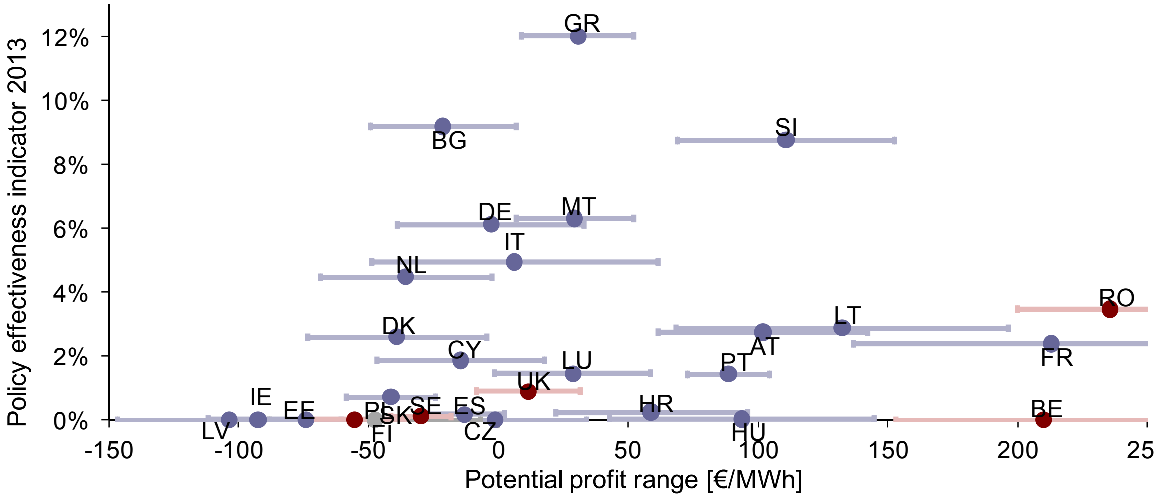


**Figure 23:** Potential profit ranges (Average to maximum remuneration and minimum to average generation costs) available for investors in 2013 and Policy Effectiveness Indicator for Solar PV in 2013

#### *4.1.4.1 Policy effectiveness*

As shown in Figure 20, high policy effectiveness could generally be observed for PV in the years from 2012 to 2014, especially in those countries with medium deployment status (yellow background area). This was due to rapid capacity increases as prices for PV installations dropped faster than support levels could follow. In response, Member States with large PV markets severely reduced support levels in order to slow down growth, leading to relatively lower effectiveness indicator values in 2014. In Spain and the Czech Republic, capacity additions already peaked in 2009 and 2011, respectively. Effectiveness has since been low due to subsidy cuts.

#### *4.1.4.2 Deployment Status*

Deployment of photovoltaic technologies in Europe has been very significant in the last 5 to 10 years; however, while some markets show steady progress, others have slowed down or virtually stopped deployment in the last years, mostly as a result of reductions in policy support. The levels of PV production in 2013 as a fraction of potentials in 2030 remain very low for most Member States, revealing the enormous untapped mid-term potential of PV technology in Europe. 8 Member States have reached intermediate deployment status. These Member States are Slovakia, Spain, Czech Republic, Bulgaria, Belgium, Greece, Italy and Germany. Similarly, 18 Member States have already surpassed the 50 MW threshold to obtain the maximum score on the sub-indicator on installed capacity.

#### *4.1.4.3 Economic incentives and generation costs*

The comparison of economic incentives and generation costs of Solar PV electricity in European MS illustrated in Figure 22 clearly indicates strong differences in support levels and generation costs. Since Solar PV development in recent years was characterised by high support costs and a strong dynamic development in some MS, support has considerably been decreased or even abolished, as happened in Spain Czech Republic and Latvia. Whilst Germany had implemented important downward revisions for its PV tariffs, support for Solar PV in Italy has come to an end after the exhaustion of the budget (€ 6 billion) foreseen for PV support in the context of the Conto Energia V programm in summer 2013. Figure 22 also shows that some MS still have problems with adapting tariffs or banding coefficients to the highly dynamic cost development of Solar PV. Thus, Belgium, France, Malta, Luxembourg, Portugal, Romania and Slovenia still offered support levels far above average generation costs allowing therefore considerable windfall profits. In contrast, a number of countries including Bulgaria, Cyprus, Denmark, Estonia, Spain, Finland, Croatia, Ireland, the Netherlands, Poland and Slovakia provide insufficient or even no support to make Solar PV projects in these countries profitable. Only some of these countries are characterised by less favourable resource conditions and renewable potentials.

#### *4.1.4.4 Profitability of renewable investments in relation to the policy effectiveness*

Comparing the potential profit range of investments in Solar PV power plants to the policy effectiveness for the year 2013 in Figure 23, it becomes clear that the highest effectiveness in 2013 has been achieved in Greece, Bulgaria, Slovenia and Slovakia. Except for the Slovenia the good performance in terms of policy effectiveness were possible at comparatively moderate profit levels. Germany and Bulgaria achieved good effectiveness with almost or partly negative profit levels, whilst policy effectiveness war much lower in France, Austria and Portugal despite the considerably higher profit level. Spain and the Czech Republic show very low effectiveness with practically no new installation in 2013 after the boom years and the introduced policy changes.

### 4.1.5 Solid & liquid biomass

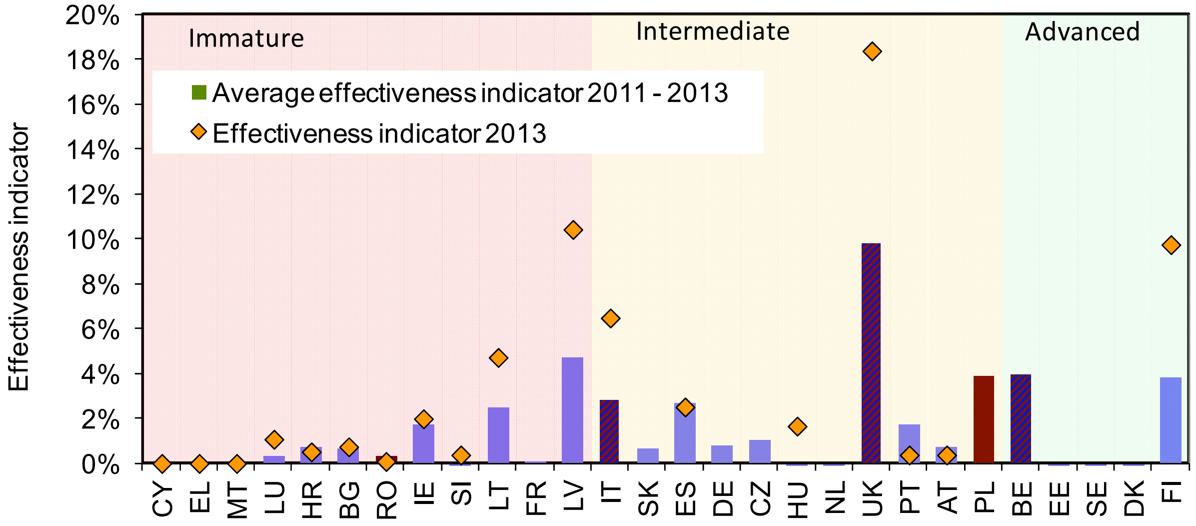


**Figure 24: Policy Effectiveness Indicator for (solid & liquid) biomass in the period 2011 – 2013**

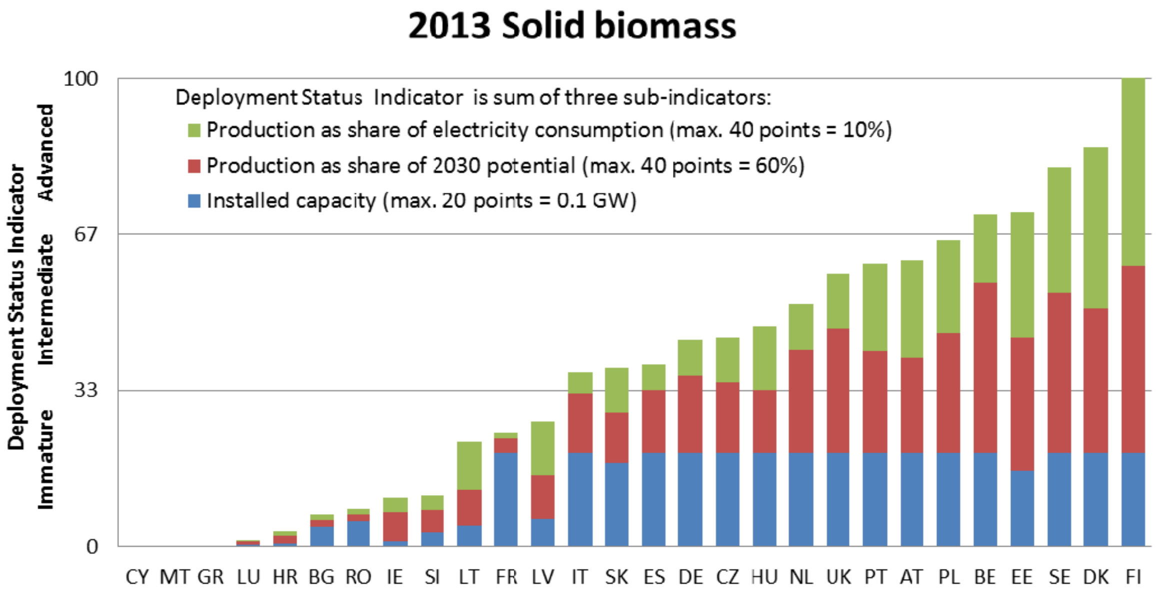


**Figure 25: Deployment Status Indicator for Solid Biomass in 2013**

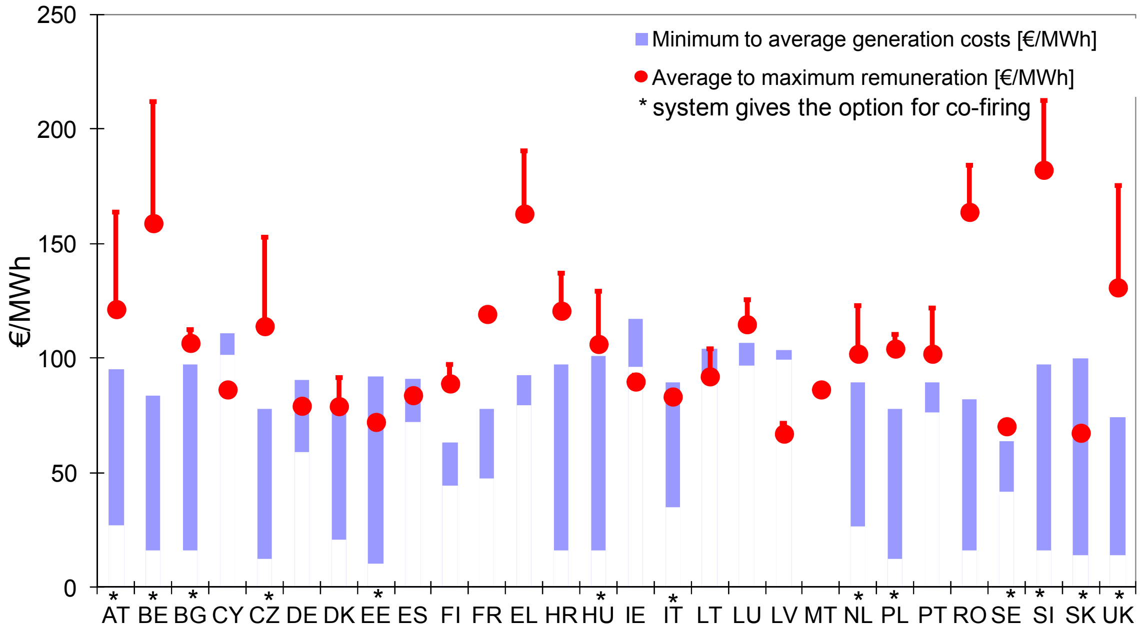


**Figure 26:** **Remuneration ranges (average to maximum remuneration) for biomass CHP-power plants in the EU-28 MS in 2013 (average tariffs are indicative) compared to the long-term marginal generation costs (minimum to average costs). Note that support levels for CZ are from 2013, before support was effectively suspended temporarily**

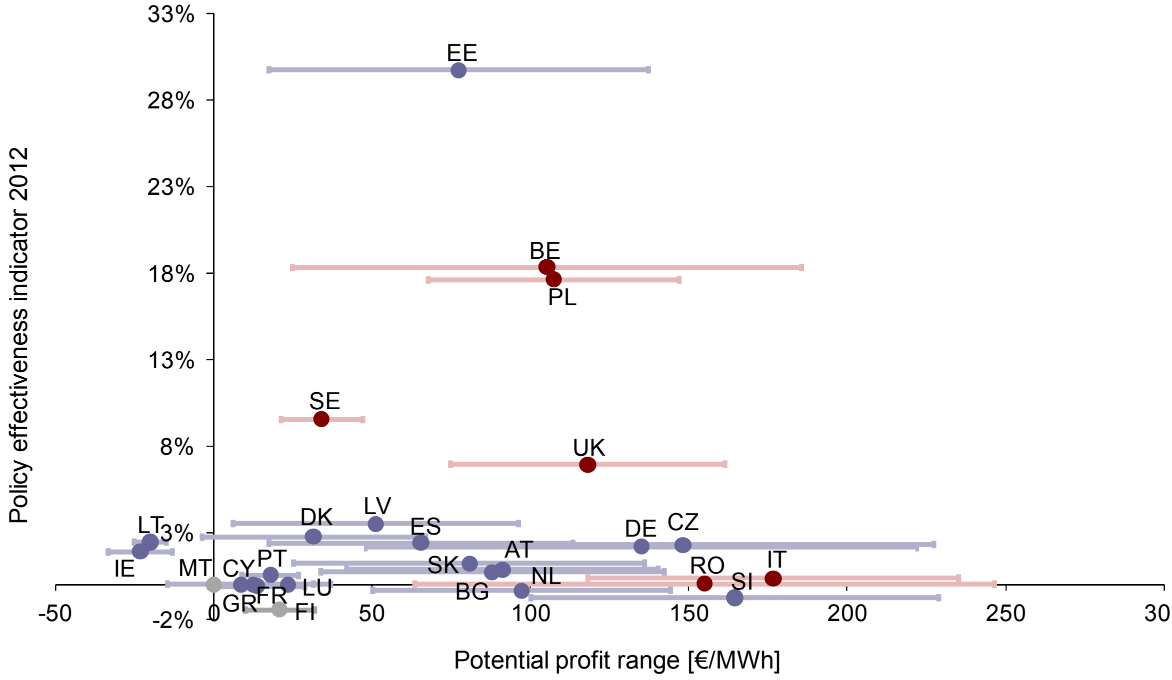


**Figure 27:** **Potential profit ranges (Average to maximum support and minimum to average generation costs) available to investors in 2013 and Policy Effectiveness Indicator (high import scenario) for biomass-based CHP-plants in 2012.**

#### 4.1.5.1 Policy effectiveness

Electricity production from biomass has decreased between 2012-2013 in a number of countries, including France, Slovakia, Germany, the Czech Republic, the Netherlands, Poland, Belgium, Sweden, Denmark, and Estonia. The highest policy effectiveness could be observed in the UK, where biomass electricity generation increased by 50% between 2012 and 2013. Compared to the target set for biomass electricity in their NREAPs, Estonia and Finland already exceeded their foreseen biomass electricity generation for 2020 at the end of 2012.

#### 4.1.5.2 Deployment Status

Solid biomass is a very heterogeneous category as it comprises different technologies (pure biomass plants and co-firing) and both domestic and imported biomass. This limits comparability between countries: co-firing in existing fossil fuel plants is by definition a more advanced market than the use of pure biomass power plants; the exploitation of domestic biomass resources is not as meaningful as for other RES, as it does not reflect biomass imports and exports. Despite these limitations, some general conclusions about this technology can be drawn. Figure 25 shows the deployment status of the solid biomass technology mix. 15 Member States reach intermediate development or higher, of which 6 Member States have advanced deployment status. These are Estonia, Finland, Denmark, Sweden, Belgium and Poland. These countries have also achieved high levels of production as a fraction of their mid-term (2030) potential.

Solid biomass is a very heterogeneous category as it comprises different technologies (pure biomass plants and co-firing) and both domestic and imported biomass. This limits comparability between countries: co-firing in existing fossil fuel plants is by definition a more advanced market than the use of pure biomass power plants; the exploitation of domestic biomass resources is not as meaningful as for other RES, as it does not reflect biomass imports and exports. Despite these limitations, some general conclusions about this technology can be drawn. Figure 25 shows the deployment status of the solid biomass technology mix. 16 Member States have reached intermediate development or higher, of which 5 Member States have advanced deployment status. These are Belgium, Estonia, Sweden, Denmark and Finland. Three EU Member States have no installed capacity.

#### 4.1.5.3 Economic incentives and generation costs

Figure 26 depicts the remuneration ranges and the generation costs of biomass electricity generation in combined heat and power (CHP) plants using wood residues as fuel input. It becomes clear that generation costs vary considerably, in particular in case MS provide renewables support for cost-efficient biomass cofiring in conventional power plants (MS are marked with an asterisk: Austria, Belgium, Bulgaria, the Czech Republic, Estonia, Hungary, Italy, the Netherlands, Poland, Romania, Slovenia, Slovakia, and the UK). In addition, generation costs of biomass electricity may vary strongly depending on the plant size. In general, Figure 26 indicates that the remuneration level for biomass electricity is clearly above generation costs in some MS. Account should be taken that generation costs are shown for the lower cost biomass technology options using CHP-plants and wood residues, but that support levels may be available also for more cost-intensive biomass power plants.

#### *4.1.5.4 Profitability of renewable investments in relation to the policy effectiveness*

The comparison of effectiveness with potential profits shown in Figure 27 reveals that Estonia achieved the highest effectiveness in 2012, while offering profits in a similar range to the other countries. Generally, many countries, especially Austria, Belgium, the Czech Republic, Romania, Slovenia and the United Kingdom show broad-ranging support levels, depending on the type of biomass used or on the conversion technology. Consequently, the profit levels shown may appear high. In reality, higher tariffs may only be applicable to certain fuels or technologies which also have higher costs. Similar to the case of wind onshore (see Figure 12) shows that a high profit level does not necessarily lead to high policy effectiveness (e.g. in Romania and Italy).

### 4.1.6 Biogas

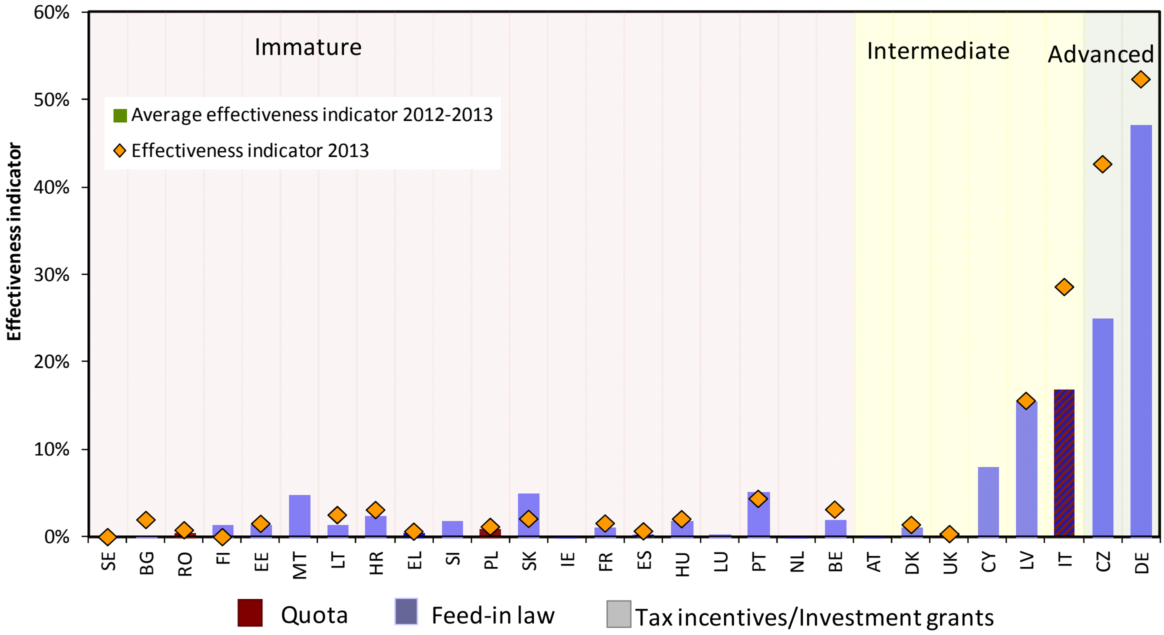


**Figure 28: Policy Effectiveness Indicator for biogas power plants in the period 2012 – 2013**

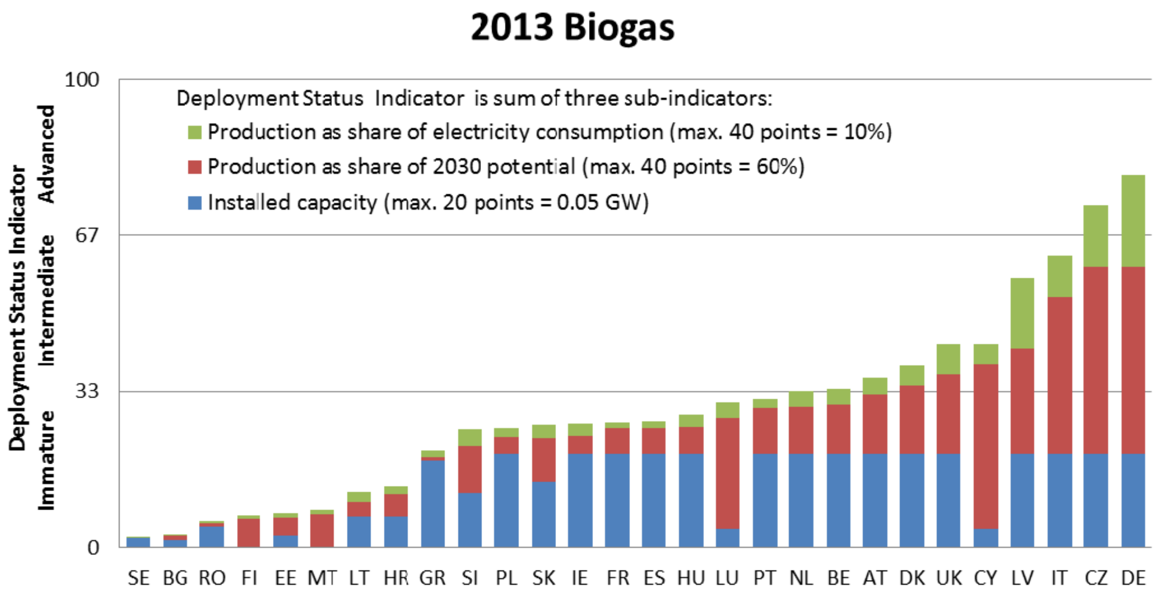


Figure 29: Deployment Status Indicator for biogas power plants in 2013

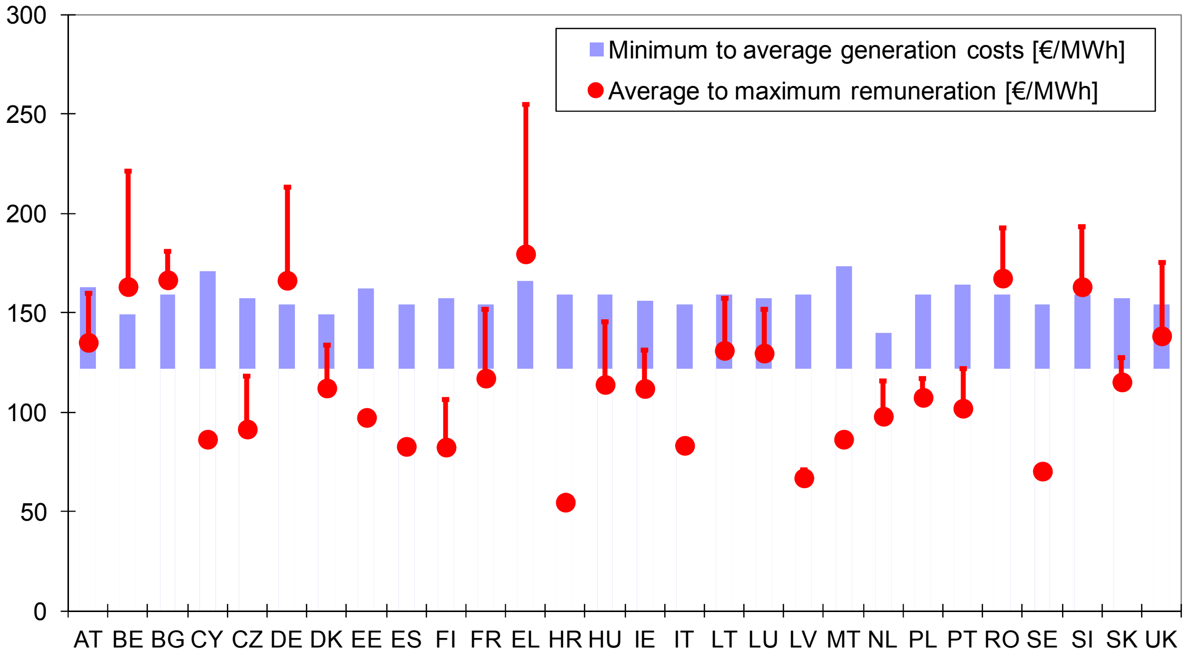


Figure 30: Remuneration ranges (average to maximum remuneration) for agricultural biogas power plants in the EU-28 MS in 2013 (average tariffs are indicative) compared to the long-term marginal generation costs (minimum to average costs). Note that support levels for CZ are from 2013, before support was effectively suspended temporarily

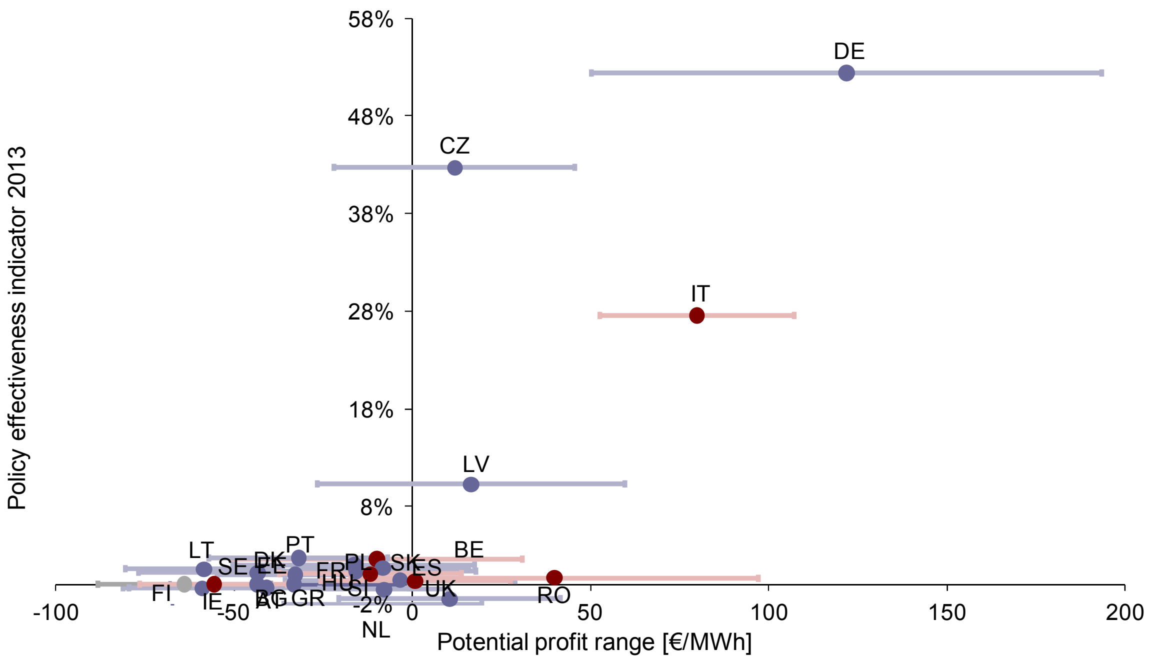


**Figure 31:** **Potential profit ranges (Average to maximum support and minimum to average generation costs) available to investors in 2013 and Policy Effectiveness Indicator (high import scenario) for biogas-based power plants in 2013.**

#### *4.1.6.1 Policy effectiveness*

Figure 28 presents the effectiveness indicator for biogas for the period from 2011 to 2013. The technologies considered include agricultural biogas resulting from anaerobic digestion of organic matter or animal waste, sewage gas and landfill gas. Germany shows the highest policy effectiveness by far on average from 2011 to 2013. Germany is also the biggest producer in absolute numbers with 29 TWh in 2013, more than all other Member States combined. This high deployment value accounts for almost 95% of the estimated 2030 potential. Apart from Germany, the Czech Republic, Latvia, Cyprus and Italy - all countries with advanced or intermediate market development status – show high average policy effectiveness from 2011 to 2013. Policy effectiveness between 2011-2013 has also been high in Cyprus, a country with a comparatively low potential. However, this is due to particularly high effectiveness in 2011, after which there has been a slight decrease in biogas electricity production.

#### *4.1.6.2 Deployment Status*

Figure 29 shows the deployment status of biogas. Most Member States remain in an immature stage of deployment. 8 Member States have reached intermediate deployment status (The Netherlands, Belgium, Austria, Denmark, United Kingdom, Cyprus, Latvia and Italy). Germany and Czech Republic are the most advanced countries with shares over total electricity consumption of 4.9% and 3.3 % respectively. Germany is already exploiting 94% of its mid-term (2030) potential. 16 Member States have passed the 50

MW threshold to obtain the maximum score in the sub-indicator of installed capacity. Luxembourg and Cyprus have very low installed capacities, but they already exploit very significant fractions of their domestic mid-term potentials.

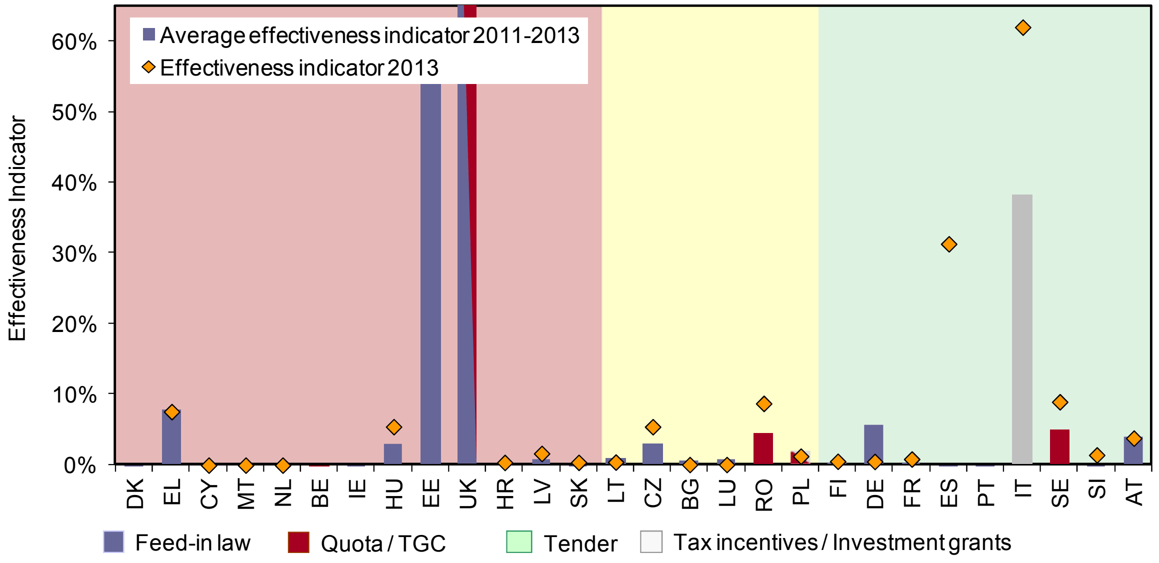
#### *4.1.6.3 Economic incentives and generation costs*

Support levels provided for biogas installations are heterogeneous in the different MS and are insufficient to cover costs in a number of countries (see Figure 30). The graph above is based on support levels for biogas-produced electricity. What is not shown here, however, is whether biogas electricity producers are able to sell the produced heat as well. With the additional revenues from heat, a biomass plant may well become profitable, even if the graph above shows a remuneration level below cost. High remuneration levels are offered by Belgium, Bulgaria, Germany, Greece and Romania. Austria, France, Hungary, Lithuania, Luxembourg, Slovenia and the United Kingdom provide a suitable remuneration considering cost levels. In the other member states, support is just enough to cover the lower cost potentials, or below the profitable range.

#### *4.1.6.4 Profitability of renewable investments in relation to the policy effectiveness*

As shown in Figure 31 comparatively high profits enabled by the German 'Renewable Energy Law' apparently lead to high policy effectiveness in 2013. The Czech Republic, follows with slightly lower policy effectiveness, but also much lower profit levels. Most other MS offer low profits, resulting in low effectiveness as can be expected.

### **4.1.7 Small-scale hydropower**



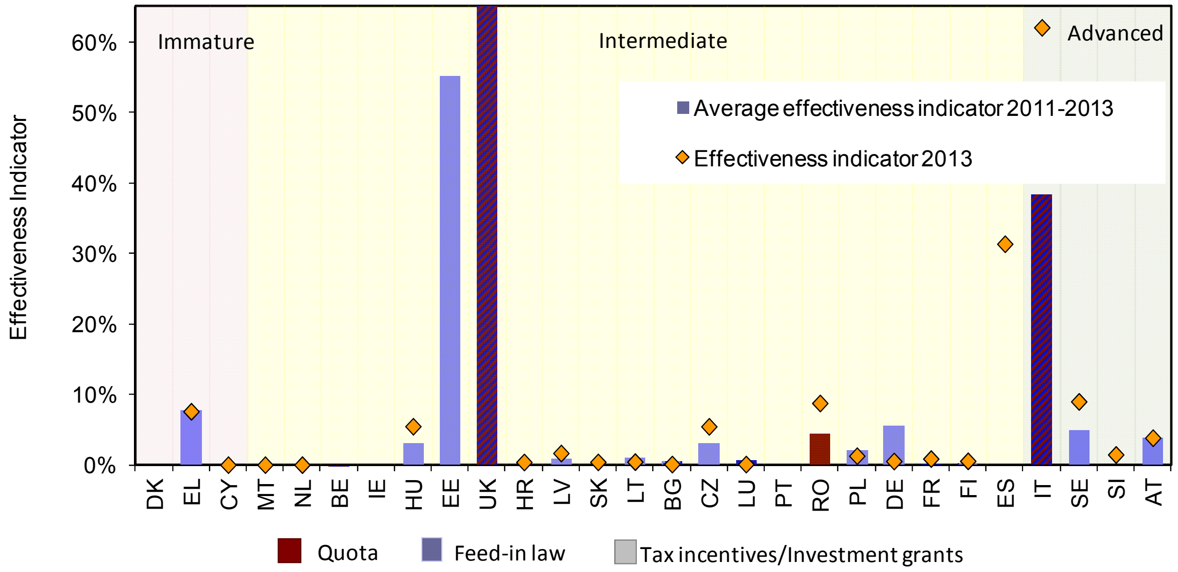


Figure 32: Policy Effectiveness Indicator for small-scale hydropower plants in the period 2011 – 2013

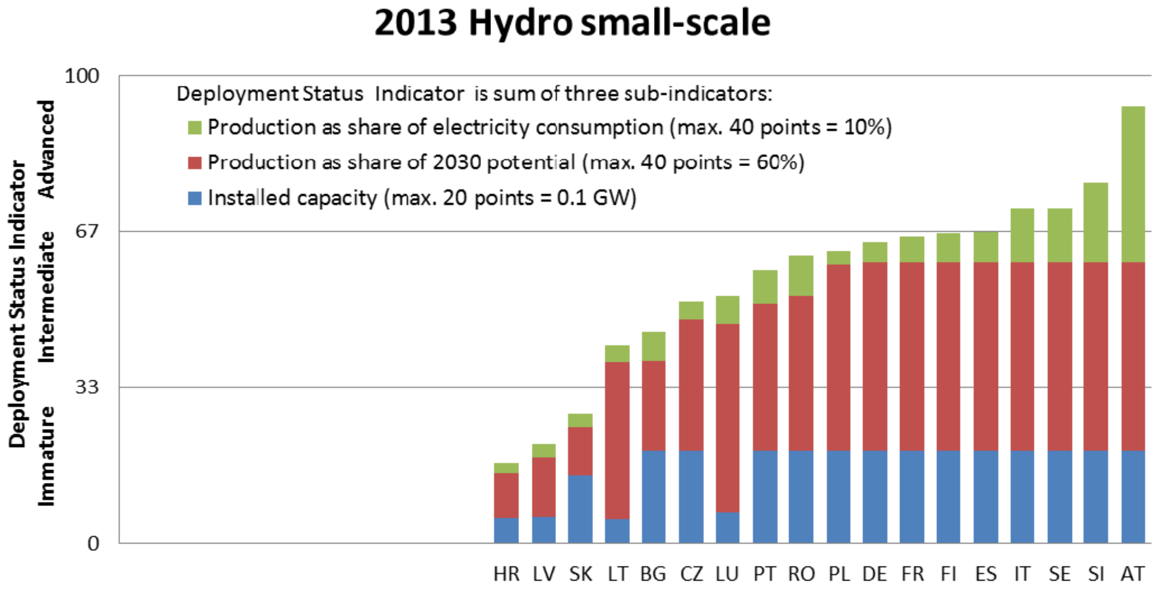


Figure 33: Deployment Status Indicator for small-scale hydropower in 2013

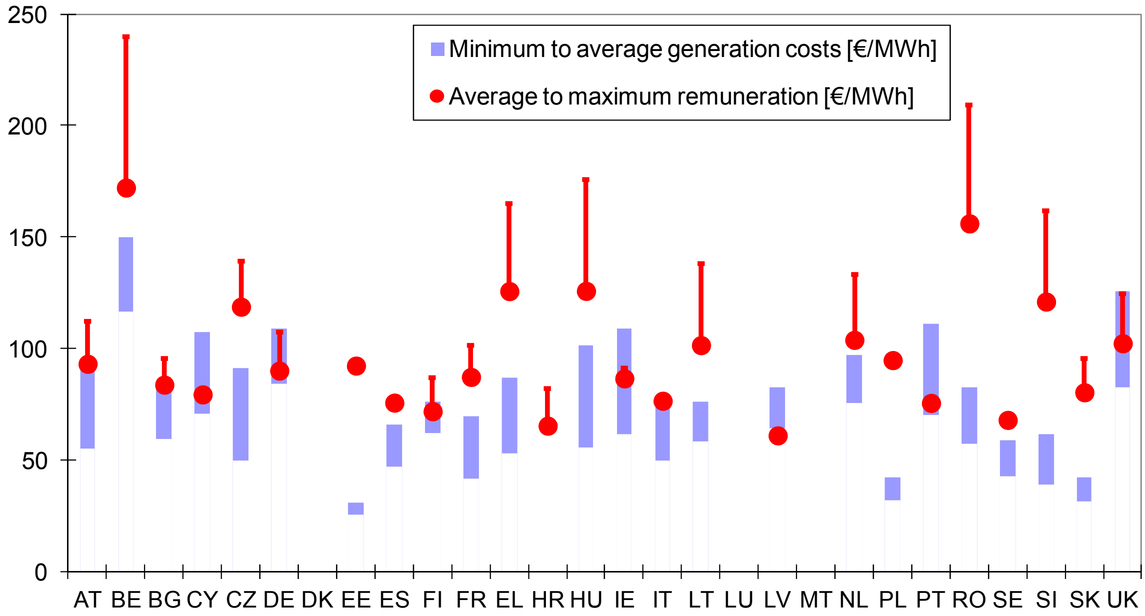


**Figure 34:** Remuneration ranges (average to maximum remuneration) for small-scale hydropower plants in the EU-28 MS in 2013 (average tariffs are indicative) compared to the long-term marginal generation costs (minimum to average costs).

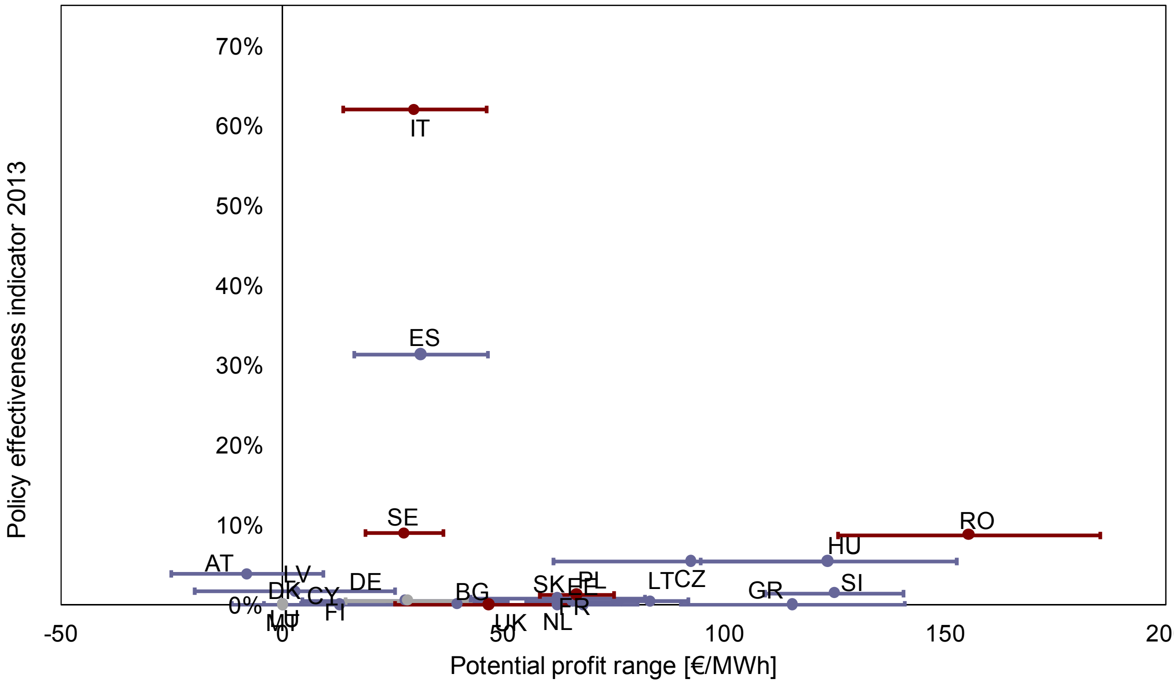


**Figure 35** Potential profit ranges (Average to maximum support and minimum to average generation costs) available to investors in 2013 and Policy Effectiveness Indicator (high import scenario) for small-scale hydropower plants in 2013.

#### 4.1.7.1 Policy effectiveness

In most European MS the additional available potential for the exploitation of hydropower plants with a capacity of up to 10 MW is limited. Thus, total capacity increased by only 2% between 2012 and 2013 from 13.2 GW to 13.5 GW. The UK and Estonia have already achieved their estimated 2030 potentials.

Italy, leading MS in terms of total capacity of small-scale hydropower plants, shows the highest average effectiveness due to several new hydropower installations between 2011 and 2013. The limited additional exploitation potential leads to the high effectiveness value. Additional capacity installed in Italy between 2012 and 2013 amounted to roughly 130 MW.

#### 4.1.7.2 Deployment Status

Figure 33 shows the deployment status of small-scale hydro. The available potential for small-scale hydro is very limited. 10 Member States have very low potential, i.e. lower than 1% of the electricity consumption, and are therefore not shown in the chart. Most Member States with small-scale hydro potential are already exploiting a substantial part of it. With the exception of Latvia, Slovakia and Croatia, the rest of the Member States have achieved at least intermediate deployment status and already exploit more than 25% of their mid-term (2030) potential.

#### 4.1.7.3 Economic incentives and generation costs

In case of small-scale hydropower or hydropower plants with a capacity below 10 MW the country-specific costs as well as support levels show very large differences (see Figure 34). The support level appears to exceed electricity generation costs of small-scale hydropower plants in Belgium, the Czech Republic, Hungary, Greece, Romania, Slovenia and Slovakia.

#### 4.1.7.4 Profitability of renewable investments in relation to the policy effectiveness

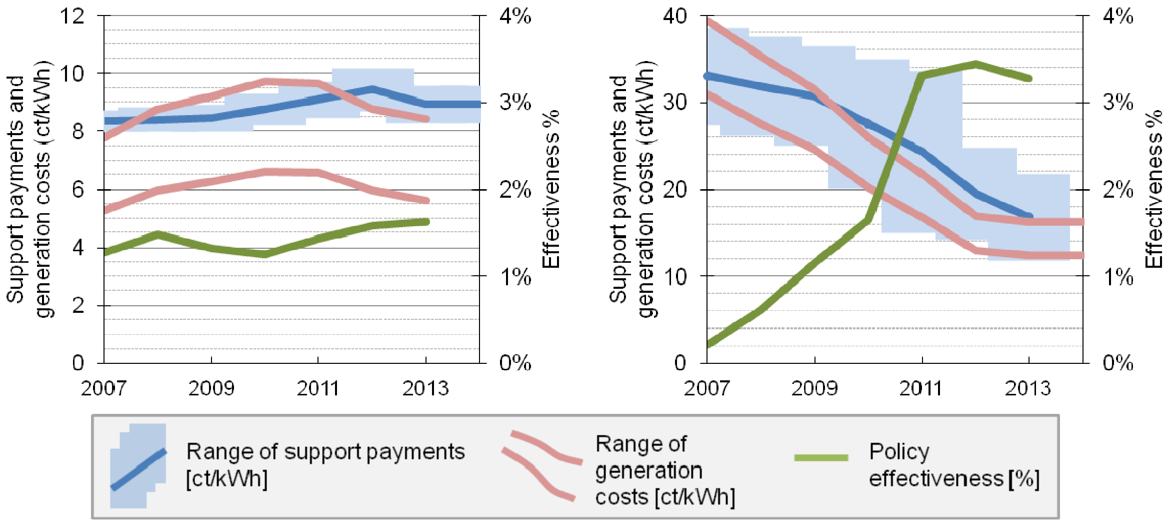
Italy and Spain achieved high policy effectiveness, providing positive profit levels. Even higher profits in countries such as Romania, Hungary, Greece and Slovenia could however only be translated into very moderate policy effectiveness.

### 4.1.8 Development of support level performance over time

For this analysis, the development of support payments, technology costs and the actual deployment of renewables from 2007 to 2014 has been evaluated. Whilst indicators have been calculated for 28 Member States and 14 technologies in the electricity, heat and transport sector, we concentrate on results for solar PV and wind onshore in this policy brief. The results are summarised in Figure 36.

Overall, the evaluation of EU renewables policy reveals the following:

- For **solar PV**, the policy effectiveness increased until 2011 and has since then remained on a stable level (see Figure 36, right side).
- The trend for the economic efficiency is less clear: Technology costs have decreased significantly since 2007 (-59%). However, the adjustment of support payments was not fully synchronised with this decrease between 2010 and 2012. This changed again after 2012 suggesting an improving economic efficiency in recent years.
- For **onshore wind power**, the policy effectiveness has been rather constant over the years with a slight decrease during the economic crisis in 2009/2010, which is contrary to the often stated view that the deployment of renewables was unaffected by the economic crisis (see Figure 36, left side).
- Technology costs slightly increased between 2007 and 2009, primarily due to the fact that material costs were on the rise in that period (e.g. steel). Since 2010, decreasing technology costs can be observed.
- Overall, payment levels have been adjusted to follow the cost trend. However, falling wind power costs after 2010 have not been reflected adequately in all EU member states. This suggests a period of decreasing efficiency which was, however, preceded by a period of low profit levels in 2008/2009 caused by increasing material prices. A national analysis shows that e.g. Italy realised strong cuts of support payments and achieved to reduce the previously high windfall profits available from the quota obligation with the introduction of an auction scheme.



(a) Onshore Wind

(b) Solar PV

Figure 36: Annualised support payments, generation costs (left axis) in the EU28 compared to policy effectiveness (right axis)

## Solar PV in Germany

The situation in Germany is of particular interest, given the massive deployment of solar PV in the years 2011 and 2012. In this period, roughly 15 GW of solar panels were installed, which corresponds to 25% of the global new installations in these years. In some cases, this raised heavy criticism, especially regarding the economic efficiency of the German support scheme.

The development of indicators is illustrated in Figure 37 and reveals the following key findings:

- From 2007 to 2011, an increasing trend for the effectiveness can be observed reaching a maximum of roughly 11% of the 2030 potential. On a European level, the effectiveness of solar PV support peaked at some 3.5% in 2012.
- Support payments were constantly adapted to reflect falling technology costs. A strong decline of solar panel prices resulted in a reduction of feed-in tariffs in 2010 and 2011. However, the level of support payments remained constant for one year in 2011.
- In December 2011, the peak of new installations was reached: 3 GW in one month. This can be understood as a pull-forward effect – investors anticipated the reduction of support payments for new installations in January 2012.
- Since 2012, tariffs are adjusted every month automatically (i.e. change does not have to be adopted by the Parliament). The absolute decrease of payments depends on whether deployment targets are met. Overachieving deployment targets leads to a stronger reduction of feed-in tariffs.
- The profit level was close to zero in 2013. This indicates a high economic efficiency.

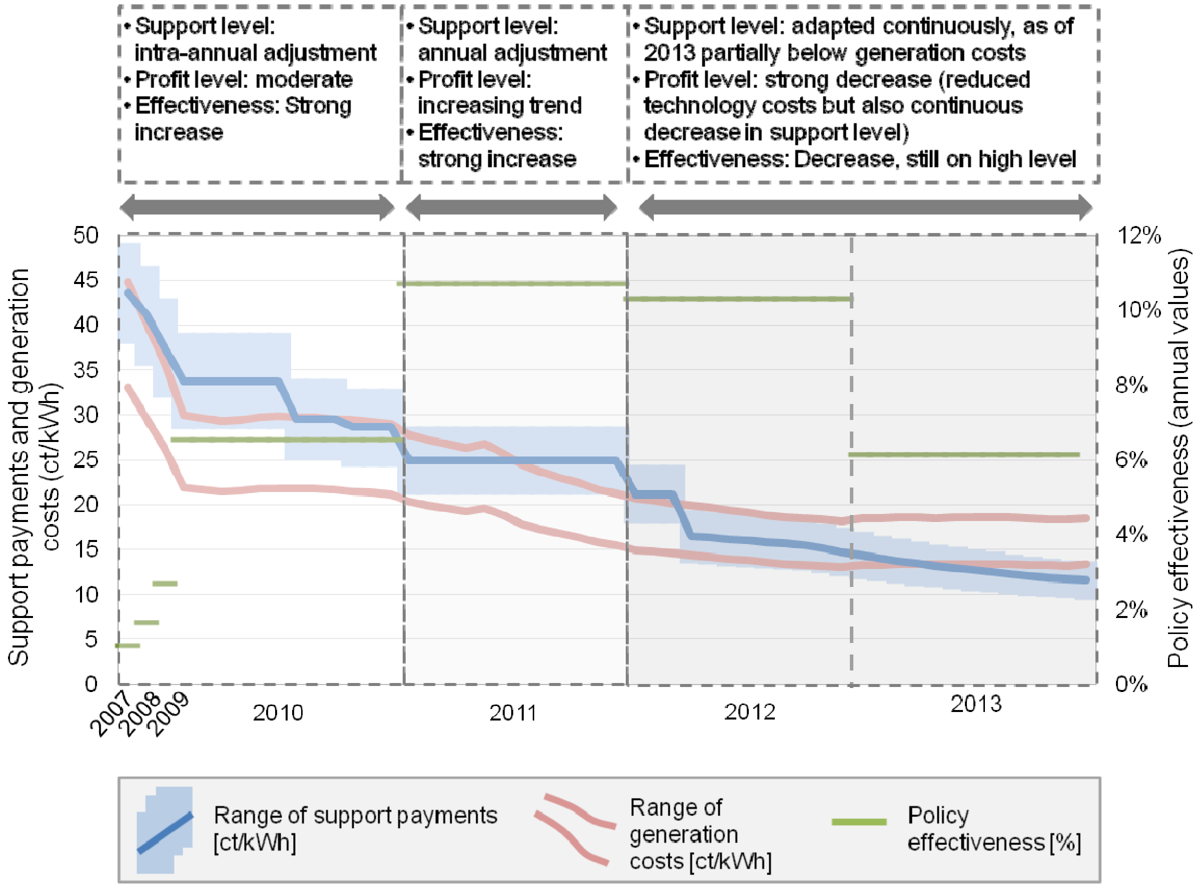


**Figure 37: Evolution of support payments, generation costs and policy effectiveness for solar PV plants in Germany from 2007 to 2013**

Overall, one of the key lessons to be learned from the development in Germany is that there is a need to constantly monitor technology costs and adapt support payments frequently to follow changes in costs rapidly. This is a solid measure to avoid overcompensation. Moreover, experience shows that automatic payment cuts based on transparent criteria are more effective than payment cuts that have to be adopted in a parliamentary process. The German example also shows that a stable and reliable support scheme ensures a high effectiveness. Conversely, high profit levels do not necessarily lead to a strong market growth, as an evaluation of other EU member states shows.

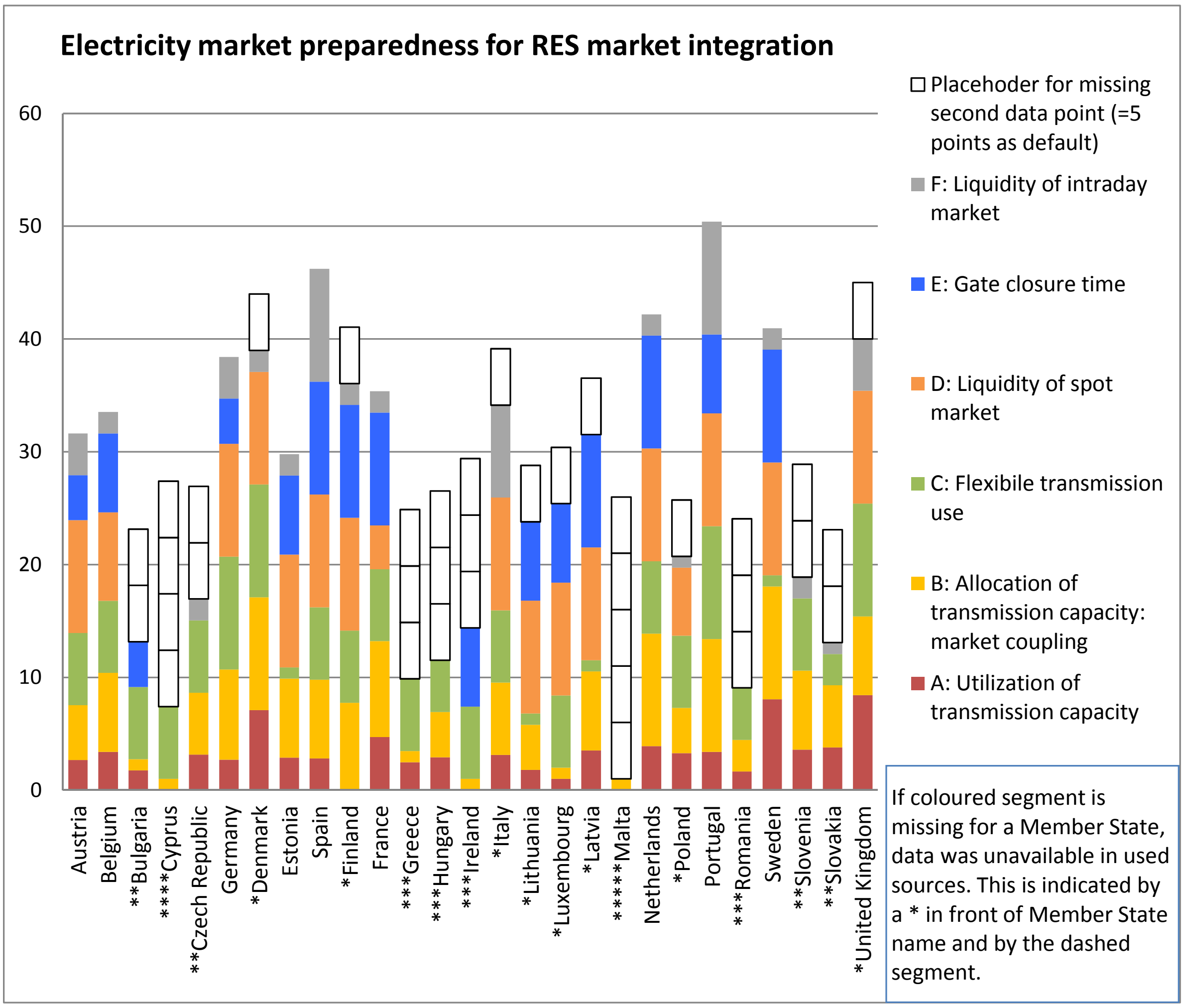
### 4.1.9 Electricity Market Preparedness

Figure 38 shows the openness of the power system for RES in the respective EU Member States. Note that the data sources used did not provide data for all Member States for all sub-indicators. In the figure this is indicated by the dashed segments on top of the stacked bars.

According to the overall aggregated indicator, the electricity markets in Portugal, Spain and the United Kingdom seem to be best prepared for RES market integration with 45-50 out of 60 possible points. Only in *Sub-indicator A: Utilization of transmission capacity* Portugal and Spain rank poorly whereas the United Kingdom ranks poorly in *Sub-indicator F: Liquidity of intraday market*. Also Austria, Belgium, Denmark, Germany, Finland, France, Italy, Latvia, Luxembourg, the Netherlands and Sweden score comparably high between 30 and 44 points.

The lack of data availability and their island status makes an assessment difficult for Cyprus and Malta whereas Bulgaria, Greece, Slovakia and Romania's markets currently seem to lack market preparedness for RES with less than 25 points.

It should be clear that the results presented in Figure 38 can only give a first overview of the preparedness of Member State electricity markets for RES market integration: The six sub-indicators indicate the status of six aspects that are of relevance to RES market integration. Looking more in detail at a specific Member State one might however conclude that certain of these aspects are more or less relevant due to local circumstances.



If coloured segment is missing for a Member State, data was unavailable in used sources. This is indicated by a * in front of Member State name and by the dashed segment.

Figure 38: Electricity market preparedness for RES

*A: Utilization of transmission capacity:* Effective use of transmission capacity allows to share and balance renewable energy across larger areas. In 2012, Denmark, Sweden and Great Britain (Northern Ireland included in Single Electricity Market with Ireland) used the transmission system to other countries in an effective manner (NTC/PTC ratios of 68%, 78% and 82%). For all other member states the ratio between short-term NTC and PTC is below 50%.

*B: Allocation of transmission capacity - market coupling:* Market coupling allows the flexible allocation of transmission capacity according to need. 4 Member States have well-prepared markets with a rate of 100% day-ahead market coupling, while 17 Member States have partly coupled markets and 6 Member States have no market coupling at all. It is important to note that intraday market coupling and flow-based market coupling are required to really consider markets as prepared for RES. Flow-based market coupling has been introduced in the CWE region in 2015. Moreover, the European Commission has established a Target Model for a European cross-border intraday market. Once intraday and flow-based market coupling are widely introduced, the sub-indicator should be changed and high scores should not be granted for high day-ahead market coupling alone.

*C: Flexible transmission use:* Connection charges can be classified from super shallow to deep. Whereby "super-shallow" means that all costs are socialized via the tariff and no costs are charged to the connecting entity, "deep" implies that grid users pay for the infrastructure connecting their installations to the transmission grid as well as all other required reinforcements/extensions in existing networks. Shallow connection charges assume that transmission capacity can be shared and thereby supports the integration of RES. 4 Member States have super shallow connection charges and receive the full 10 points. 4 Member States still have deep connection charges.

*D: Liquidity of spot market:* In the power exchanges of 14 Member States more than 30% of the national electricity consumption is traded, which can classify as liquid markets. In 11 Member States either no power exchange exists, no data was available or less than 5% of national consumption is traded in the power exchanges.

*E: Gate closure time:* The value of intermittent RES increases if adjustments are possible close to real time. In seven Member States the gate closure time is one hour or less and full 10 points are attributed. In three Member States gate closure time is still 24 hours.

*F: Liquidity of intraday market:* Effective intraday markets allow all generation to accommodate for changing forecasts of intermittent and other generation at intraday stage. Although the liquidity of intraday markets is expected to be generally low as they are simply used to correct forecast errors, in only 3 Member States more than 5% of national consumption is traded.

## 4.2 Heat

The technological disaggregation is based on the respective data availability and shows the effectiveness indicator for the following categories:

- Centralised biomass installations (district heating plants and large CHP-plants), where the heat is distributed to the final consumer via heating networks
- Decentralised biomass-based heating applications
- Ground source heat pumps
- Geothermal heating applications
- Solar thermal heat

### 4.2.1 Biomass heating applications (centralised and decentralised)

Figure 39 shows the effectiveness indicator for all biomass-derived heating applications, including centralised and decentralised installations. We calculated the indicator, which covers the time horizon from 2010 to 2012 based on moving average values of temperature-adjusted heating consumption data over three years.

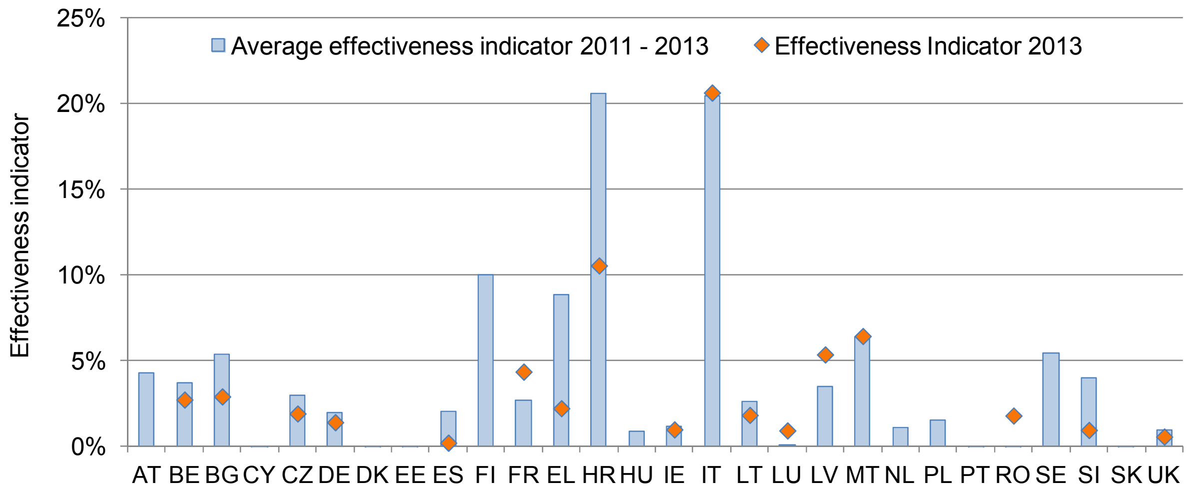


**Figure 39: Policy Effectiveness Indicator for all biomass-based heating applications in the period 2011 – 2013**

Similar to biomass-based electricity production, the effectiveness of biomass heating support policy is calculated using potentials based on a high-import scenario from Green-X (see chapter 3 for further explanation). The effectiveness values for 2013 as presented in Figure 39 are negative for a number of Member States. This is partly due to the fact that biomass-based heat consumption is still characterised by annual fluctuations, even though consumption data are temperature-adjusted and moving averages are calculated. Croatia and Italy show the highest effectiveness. In the case of Croatia, current biomass use is already approaching its 2030 potential. Finland and Greece follow in terms of policy effectiveness. As explained in the next two sections, some countries put a stronger focus on the support of centralised heating systems, whilst others utilise more decentralised on-site heating systems.

### 4.2.2 Centralised biomass heating plants (District heating plants and CHP-plants)

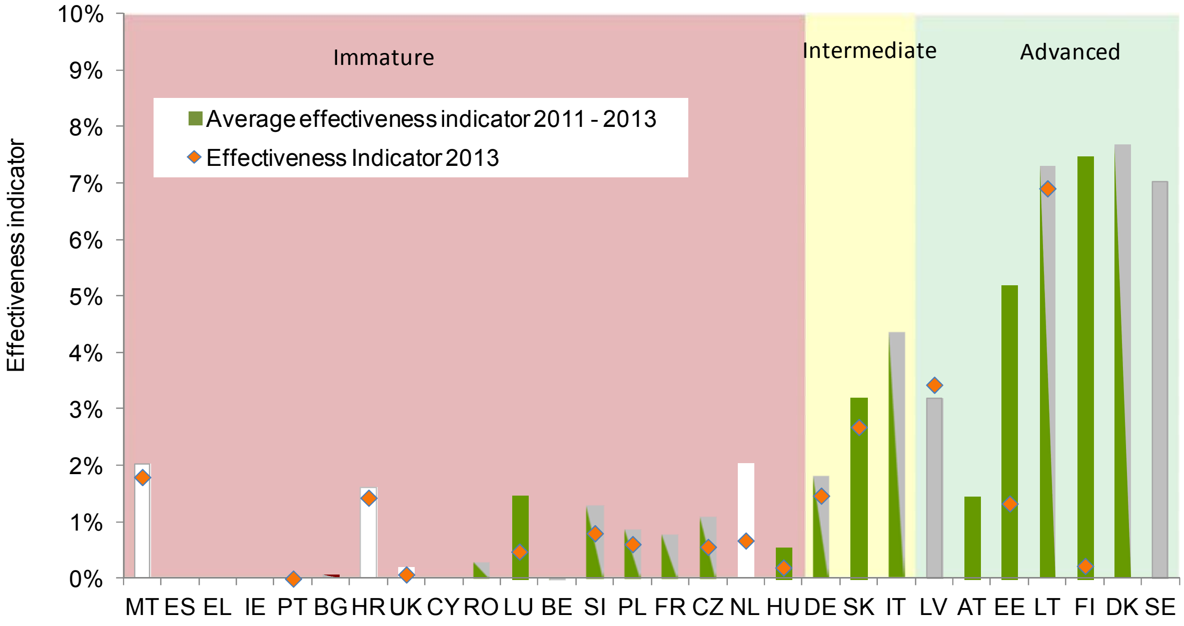


**Figure 40: Policy Effectiveness Indicator for centralised biomass heating plants (District heating plants and CHP-plants) in the period 2011 – 2013**

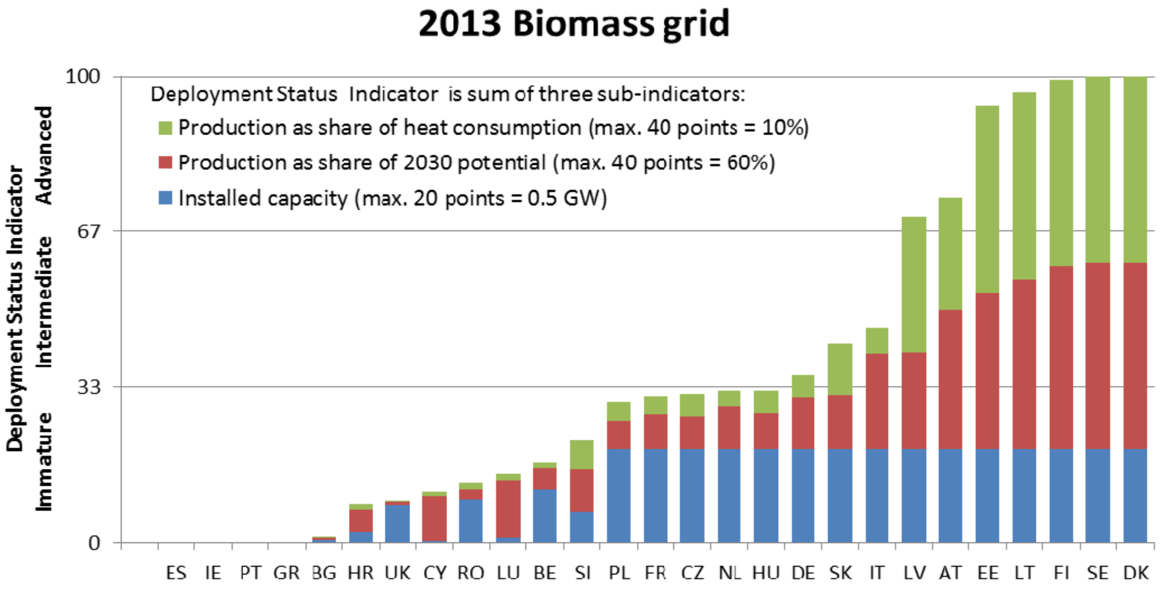


**Figure 41: Deployment Status Indicator for grid connected biomass heat in 2013**

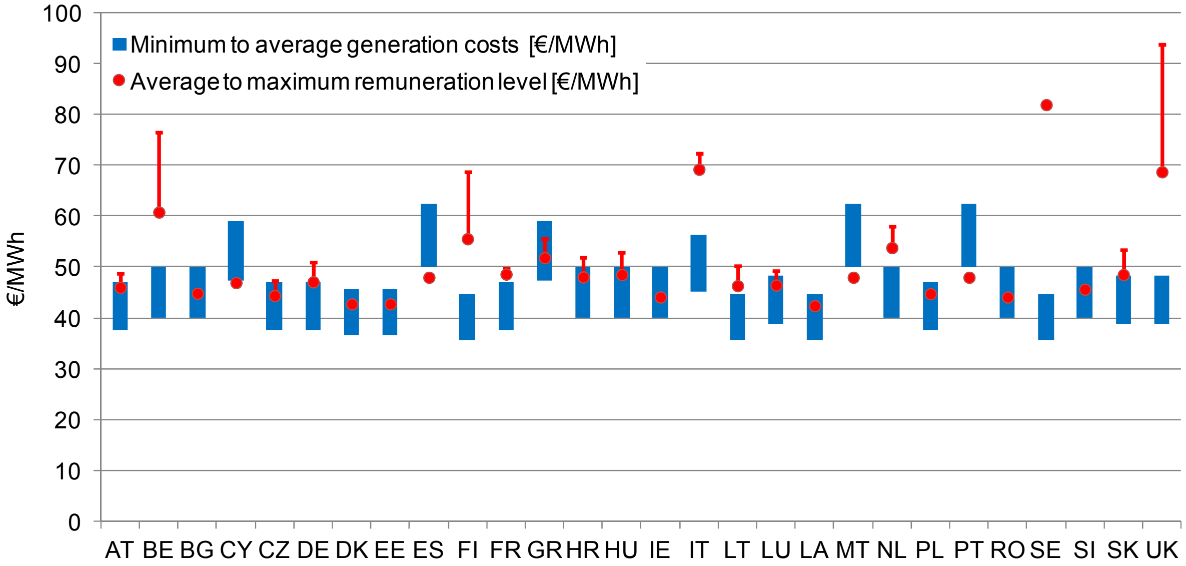


**Figure 42:** Remuneration ranges (average to maximum remuneration) for centralised biomass heating plants in the EU-28 MS in 2013 (average remuneration levels are indicative) compared to the long-term marginal generation costs (minimum to average costs)

#### 4.2.2.1 Policy effectiveness

District heating by RES in this section typically refers to large biomass plants producing centralised heat which is fed into a heat grid. Policy effectiveness for grid-connected biomass heating applications illustrated in Figure 53 indicates that particularly Scandinavian countries including Denmark, Finland and Sweden as well as the Baltic countries Estonia, Lithuania and Latvia are characterised by a good performance in terms of effective policy support. Slovakia and Italy also show high policy effectiveness for grid-connected biomass heat. It can be seen that in case of centralised biomass heat high policy effectiveness is achieved in countries with well advanced markets. Several factors including the tradition of Northern European countries to use grid-connected heating systems with an existing infrastructure of district-heating networks, the biomass availability, the relevance of the wood and pulp and paper industry and the sufficiently available heat demand certainly favour the successful support of biomass-derived district heating and CHP-plants. Given the low heat demand in Southern European countries, only little effort is made to support heating technologies with the exception of Italy, showing high policy effectiveness between 2011 and 2013.

#### 4.2.2.2 Deployment Status

Figure 41 shows the deployment status of grid-connected biomass heat. The market is fully or almost fully advanced in the Denmark, Sweden, Finland, Lithuania and Estonia, with contributions to heat consumption close to or above 10% and exploitation of close to or above 60% of their mid-term (2030) potential. Latvia and Austria are also very advanced markets, however with slightly lower contributions to total heat consumption and exploitation of their mid-term potentials. 3 Member States have reached intermediate deployment status. These are Italy, Slovakia and Germany. The rest of the Member States remain immature, although five of them already reach the 500 MW threshold to obtain maximum score in the sub-indicator on installed capacity.

#### *4.2.2.3 Economic incentives and generation costs*

According to Figure 42 most of the EU MS provide adequate remuneration for centralised biomass heating applications, with only a few countries providing excessive support including Belgium, Finland, Italy, Sweden and the United Kingdom. Whilst high support levels led to high policy effectiveness in Finland, Sweden and Italy, the high support levels in Belgium and United Kingdom could not be translated into high policy effectiveness.

### 4.2.3 Decentralised biomass heating plants

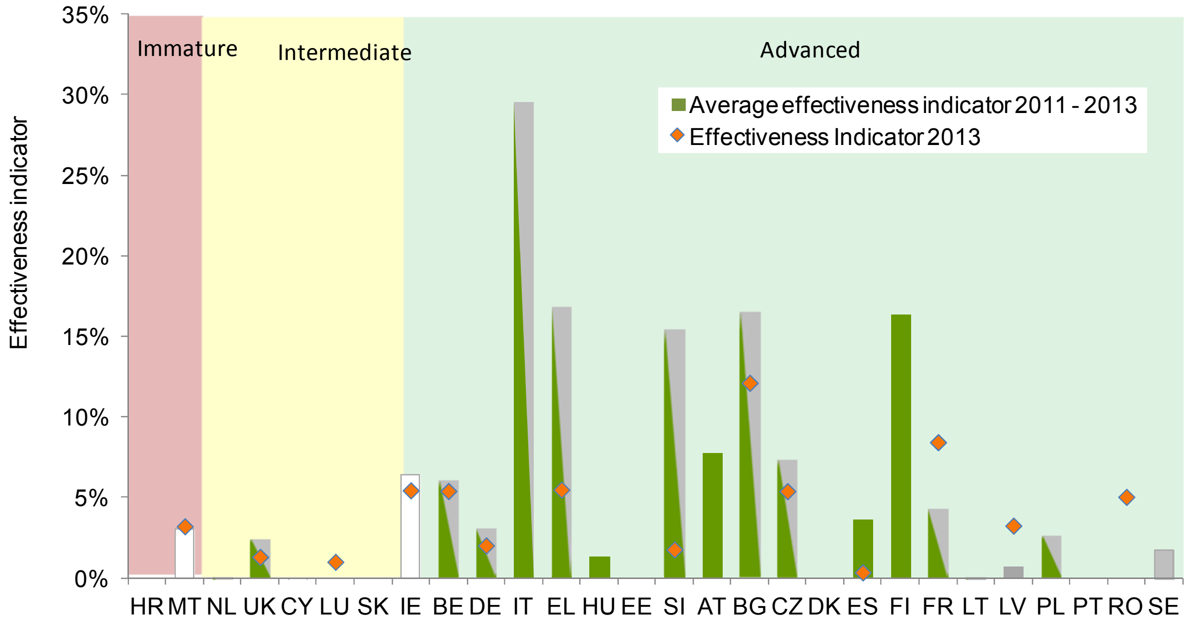


**Figure 43: Policy Effectiveness Indicator for decentralised biomass-based heating applications in the period 2011 – 2013**

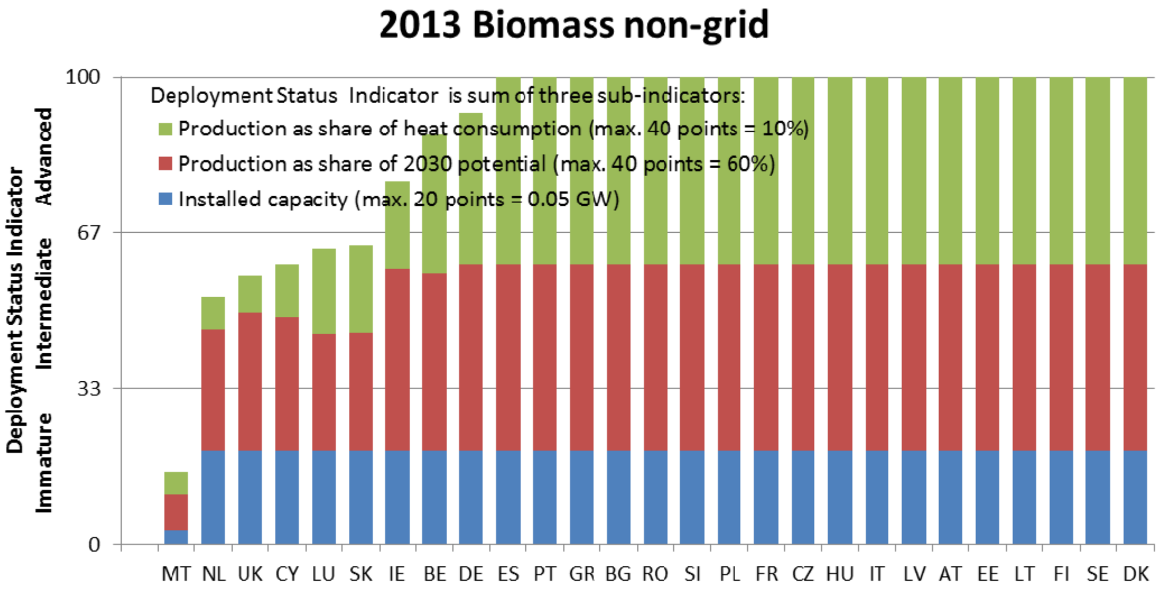


**Figure 44: Deployment Status Indicator for non-grid connected biomass heat in 2013**

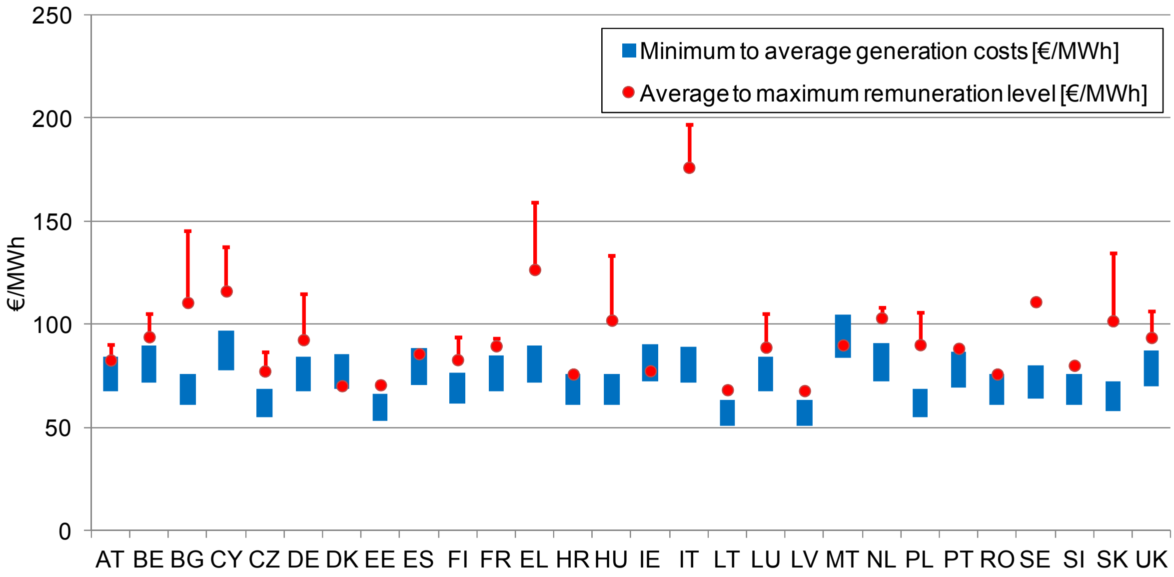


**Figure 45: Remuneration ranges (average to maximum remuneration) for decentralised biomass heating plants in the EU-28 MS in 2013 (average remuneration levels are indicative) compared to the long-term marginal generation costs (minimum to average costs)**

#### *4.2.3.1 Policy effectiveness*

Compared to the effectiveness of grid-connected installations, the effectiveness values achieved for decentralised heat plants using pellets, wood chips, or log wood as fuel is higher (see Figure 43 and Figure 40). In contrast to the dominance of Northern European countries regarding centralized, grid-connected heating, MS from other regions perform well regarding policy effectiveness for decentralized biomass heating plants. Besides Finland, high effectiveness values can be observed in Italy, Greece, Slovenia, and Bulgaria.

#### 4.2.3.2 Deployment Status

Figure 44 shows the deployment status of biomass heat installations that are not connected to any heating network, i.e. mainly traditional and modern wood combustion technologies. The deployment status of this technology is generally mature. 18 countries have reached fully advanced deployment status, i.e. they exploit more than 60% of their potential and non-grid biomass covers at least 10% of their heat consumption. Further 3 countries have reached advanced deployment status, with high shares in exploited potential, but lower contributions to their total heat consumption. There are 5 Member States in an intermediate stage of deployment. These are Slovakia, Luxemburg, Cyprus, United Kingdom and The Netherlands. Malta remains an immature market.

The high scores for exploited biomass potential can be explained by the fact that Europe has only limited additional potential that can be harvested in a sustainable way. In that sense, biomass technologies have a structural advantage when the deployment status is calculated compared to other renewable energy technologies with vast potential such as solar energy.

#### 4.2.3.3 Economic incentives and generation costs

Figure 45 reveals both heterogeneous support levels as well as generation costs in the EU MS for small-scale biomass heating plants. Some countries such as Italy, Belgium, Bulgaria, Sweden, Slovakia and the United Kingdom provide a support level which is considerably above the average generation costs in the respective country. In most of the other countries, support is well adapted to the requirements of the technology.

### 4.2.4 Solar thermal heat

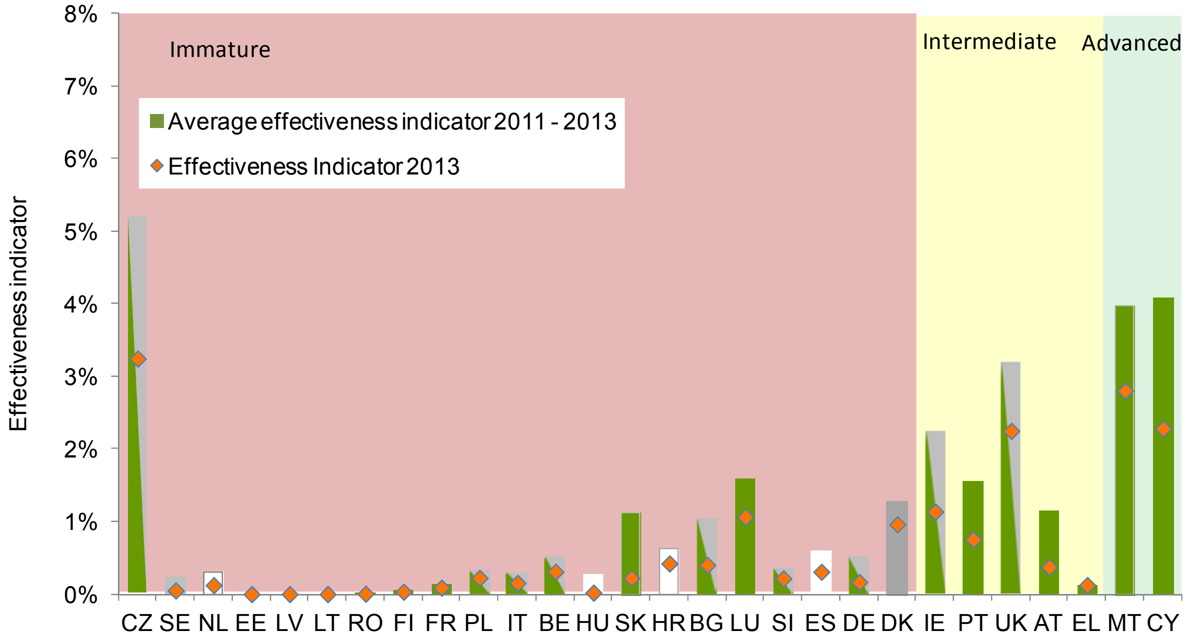


Figure 46: Policy Effectiveness Indicator for solar thermal heat in the period 2011 – 2013

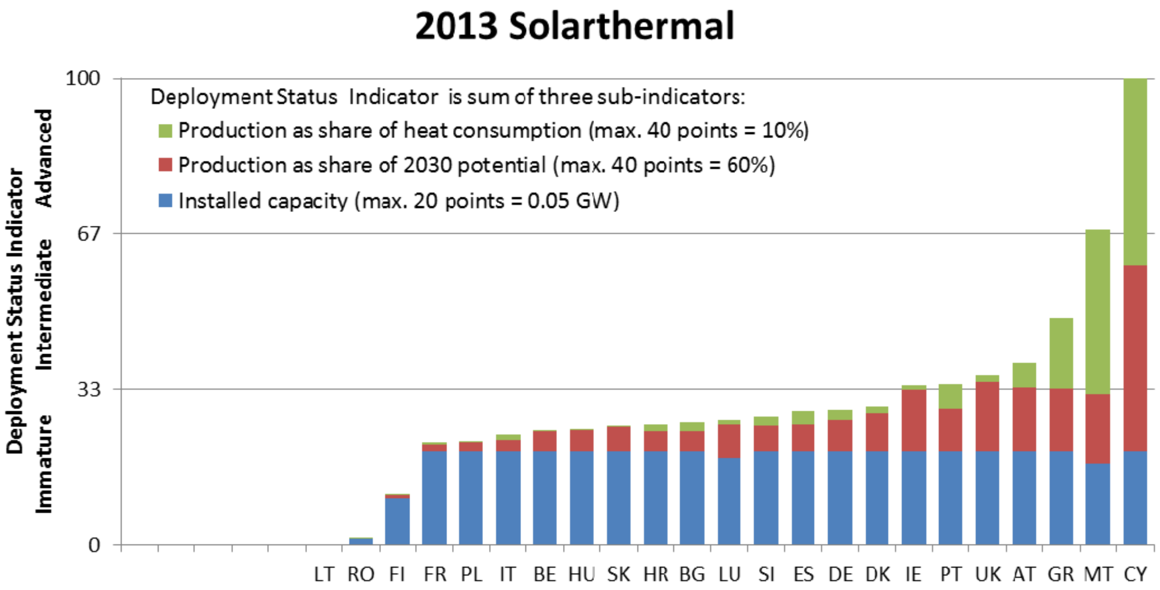


Figure 47: Deployment Status Indicator for solar thermal heat in 2013

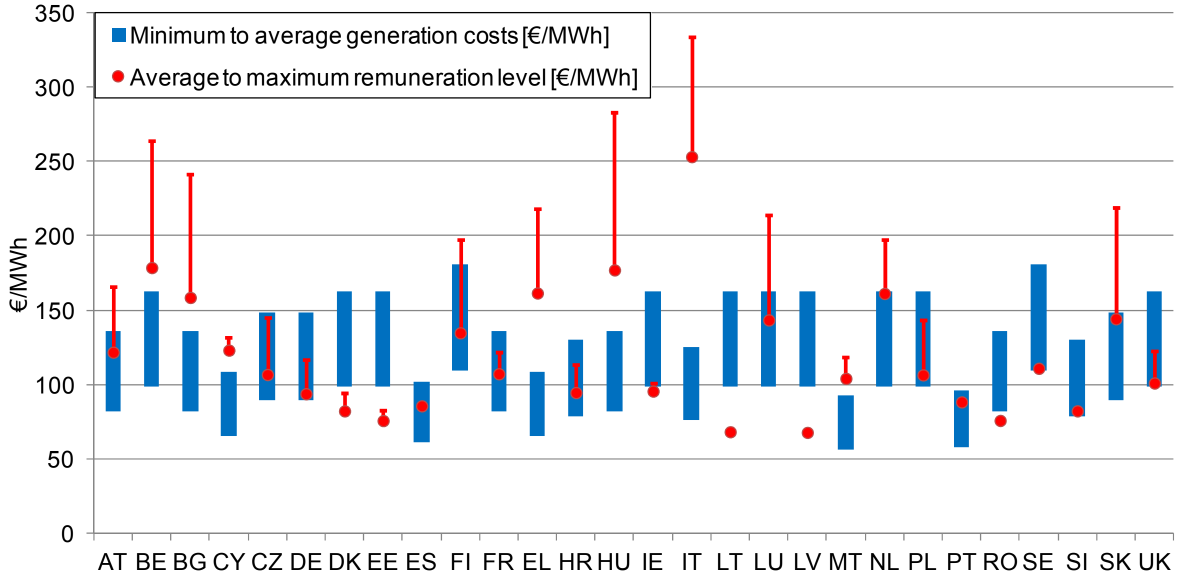


**Figure 48:** **Remuneration ranges (average to maximum remuneration) for solar thermal heating plants in the EU-28 MS in 2013 (average remuneration levels are indicative) compared to the long-term marginal generation costs (minimum to average costs)**

#### *4.2.4.1 Policy effectiveness*

In general the market of solar thermal heating applications including glazed and unglazed solar collectors is less developed than biomass-based heating. Given the vast available potential for solar thermal heating the effectiveness indicator in the EU is still on a comparatively low level. Thus, only Cyprus and Malta are judged to have achieved an advanced status of market development. In terms of policy effectiveness, the leading countries for the time frame between 2011 and 2013 are Malta, Cyprus, and the Czech Republic, followed by Ireland and the UK. Whilst policy effectiveness in Germany, the EU's leading country in terms of installed solar thermal heating capacity (11 $GW_{th}$ in 2012), has somewhat contracted, the EU's second largest market Austria is characterised by a good average policy effectiveness between 2010 and 2012 but with a decreasing trend in 2012 with an additionally installed capacity of roughly 150 $MW_{th}$. In southern European countries including Spain, Greece and Italy, policy effectiveness between 2010 and 2012 was lower as a consequence of the financial crisis damaging the construction industry. Only in Portugal, average policy effectiveness between 2010 and 2012 was on a comparatively high level, but also with a decreasing trend for 2012.

#### *4.2.4.2 Deployment Status*

Figure 47 shows the deployment status for solar thermal installations. Only 2 Member States (Malta and Cyprus) have reached advanced levels of deployment. Greece, Austria, UK, Portugal and Ireland have achieved intermediate deployment status. All other Member States score immature. Cyprus and Malta are small markets in absolute size, but large in relative terms, as solar thermal already contributes to a sizeable fraction of the total heat demand. In terms of absolute thermal energy generation Germany, Spain and UK are the largest solar thermal markets in Europe; however, deployment status is still low in these countries due to the small shares as a fraction of mid-term potentials and as fraction of total heat consumption.

#### *4.2.4.3 Economic incentives and generation costs*

The remuneration level for solar thermal heating shown in Figure 48 indicates large differences in support levels and in generation costs between countries, whereby the overwhelming part of support is provided in terms of investment incentives. Belgium, Bulgaria, Greece, Hungary, and Italy provide rather high support to solar-thermal installations. In other Member States, support is too low to incentivise deployment. There is no support in Spain, Latvia, Lithuania, Portugal and Romania.

### 4.2.5 Ground-source, aerothermal and hydrothermal heat pumps

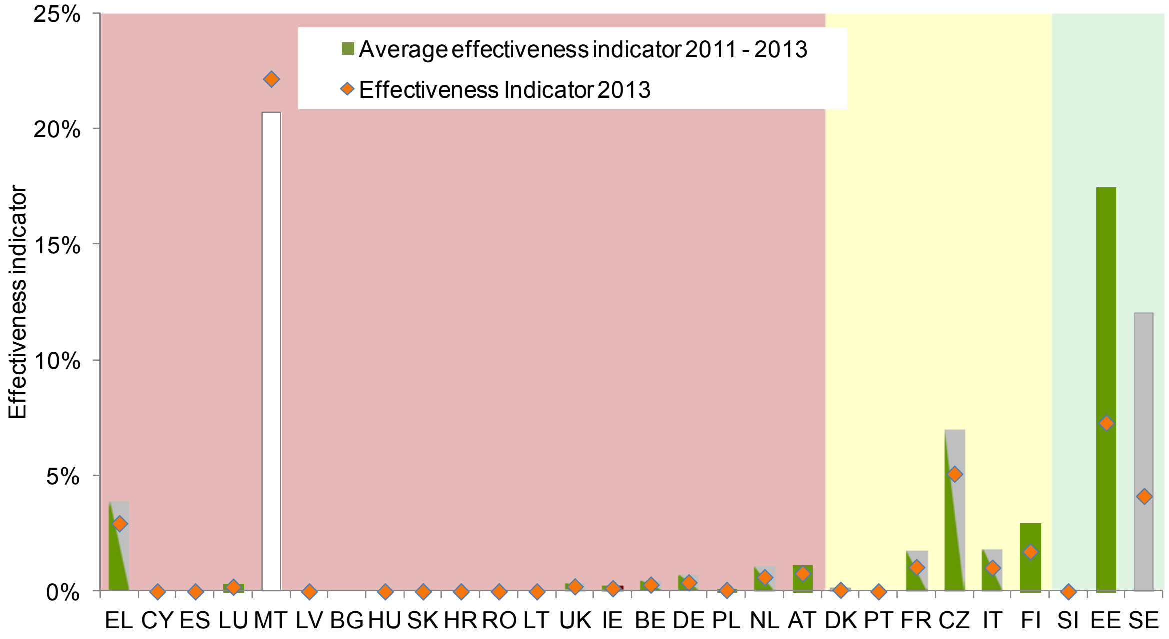


**Figure 49: Policy Effectiveness Indicator for ground-source, aerothermal and hydrothermal heat pumps in the period 2011 – 2013**

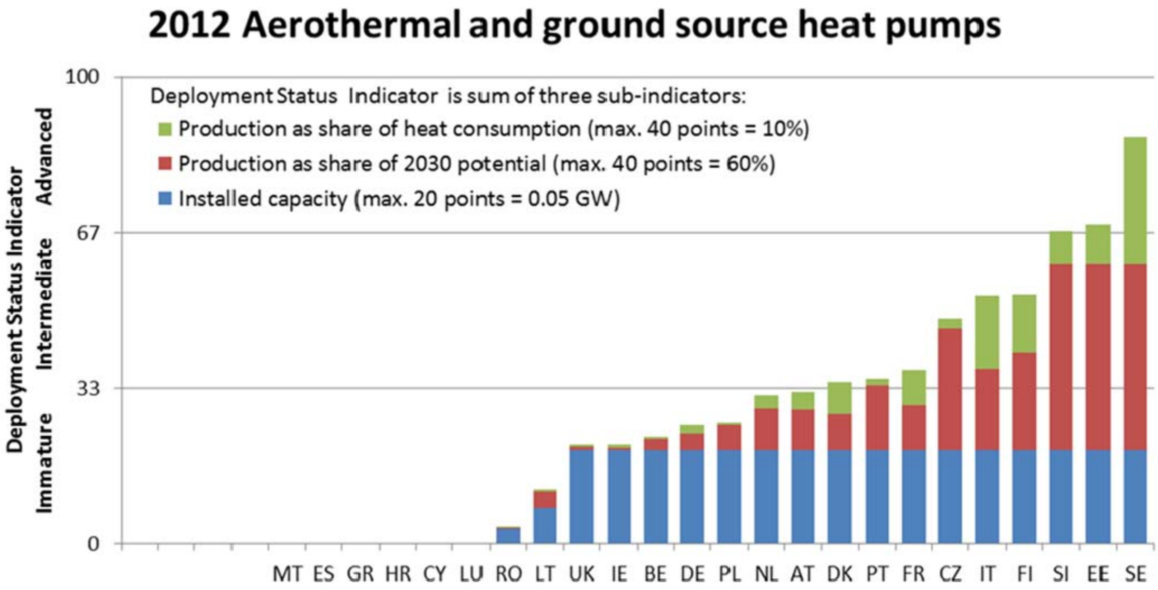


**Figure 50:** Deployment Status Indicator for ground-source, aerothermal and hydrothermal heat pumps in 2012

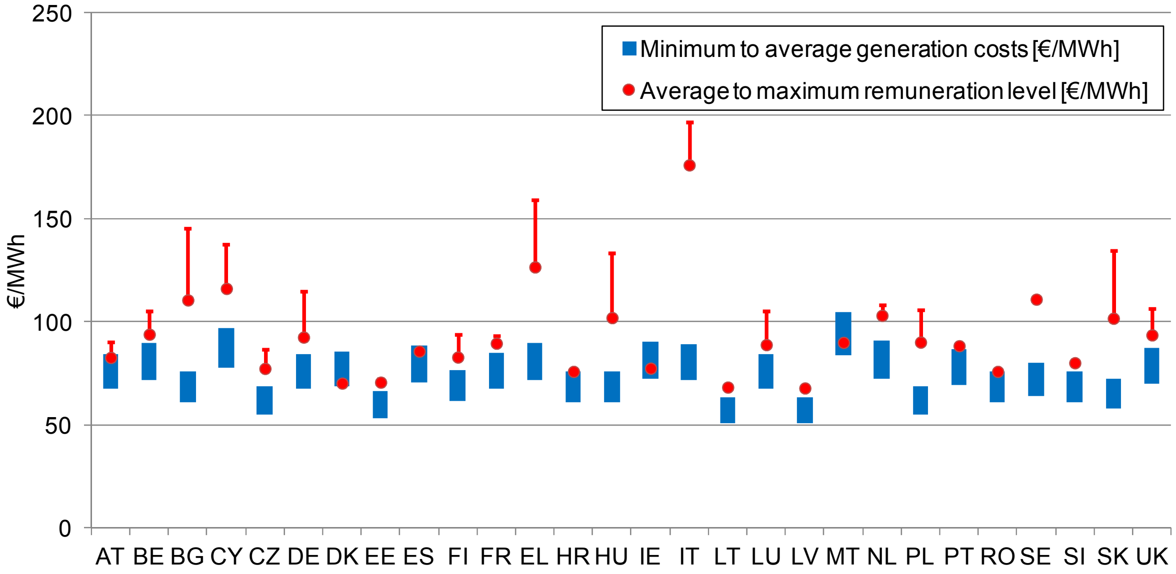


**Figure 51:** Remuneration ranges (average to maximum remuneration) for ground-source, aerothermal and hydrothermal heat pumps in the EU-28 MS in 2013 (average remuneration levels are indicative) compared to the long-term marginal generation costs (minimum to average costs)

#### 4.2.5.1 *Policy effectiveness*

The market for renewable heat pumps is still comparatively immature in most Member States. However, policy effectiveness shows good values in Sweden, Estonia, the Czech Republic and Malta who only reported heat pumps being installed since 2012. Greece, France and Finland follow the first group of countries in terms of policy effectiveness performance. In general the market for heat pumps depends on the building and construction market, meaning that in particular Southern European countries hit by the financial crisis show low policy effectiveness.

#### 4.2.5.2 *Deployment Status*

The markets for heat pumps are still quite immature in the majority of EU Member States (see Figure 50). The most advanced market in 2012 was Sweden with 64% of the potential being exploited and 6.8% contribution to total heat consumption. Estonia and Slovenia also reached advanced deployment status, however with lower contributions to heat consumption. A group of 6 Member States (Finland, Italy, Czech Republic, France, Portugal and Denmark) are in an intermediate development stage. The rest of Member States remain in an immature stage.

#### 4.2.5.3 *Economic incentives and generation costs*

Heat pumps receive remuneration levels that make them profitable in almost all Member States. In many countries, remuneration is actually higher than necessary to cover generation costs. There are also a few MS which do not provide financial support for heat pumps including Denmark, Spain, Croatia, Lithuania, Latvia, Romania, Portugal and Malta. However, the comparison with generation costs shows that heat pumps can be profitable without additional financial support.

### 4.2.6 Geothermal heat

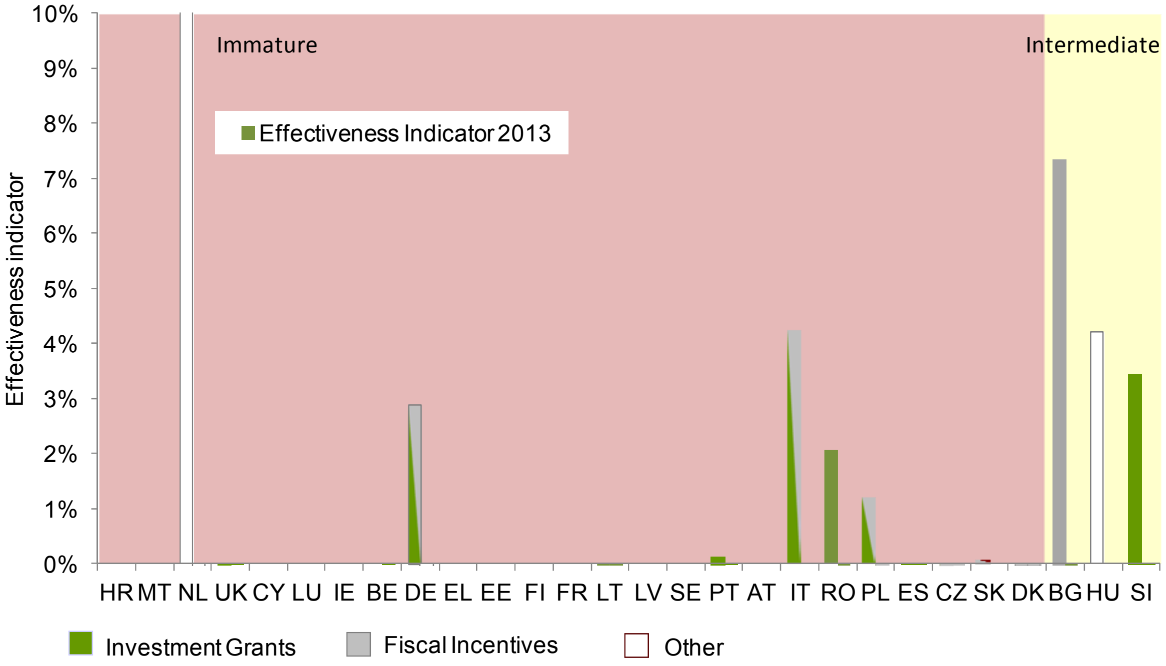


Figure 52: Policy Effectiveness Indicator for geothermal heat in 2013

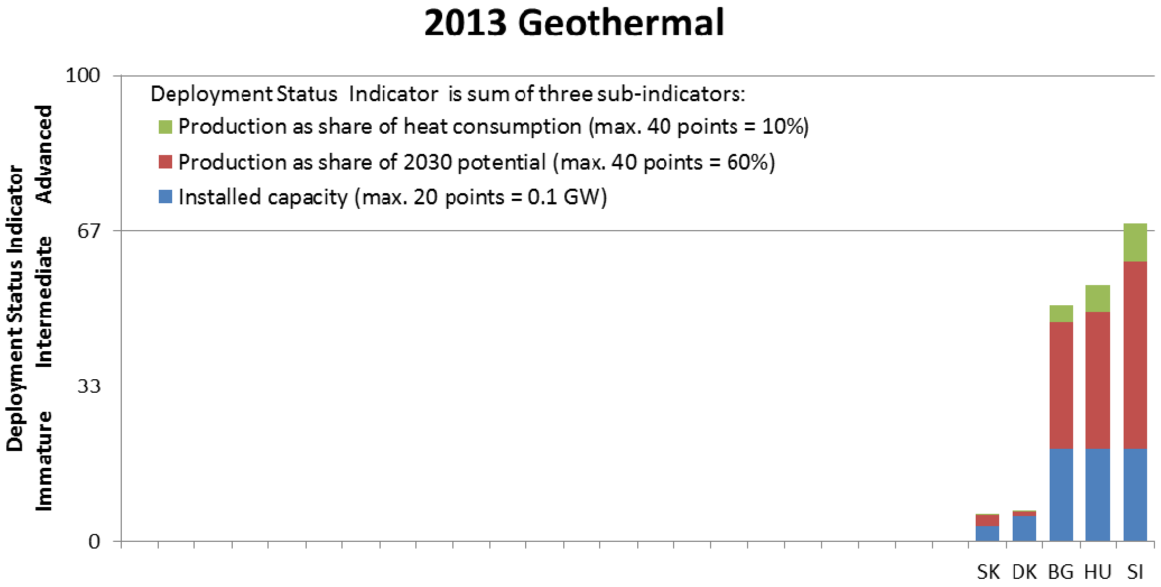


Figure 53: Deployment Status Indicator for geothermal heat in 2013

#### 4.2.6.1 Policy effectiveness

No continuous time series are available for geothermal heat deployment. Eurobserver data for 2012 and 2013 was used for this report, resulting in effectiveness indicator values for 2013 only (see Figure 52). Policy effectiveness of geothermal heat was highest in the Netherlands, with an increase from 11.3 ktoe in 2012 to 21.63 ktoe in 2013. Slovenia, Hungary, and Bulgaria, all countries with intermediate or advanced market development, also show relatively high effectiveness.

#### 4.2.6.2 Deployment Status

Figure 53 shows the deployment status of geothermal heat. The most advanced markets are Slovenia, Hungary, and Bulgaria. There are some (minor) developments in Denmark and Slovakia and the rest of the Member States have such low potential that they are not shown in the figure. The latter applies to 23 out of 28 countries.

## 4.3 Transport

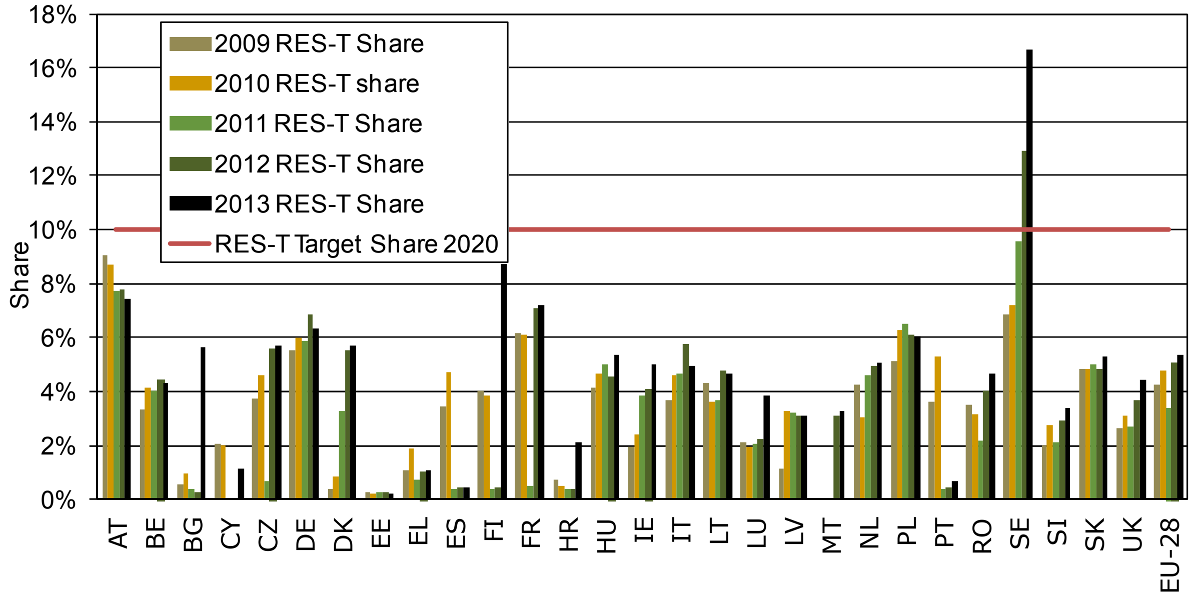


**Figure 54: Development of RES-T share compared to the 10% target for 2020. Based on data from Eurostat.**

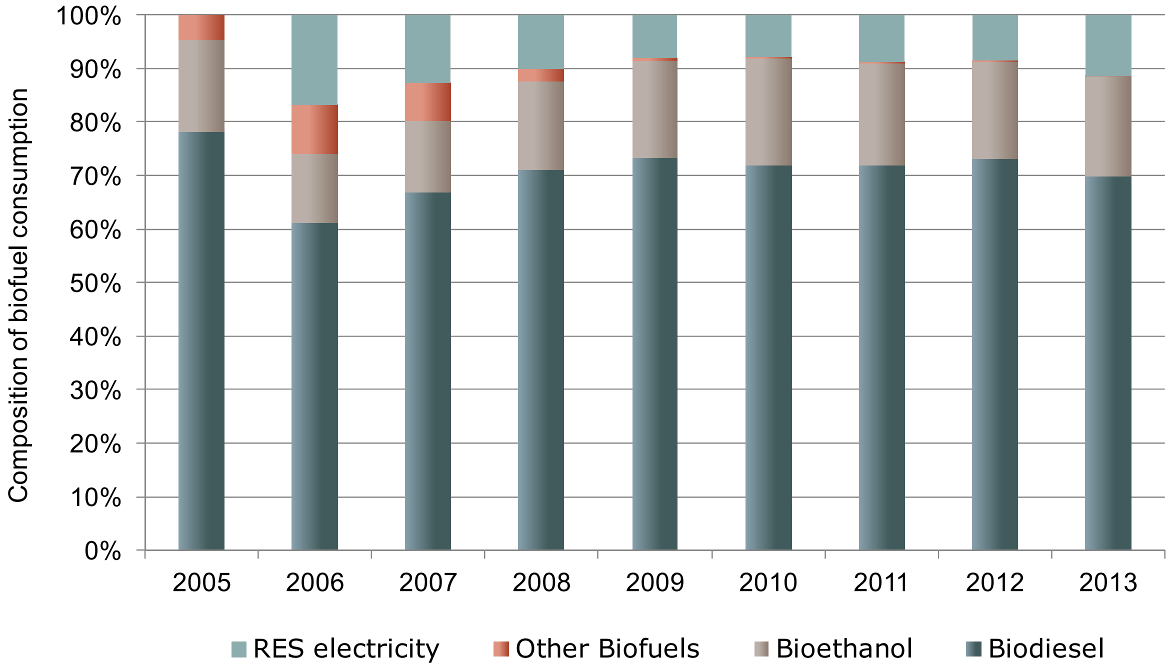


**Figure 55: Composition of biofuel consumption between 2005 and 2013**

In case of biofuels, we do not calculate the effectiveness indicator as used for the electricity and the heating & cooling sector. Instead, we analyse biofuel consumption as share of final energy demand in road transport and compare it to the 10% target set for 2020. The effectiveness indicator, as applied to the RES-E and RES-H&C sectors, is not meaningful in the RES-T sector given that liquid biofuels are an internationally traded commodity. The production potential of a given country is therefore not directly related to the amount of biofuels consumed in its transport sector. In addition, an amendment proposal of the European Commission (2012) suggested limiting the use of food-crop based biofuels (1st generation biofuels) to 5 % in order to ensure a sustainable use of biofuels that to not involve emissions from indirect land use changes (ILUC). In the context or rising concerns regarding the sustainable use of biofuels, the development of several countries have phased out financial support in recent years involving a slowdown of biofuels development. Figure 54 shows the development of RES-T shares from 2009-2013. A sudden decline in RES-T shares can be observed for several Member States between 2010 and 2011. This strong decrease is due to a late transposition of Articles 17 and 18 of Directive 2009/28/EC in the affected MS. Starting from 2011, only those biofuels could be counted towards the target which complied with the sustainability criteria and verification procedures specified under Articles 17 and 18, and MS who had not transposed the two articles by this deadline were not able to have their non-compliant biofuels counted towards their target. With MS making continuous progress regarding the transposition of the sustainability criteria, RES-T share have been increasing again since 2011.

Sweden is the only MS that has fulfilled the minimum target of 10% for 2020 already in 2013, showing the highest RES-T share of all EU MS in 2013 (16.65%). Sweden is followed by Finland, France and Austria in terms of RES-T share in 2013.

With regard to the composition of RES-T shown in Figure 55, it becomes clear that the most commonly used biofuel is biodiesel with an absolute contribution of 10,292 ktoe in 2013. Bioethanol or ETBE is the second largest contributor, amounting to 2,716 ktoe in 2013. Other biofuels including vegetable oil or biogases have shown increased uses in 2006 and 2007, but declined to only a marginal contribution in 2013. All these figures include compliant and non-compliant biofuels. While the amount of compliant biofuels has risen in the past two years, as explained above, the total amount of biofuels used has declined between 2012 and 2013. Figure 55 also shows a visible contribution by renewable electricity, mainly based on already existing transport modes such as railway, trams and trolley buses. The use of hydrogen is not yet present in the EU.

Support for biofuels in EU MS is heterogeneous and is dominated by tax reductions blending mandates. In the context of the discussions about biofuel sustainability, quite some financial support in terms of tax incentives has come to an end in recent years. With regard to using renewable electricity in transport, only limited incentives exist in some countries including subsidies for building up the required infrastructure, charging points or publicity campaigns.

# 5 Forecasting the diffusion of renewable energies in the EU (forward looking RES diffusion indicator)

## 5.1 Composite RES-diffusion indicator

### 5.1.1 Components of the indicator

As already described in section 2.5, a core requirement for the development of the forward-looking diffusion indicator is the design of a conceptual framework which truly reflects the view and decision-making process of RES developers and investors when evaluating potential RES markets. A comprehensive literature review and intense stakeholder dialogue including a series of moderated expert-workshops and in-depth interviews has led to the identification of four major determinants8: (A) The political and economic framework for RES deployment including RES targets and policy stability, support schemes and access to finance for RES projects; (B) The electricity market structure and respective market regulations determining the possibilities for marketing RES-E; (C) The availability of grid infrastructure and the regulation grid access and usage; and (D) The characteristics of the administrative framework and spatial planning regime for realizing RES projects. The above determinants are reflected in the design of the conceptual model presented in Figure 56.

Based on the conceptual model, a composite indicator is derived which consists of four components (main determinants, A, B, C, D) with three to five sub-components (sub-determinants, I.-V.) each (see Figure 56). Each of the sub-determinants is again represented by a set of indicators which can be quantified, values normalized and aggregated to the final indicator score. Some of the indictors are represented by binary functions (taking either a value of 1 or of 0), some are represented by stepped or continuous functions. The list of indicators per sub-determinant, the respective value ranges and data sources is presented in Figure 56 and further explained in the following text.

The indicator values for each sub-determinant are added up and normalized to a range between 0 and 1, leading to a possible total score of 16 points (unweighted). The general methodology for constructing the composite indicator is in line with the common guidelines for constructing composite indicators as described by (OECD 2008).

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[8] Further details about the methodology that led to the design of the model are presented in Boie et al (2015).

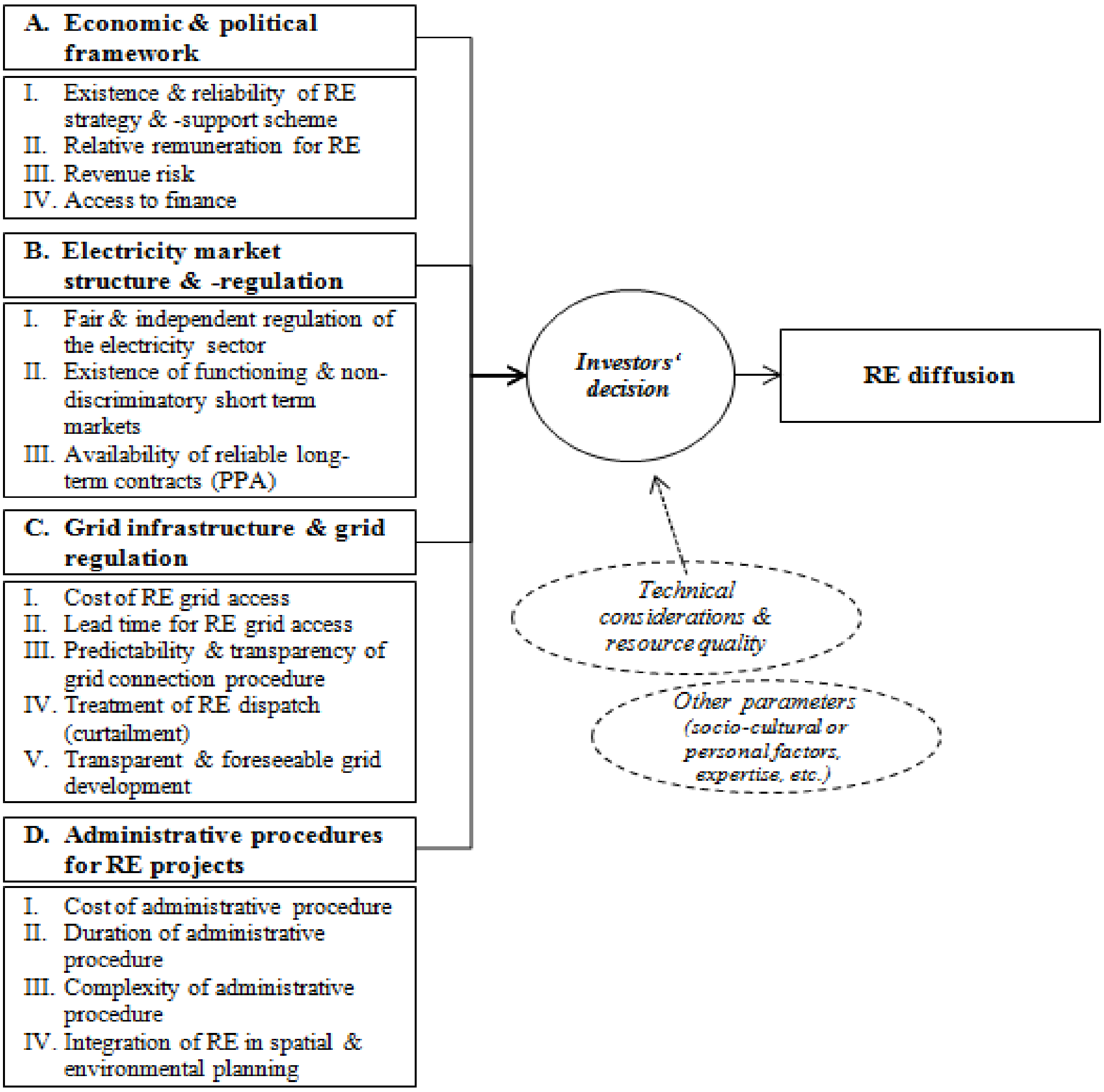

Figure 56 Conceptual model summarizing the main determinants for RE diffusion from the investors' perspective

Source: Boie et al (2015)

## Table 4 Indicators, value ranges and data sources per sub-determinant of the forward-looking diffusion indicator[9]

| Indicators | Value ranges / normalization | Data sources |
|---|---|---|
| *A - Economic and political framework* | | |
| *A I ) Existence and reliability of RES-E strategy and -support scheme* | | |
| **General RES-E target** | Existent (= 1), Not existent (= 0) | National legal documentation, policy databases |
| **Liability of RES-E target** | Binding / part of legislation (= 1), No binding targets (= 0) | National legal documentation, policy databases |
| **Technology specification of RES-E target** | Yes (= 1), No (= 0) | National legal documentation, policy databases |
| **Time frame of RES-E target** | Long: ≥15 years (= 1)<br>Medium: 5-15 (= 0.5)<br>Short: ≤ 5 years (= 0) | National legal documentation |
| **RES-E support scheme** | Existent and enforced (= 1)<br>Not existent or not enforced (= 0) | National legal documentation, policy databases |
| **Mechanism for adjustments or changes of the RES-E support level** | Transparent & clear mechanism based on scientific expertise (= 1)<br>Intransparent, No clear mechanism defined (= 0) | National legal documentation |
| **Frequency of drastic support scheme changes**[10] | Stable / good: Max. 1 policy change in past year (=1)<br>Variable / intermediate: Two or more changes (=0.5)<br>Unstable/poor: Retroactive changes of the support scheme (=0) | National legal documentation and respective secondary documentation |
| **General policy stability** | Risk of political instability ranging from very high alert (= 0) to very sustainable (= 1), Normalization across value range of EU Member States. | Fragile States Index published yearly by the 'Fund for Peace' (http://ffp.statesindex.org/) |
| *A II) Relative remuneration level for RES-E* | | |
| **Relative remuneration level (average income under the given resource conditions & technical performance parameters)** | Average profit level derived from average income for a specific RES-E technology minus average generation costs for the respective technology (continuous scale between: cost covering = 1, not cost covering = 0). | Support levels based on RES legal policy database (www.res-legal.eu/), different sources on technology cost |
| *A III) RES-E revenue risk* | | |
| **RES-E support scheme inherent risk** | Normalized risk factors for different RES-E support scheme design options ranging from a Quota scheme with TGCs (highest risk = 0) to a fixed FIT (lowest risk = 1). | Risk assessments provided by scientific literature, reference is made to 'risk multipliers' as applied in techno-economic modelling tools such as the model Green-X (www.green-x.at/) |

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[9] Table adapted based on Boie et al (2015)

[10] Change of the support mechanism itself or unscheduled changes in the support level.

| Indicators | Value ranges / normalization | Data sources |
|---|---|---|
| ***A IV) Access to finance*** | | |
| **National credit rating** | Normalized score ranging continuously from the optimum score AAA (=1) to the minimum score D (=0) | International government credit ratings provided by 'Standard & Poor's' (www.standardandpoors.com/) |
| **Interest rates for long-term government bonds** | Normalized score (Min-max – normalization, 0-1) of interest rates for long-term government bonds across the EU Member States | EUROSTAT, interest rates on long-term government bonds (http://ec.europa.eu/eurostat/web/interest-rates/data/main-tables) |
| **Ease of obtaining credit (in terms of availability of information & legal strength in finance sector)** | Normalized score of 'access to capital' index (continuous score 0-1) | Indicator on 'Ease of Getting Credit' of the 'Doing Business Index' (www.doingbusiness.org/) |
| **Availability of financing for RES-E projects** | Good: Access to capital is good and /or dedicated institutions and programs for RES-E projects are existing & operational (= 1)<br>Moderate: Access to capital is limited, specific institutions and programs for RES-E might exist but are either not operational or not sufficient (= 0.5)<br>Poor: Access to capital is very difficult, specific institutions or programs for RES-E do not exist (= 0) | Qualitative assessment based on interviews and secondary literature |
| **B - Electricity market structure and regulation** | | |
| ***B I) Fair and independent regulation of the electricity sector*** | | |
| **Unbundling of generation, transmission & distribution** | Full (= 1), Partial (= 0.5)<br>No (= 0) | National legal / regulatory documents or policy databases, ACER, CEER |
| **Regulatory authority** | Existing & fully empowered (= 1)<br>Existing but lacking authorisation (= 0.5)<br>Not existing (= 0) | National legal / regulatory documents or policy databases, ACER, CEER |
| **IPP access to the electricity market** | Full: selling to utilities or to 3rd parties without concession (= 1)<br>Limited: only to utilities, concession based access (= 0.5)<br>Not provided (= 0) | National legal / regulatory documents or policy databases, ACER, CEER |
| **Auto-production of electricity** | Allowed & combined with remuneration scheme (e.g. Net Metering or FIT) (=1)<br>Allowed only for own consumption (= 0.5)<br>Not allowed or no legal framework existent (= 0) | National legal / regulatory documents or policy databases, ACER, CEER |
| ***B II) Existence of functioning and non-discriminatory markets*** | | |
| **Liquidity of power exchange (spot market)** | High liquidity (>30%) (= 1)<br>Limited liquidity (5 to <30%) (= 0.5)<br>Very low liquidity (<5%) or not implemented (= 0) | ACER, CEER, (European Commission 2014) |

| Indicators | Value ranges / normalization | Data sources |
|---|---|---|
| **Gate closure times** | < 2 hours ahead<br>2-6 hours ahead<br>6-24 hours ahead<br>> 24 hours ahead | Electricity trading platforms (e.g. EPEX, EEX, Nordpool, OTE, PXCE) |
| ***B III) Availability of reliable long-term contracts (PPA)*** | | |
| **Availability of long-term PPA's for RES-E** | Good: Sufficient number of offtakers available or PPA provided through support scheme (FIT or floating premium) (= 1)<br>Medium: Offtakers available but high level of market concentration (= 0.5)<br>Poor: Availability of offtakers for RES-E insufficient or not provided(= 0) | Official legal / regulatory documents and interviews with local stakeholders |
| ***C - Grid infrastructure and grid regulation*** | | |
| ***C I) Grid access cost*** | | |
| **Charging-/ grid reinforcement approach for access to distribution and transmission grids** | Shallow (or super-shallow) approach (developer pays only for connection to the nearest access point) (= 1)<br>Mixed (or undefined) approach (= 0.5)<br>Deep charging approach (full cost for connection and grid enhancements borne by developer) (= 0) | National legal/regulatory documentation, supplemented by consultation of local stakeholders, CEER status reports |
| ***C II) RES-E grid access lead time*** | | |
| **Total lead time for obtaining grid access (weeks/ months)** | Continuous scale between:<br>Wind: < 6 months = 1, >34 months (136 weeks) = 0 [11]<br>PV: < 1 month = 1, > 12 months = 0[12] | Past and ongoing projects (e.g. PV-GRID/PV-LEGAL, Wind Barriers), interviews with local stakeholders |
| ***C III) Predictability & transparency of grid connection procedures*** | | |
| **Transparency of grid connection procedure (availability of regulations & reliable information on terms & procedures)** | Transparent & predictable (= 1)<br>Average / medium (= 0.5)<br>Intransparent & unpredictable (= 0) | Interviews with local stakeholders, supplemented by national legal and regulatory documentation and past and ongoing projects (e.g. PV-GRID/PV-LEGAL, Wind Barriers, Keep-on-Track!), EU RE progress reports |
| ***C IV) Treatment of RES-E access and curtailment*** | | |
| **RES-E grid access regime and regulation for curtailment** | RES-E priority: Priority or guaranteed access and full compensation in case of | National legal/ regulatory documents |

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[11] Range is based on recommendations given in (Cena et al. 2010) to lower grid connection time for wind onshore below 6 months and the lead time in the worst performing country across the EU which is 3.5 months.

[12] Range is based on the spread of grid connection times across EU countries as given in the 'PV Grid' database (PV Grid 2014), in the best performing country grid connection permit and connection take 3 weeks, in the worst performing country 50 weeks.

| Indicators | Value ranges / normalization | Data sources |
|---|---|---|
| | curtailment (= 1)<br>Either RES-E priority / guaranteed access or compensation in case of curtailment (=0.5)<br>No RES-E priority or guaranteed access and no compensation in case of curtailment (= 0) | |
| ***C V) Transparency and predictability of grid development*** | | |
| **Predictability of grid development / availability of information on rid extensions** | Transparent & reliable: detailed long-term plans and information publicly available (= 1)<br>Average / medium: Plans available but implementation unclear or lack of clarity and level of detail or long-term vision (= 0.5)<br>Intransparent & non-reliable: No credible plans or information available (= 0) | Grid development plans provided by national TSOs and regulatory agencies, regional associations (e.g. ENTSO-E, ACER), supplemented by consultation of local experts |
| ***D – Administrative procedures for RES-E projects*** | | |
| ***D I) Administrative cost*** | | |
| **Share of administrative cost in total project development cost** | Continuous ranges:<br>Wind : <1.5% = 1, >10% = 0[13]<br>PV: 0% = 1, >50% = 0[14] | Past and ongoing projects (e.g. PV-GRID/PV-LEGAL, Wind Barriers, Keep-on-Track!), EU guidance and RE progress reports, consultation of local stakeholders |
| ***D II) Duration of administrative procedures*** | | |
| **Total administrative lead time (weeks)** | Continuous ranges:<br>Wind: <20 months = 1, >60 months = 0[15]<br>PV: <8 weeks = 1, >48 weeks = 0[16] | Past and ongoing projects (e.g. PV-GRID/PV-LEGAL, Wind Barriers), EU guidance and RE progress reports, consultation of local stakeholders |
| ***D III) Administrative complexity*** | | |
| **Complexity of the administrative process** | Low complexity (= 1)<br>Medium / average complexity (= 0.5)<br>High complexity (= 0) | Perception of local stakeholders, supported by national RE information platforms / institutions , EU guidance and RE progress reports, past and ongoing projects (e.g. PV-GRID/PV-LEGAL, Wind Barriers, Keep-on-Track!) |

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[13] Ranges based on the recommendation given in (Cena et al. 2010) to lower the share to 1.5 % of the total project cost. The highest value across the EU is 5%.

[14] Ranges based on value range across EU countries as presented by (PV Grid 2014). The lowest value is 0%, the highest value is 100%.

[15] Ranges based on the recommendation given in (Cena et al. 2010) to lower administrative lead times to a maximum of 20 months. The highest value across the EU is 58 months.

[16] Ranges are based on own interview results. Interviewees considered a duration of <2 months as acceptable and over 12 months as inacceptable. Average value ranges across EU countries presented by (PV Grid 2014) show a spread between 1 week (for 50 kWp systems) up to 39 weeks (for 2500 kWp systems).

| Indicators | Value ranges / normalization | Data sources |
|---|---|---|
| ***D IV) Integration of RES-E in spatial & environmental planning*** | | |
| **Prioritization of areas for RES-E development in national spatial planning** | Good: specific and sufficient areas for RES-E development are reserved, transparent procedures exist (= 1)<br>Average / medium: No specific areas reserved but RES-E friendly attitude in spatial planning (= 0.5)<br>Poor: no areas for RES development reserved, developers face difficulties to obtain access to possible project sites (= 0) | Interviews with local stakeholders, national legal and regulatory documentation, EU guidance and RE progress reports, policy databases |

## A. Political and economic framework

### I. Existence and reliability of general RE strategy and support scheme

The reliability of the general RES-E policy framework represents the risk associated with drastic and sudden changes in the RES-E strategy and the support scheme itself. In the worst case, this could imply a complete change or abandoning of the present RES-E targets or support scheme or even retroactive changes of support. Desirably, transparent adjustments would be made to continuously improve RES-E support conditions (European Commission 2013b). Therefore, this aspect is highly relevant to provide investors with the certainty that their future projects will still be supported under the national policy environment (Dinica 2006)(Margolis and Zuboy 2006)(Holburn 2012)(Lüthi and Wüstenhagen 2012)(Mani 2012).

Indicators for quantification of this determinant comprise the existence, liability and timeframe as well as the technology specification of the RES-E targets as defined by the national legal documentation. Further, the existence, stability and reliability of the RES-E support scheme are assessed. The reliability is represented by the mechanism for support level adjustments which is, in the best case, based on transparent, scientifically grounded mechanisms or, in the worst case, arbitrary and unpredictable. Relevant data sources for these indicators comprise, besides primary national legal documents, the NREAPs (European Commission 2010) and the RE progress reports (European Commission 2013c) of the Member States. Finally, we included the general policy stability. Although this is not a RES-E investment specific criterion, it exerts a significant impact also on RES-E investment decisions since *force majeure*, corruption or a change of the government could strongly impact RES-E projects. It is represented by the score of the 'Fragile States Index' published by the 'Fund for Peace' (http://ffp.statesindex.org/).

### II. Relative remuneration level for electricity from RES-E

The relative remuneration level under the given RES-E support scheme defines the expected return from a RES-E project under given resource conditions and technological performance parameters. This includes the overall average RES-E remuneration, namely either the FIT or the certificate price (in case of a quota scheme) or premium (in case of a feed-in premium scheme) plus the final electricity price.

This determinant is represented by the net present value of the average remuneration level over the economic lifetime of a RES-E project as resulting under the current RES-E support scheme minus the actual generation cost. Information on RES-E remuneration levels in EU countries can be retrieved from databases such as RES-LEGAL (www.res-legal.eu/) or the regular progress reports of EU MS to the EU Commission (European Commission 2013c) regarding the implementation of Directive 2009/28/EC (European Commission 2009).

### III. Revenue-risk under given RES-E support-scheme

The revenue risk represents the expected stability of the RES-E support level under the given financial support instrument. It may be affected by fluctuations in the remuneration level due to tariff adjustments as foreseen in legislation as well as due to risk factors inherent to the type of support scheme. Broadly speaking, the risks associated with fluctuating certificate- and electricity prices under a quota scheme are higher (i.e. they imply additional market risks) than given the relative stability of a fixed FIT or a premium scheme. However, the resulting risk depends, to a large extent, on the detailed design of the respective support scheme and its elements. The representation and scale for this indicator is based on comparative analyses of risks resulting under different support design options as provided e.g. by works of (Mitchell, Bauknecht, and Connor 2006)(Ragwitz et al. 2007)(Jager and Rathmann 2008)(Bürer and Wüstenhagen 2009)(Rathmann et al. 2011)(Lüthi and Wüstenhagen 2012).

### IV. Access to finance

The access to finance represents the maturity of the national financing environment and the ease to obtain attractive financing for RES-E projects. It includes the availability of capital and the respective financing costs which are influenced by national risk surcharges and the existence of specific RES-E financing schemes.

The indicators for this determinant include generic indices such as the national credit rating (provided by standard&poor) and the interest rate on long term government bonds which are not RE-specific but which can serve as indications for the overall maturity and trustworthiness of the national financing market. These two general indices could be supplemented by evaluation of the ease of getting credit in terms of availability of credit information and the legal liability in the financing sector (http://www.doingbusiness.org/methodology/getting-credit ) as well as the assessment of RES-E stakeholders regarding the access to capital for RES-E projects. For this purpose, it is referred to interviews with national RES-E stakeholders.

## B. Electricity market structure and –regulation

### I. Fair and independent regulation of the electricity sector

Fair and independent regulation implies that electricity market regulation ensures a non-discriminatory access of RES-E producers to the market. This involves a removal of barriers such as unfavourable legislation hindering participation of independent power producers (IPPs) or strong market concentration due to incomplete unbundling. Market barriers and difficulties entering established energy systems are frequently mentioned as major relevant factors for RE technology diffusion (Margolis and Zuboy 2006). Fair regulation also implies the creation and full empowerment of truly independent regulatory organs in the electricity sector (Holburn 2012).

Therefore, the determinant can, on the one hand, be represented by assessing the level of vertical integration in the electricity market (unbundling) and the existence and independence of regulatory institutions and, on the other hand, by evaluating different opportunities for IPPs to participate in the market, represented by the number of options to sell or to generate electricity for own consumption as defined by national legal and regulatory documents. Respective information can also be retrieved from national regulators and regional associations of regulatory agencies such as ACER (www.acer.europa.eu/) or CEER (http://www.ceer.eu/).

### II. Existence of functioning and non-discriminatory short term markets

The availability and accessibility of liquid markets implies short term flexibility for RES-E developers to participate on even ground and to profitably market their RES-E production. For example, gate closure times, the deadlines ahead of real time operations set for participation in the market, may affect the integration of variable RES-E as they reduce the forecasting error, especially for volatile RES-E technologies like wind energy. Thus, shorter gate closure times favour RES-E integration whilst longer gate closure times tend to discriminate against RES-E compared to dispatchable, conventional technologies. The certainty of wind power forecasts is close to 98% for a period of 2 hours ahead but it entails a high error margin if periods go beyond 24 hours (European Commission 2013b:15). To improve the functioning of intraday markets, day-ahead spot auctions should develop towards continuous spot trading close to physical gate closure times (European Commission 2013b:15).

Therefore, this determinant can be represented by an assessment of the liquidity of electricity exchanges (spot markets) as well as through access conditions, i.e. gate closure times. Important data sources in this respect comprise the guidance documents on the internal European electricity market (European Commission 2013a) and the related country reports (European Commission 2014) as well as information provided by regulatory associations such as ACER (www.acer.europa.eu) and CEER (www.ceer.eu) and directly by electricity traders.

### III. Availability of reliable long-term contracts (PPA)

Availability of attractive purchase agreements for RES-E provides long-term certainty for developers, mitigates risks associated with volatile electricity prices and thus provides revenue certainty (Dinica 2006). PPAs are of crucial relevance in support schemes where the electricity price is part of the overall remuneration, such as quota systems with tradable green certificates (TGC) or premium systems. In sliding premium systems and feed-in tariff systems the support scheme itself provides the PPA. The suggested indicator is thus the availability of PPAs for RES-E under the respective RES-E support scheme.

## C. Grid regulation and infrastructure

### I. Cost of RES-E grid access

The cost of grid connection and grid reinforcement indicates how much additional cost the investor will have to face for connecting his project to the grid. This can be a relevant factor influencing investment decisions (Alagappan, Orans, and Woo 2011). Shallow (the developer pays only for connection to nearest grid connection point) or even super-shallow approaches (the developer does not have to pay for grid connection at all) imply a low additional burden, whereas deep charging (developer bears the cost for grid connection and potential grid reinforcement) results in possibly very high extra costs for grid connection which are a major barrier for RES-E diffusion, also in many EU countries (European Commission 2013b). Mixed approaches are also possible.

The assessment of this indicator is based on the charging approach as defined by the national regulation. If there is no such definition in the regulation and the approach is decided on case by case basis, an assessment of past projects or consultation of local stakeholders might be necessary. However, an unclear approach usually implies a lower attractiveness for investors.

### II. Lead time for obtaining RES-E grid access

The lead time for obtaining access and connection to the electricity grid covers the time between the first application for grid access and the realization of the physical access (including waiting times). It can imply substantial delays of the whole project implementation process and might thereby delay the time from which on a project becomes operational and generates revenues. Depending on the technology, the duration can range from a few weeks up to far more than a year. Therefore, it can be a highly relevant factor for the overall project feasibility (Lüthi and Prässler 2011).

As an indicator the total grid access lead time per technology is used.  The range varies depending on the technology and is defined based on interviews with RES-E developers (asking them what would be an acceptable timeframe and when they would refrain from project development) and on observed ranges across EU countries. Grid access lead times in EU countries have been quantitatively assessed in the frame of projects such as

PV-LEGAL/PV-GRID (www.pvgrid.eu) and Wind Barriers (www.windbarriers.eu). Recent, however mostly qualitative, information is e.g. included in the EU progress reports on implementation of the EU RES Directive (European Commission 2013c) and in the database of the project Keep-on-Track! (www.keepontrack.eu). Interviews with project developers and RES-E industry associations are used to fill data gaps.

### III. Predictability and transparency of grid connection procedure

The transparency of the grid connection procedure is influenced by the predictability of the duration and the related cost until the grid connection is established (or the variance in duration and cost, respectively). An obscure and badly defined procedure implies uncertainty and an additional risk for the investor and thus lowers the attractiveness of the project (Lüthi and Prässler 2011) (Alagappan et al. 2011). Although the relevance of this determinant might be technology specific, it has been mentioned as an important criterion by developers of both, wind- (Cena et al. 2010) and PV projects (Lüthi and Wüstenhagen 2012).

It can be represented by assessing the availability of national documentation regulating the process and its duration (e.g. defined maximum durations) complemented by assessing the perception of local stakeholders through interviews. Recent information for the EU is compiled, e.g. in (European Commission 2013b) and on MS level provided in NREAPS (European Commission 2010) and RE progress reports (European Commission 2013c).

### IV. RES-E grid access regime and regulation for RES-E curtailment

The grid access and the regulation in case of curtailment represent the level of certainty that generated RES-E can be fed into the national grid and that it will be remunerated. If power markets are dominated by large incumbents, RES-E access to the market might be difficult, entailing higher volume risks for RES-E generators (European Commission 2013b:16). Therefore, the EU RES Directive  defines that either guaranteed or priority access shall be provided for electricity from renewable sources (European Commission 2009 article 16, paragraph 2 b). Further it defines that, when dispatching electricity, priority should be given to RES-E and that curtailment of RES-E should be minimized and, if necessary to assure system stability, it should be based on transparent criteria (European Commission 2009 article 16, paragraph 2 c). In case that not all RES-E can be transmitted, due to system safety or stability issues, financial compensation could be required for RES-E generators (European Commission 2009 preface, paragraph 61).

However, the level of implementation of these aspects still varies across the EU Member States. In positive cases, RES-E benefits from priority access and is either dispatched with priority or guarantee. Also compensation payments could be guaranteed in case of grid-related curtailment. A less favouring option, which poses a major risk from the viewpoint of RES-E developers, would imply no priority access and no foreseen compensation of curtailment.

### V. Transparent and foreseeable grid development

The transparency and predictability of the future grid development can be relevant factors for the evaluation of potential RES-E project sites (Alagappan et al. 2011). Developers wanting to assess connection options to the grid, depend on the respective information outlining the future development of new grid structures or reinforcements of the existing network. This applies in particular to wind energy projects, which are often located in remote areas. Unavailability of information on grid development plans or, in the worst case, the nonexistence of such plans increases risks for project developers.

Therefore, the availability and accessibility of long-term grid development plans through national TSOs, regulatory- or network agencies is used as indictor for the measurement. In this respect, ENTSO-E (www.entsoe.eu) and ACER (www.acer.europa.eu) are particularly relevant data sources. Also the status of implementation of these plans is included in the indicator.

## D. Administrative procedures for RE projects

### I. Cost of administrative procedure

The cost of administrative procedures comprises the official expenses for obtaining all required building permits, environmental impact assessments and administrative processing fees. The European RES Directive requires Member States to assure that administrative charges are transparent and cost-related (European Commission 2009 article 13, paragraph 1 e). However, depending on the national regulations and administrative practice, the administrative costs can constitute substantial extra cost in the overall project cost and can be a decisive factor for the expected return of a RES-E project.

A suitable indicator for this determinant is the share of administrative cost in total project development cost (excluding RES-E equipment) derived from past projects. Since the administrative cost share will vary substantially between different RES-E technologies, a technology specific range is defined based on interviews with project developers and results from past projects (wind barriers, PV GRID). Besides consultation of local stakeholders, relevant data sources comprise past and ongoing research projects, guidance documents prepared by the EU Commission (European Commission 2013b) and the Member States’ RE progress reports (European Commission 2013c).

### II. Duration of administrative procedure

The realization of a RES-E project can, in principle, be structured into three phases: The planning phase (involving e.g. site selection, resource measurements, conduction of feasibility studies and environmental impact assessments), the implementation phase (construction of the power plant after a construction permit was granted) and the production phase (actual generation and sale of electricity after commissioning and physical connection of the plant to the grid) (Uyterlinde et al. 2003). The administrative lead time, in this context, refers to the phase between the first official inquiry made to the responsible authority and the time when all permits needed for starting the construction of the power plant are available (Cena et al. 2010). This can also be influenced by public resistance to RES-E projects. The administrative lead time can imply substantial delays in the whole project implementation process. Especially for wind energy projects, delays in the permitting process can be a substantial risk factor (Holburn, Lui, and Morand 2010) (Lüthi and Prässler 2011) but also for PV developers the duration of administrative procedures is perceived as an important attribute in their investment decision process (Lüthi and Wüstenhagen 2012).

A suitable indicator for this determinant is the total lead time for obtaining all required permits. The same data sources apply as mentioned under D-I.

### III. Complexity of administrative procedure

The complexity of administrative procedures determines the required effort for the developer to successfully complete the permitting process. A transparent process has clearly defined and manageable requirements in terms of required permits, intermediate steps, evaluation criteria and time limits for decisions. The EU RES Directive requires Member States to safeguard a clearly defined, transparent and coordinated procedure for authorisation, certification and licensing procedures for RES projects (European Commission 2009 article 13, paragraph 1 a). Opposed to this would be an obscure process without time limits for permitting decisions which imply uncertainty. Also the setup of the administrative authorities (e.g. number of authorities on different levels which need to be contacted directly or indirectly, communication & coordination between authorities, etc.) plays a role for the complexity of administrative procedures (Cena et al. 2010). The complexity can be further aggravated if regional differences or a lack of transparency in the procedures exist (Iglesias, del Río, and Dopico 2011).

Therefore, the administrative complexity can’t simply be represented by the number of permits or authorities but depends on the interplay of the concerned stakeholders, namely RES-E project developers and the national authorities. The indicator thus refers to the complexity of the overall process as perceived by local project developers (based on interviews). Besides national RE information platforms the same data sources apply as mentioned for D-I and D-II.

### IV. Integration of RES-E in spatial and environmental planning

Spatial and environmental planning issues can cause additional delays in RES-E project development, e.g. due to conflicts of interest in land use and opposition of other concerned parties (McLaren Loring 2007). Also insufficient or unsuitable areas reserved for RES-E deployment can constitute a barrier (Ohl and Eichhorn 2009). In the best case, suitable areas for RES-E development could be reserved in regional development plans to facilitate the site selection process and to enhance the availability of resource information for project developers (Mani 2012). The RES Directive 2009 requires all EU Member States, apart from coordinating and clearly defining the responsibilities for authorisation, certification and licensing of RES projects, also to coordinate RES with spatial planning (European Commission 2009 article 13 a).

This determinant is represented by assessing the availability of areas for RES-E development as experienced by RES-E developers and as defined by the national legal documentation. Relevant data sources in this respect comprise, apart from interviews, the NREAPS (European Commission 2010) and RE progress reports (European Commission 2013c).

Based on the above mentioned data sources and normalization methods for each indicator representing the 16 determinants, the overall composite indicator can be derived. To this end, the score for each determinant is added up and normalized to 1, leading to a potential maximum score of 16 points.

### 5.1.2 Relevance of the indicator components

In the previous section, the components and data sources of the composite framework indicator have been presented. However, for deriving the final composite indicator score, it is essential to understand the relative weight of every component in the overall RES-E framework. The aggregation of the different components and sub-components of a composite indicator is a particularly critical issue, as the weighting of the sub-components can strongly influence the overall score and thus the message of the indicator result.

Therefore, the weighting of the presented composite framework indicator components is based on empirical results of a comprehensive stakeholder consultation process. This was done via an online platform (www.re-frame.eu) and send-out of questionnaires (see Annex III) to stakeholders from the RES sector (mainly project developers and other actors from the RES industry). The stakeholders were requested to indicate the relevance of the determinants and sub-determinants with respect to a RES-E investment decision on a scale between 10 ("extremely relevant") and 0 ("not relevant at all"). The weighting was supposed to be independent from the country situation but valid on a general level. More than 200 datasets were collected from RES stakeholders across 24 EU countries (plus datasets from actors that described themselves as being active EU-wide and several experts from non-EU countries or with worldwide activities). All major RES technologies (wind, solar photovoltaics, biomass, geothermal, hydro, concentrated solar & solar thermal) are represented among the respondents, especially wind and solar photovoltaics (PV). Graphs showing the characterization of the data sample are provided in Annex III.

Exemplary results on determinant level (see Figure 57) and on sub-determinant level for "political and economic framework" (Figure 58) are presented in the following. Further results are included in Annex III.

Figure 57 shows the weights attributed by the stakeholders to the main determinants of the composite indicator in form of box-whisker plots. Thereby, the boxes represent the ranges which cover 50% of the values (upper and lower quartiles separated by the median) whereas the lines indicate the full range of attributed points (minima and maxima).

The results have been differentiated with respect to the technology background of the respondents in order to identify aspects which relevance might vary depending on the technology concerned. The green bars show the weighting results across all datasets (including experts for all RES technologies). The light orange bars represent the weighting results only for stakeholders who indicated that they were active in the PV (large scale applications) business (but might also be active in other technologies as well). The dark orange bars represent datasets of stakeholders which indicated only expertise with regard to PV (large scale) and which are called "PV-focused". The light blue bars represent the results of datasets for respondents who have expertise in wind onshore (but might also be active in other technologies). The dark blue bars summarize the datasets of respondents who indicated expertise only for wind onshore ("wind-focused"). Consequently, overlaps exist among the datasets for "all RES", "PV" and "wind" but not among the datasets for the technology experts. An overview over the sample differentiation is provided in annex III. The assumption behind this differentiation is that technology experts, who are concentrated on only one RES technology, might have a stronger expertise or a deeper knowledge on certain aspects than stakeholders which are not focused on a specific technology. Therefore, the final weights which are applied to the composite framework indicator are based on the experts' opinions for each technology whenever there is a deviation from the overall weights.

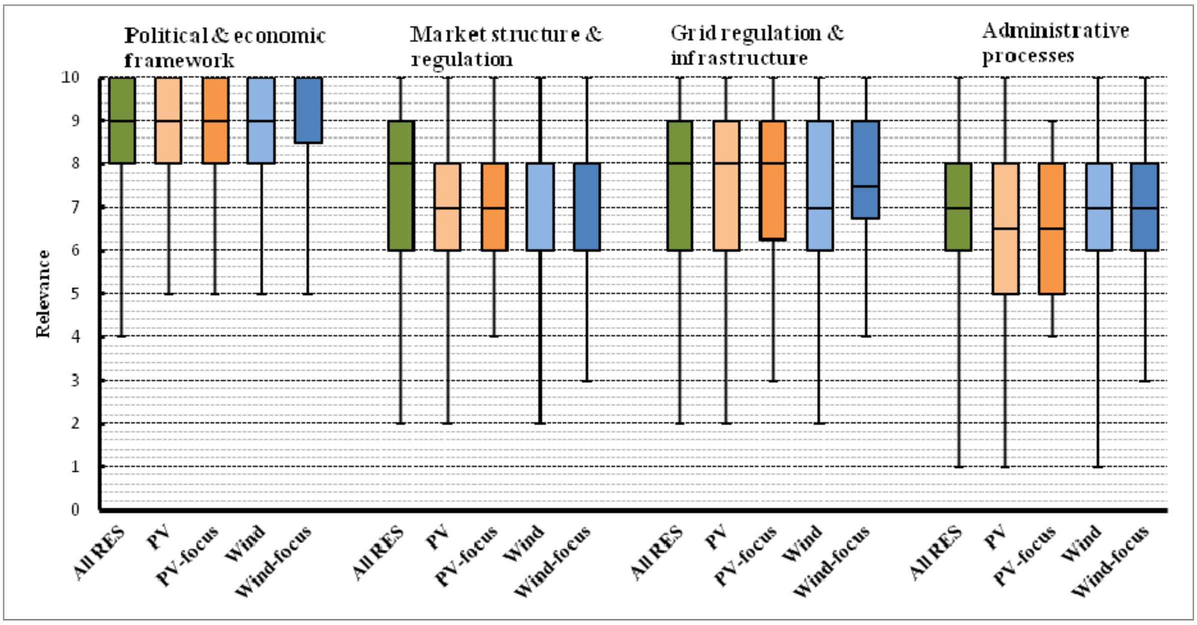

Figure 57 Weights for the main determinants of the composite indicator

It is clearly visible in Figure 57 that the main determinant "political and economic framework" is by far the determinant with the highest relevance to all types of technology experts, with a median relevance of 9 out of 10. This means that 10 points ("extremely relevant") have been attributed most frequently to this determinant and that half of the stakeholders attributed at least 9 points to this factor. For the "wind experts" the median is even 10 points, thus highlighting the relevance for this aspect to the investment-intensive wind projects. Moreover, this determinant shows the lowest spread between minimum and maximum attributed relevance score.

Other determinants such as the market structure, grid regulation and administrative processes are considered as less relevant than the economic framework scoring a median value of 7 to 8. This result underpins the importance of a clear and reliable policy framework in order to achieve a stable and sustained diffusion of renewable energy technologies.

Interestingly, the results for the technology experts show that, for example the market structure and market regulation have a lower relevance for PV experts (median = 7) than for wind experts (median = 8), possibly due to the fact that market integration issues have stronger implications for volatile wind energy generation than for electricity generation from PV. Also administrative processes have a slightly higher relevance for wind projects (median = 7) than for PV projects (median = 6.5) which might be due to the fact that planning and realization of wind projects usually takes longer and involves more complex requirements (e.g. related to environmental impacts) than for PV projects.

On sub-determinant level the weights between the different technologies are more diversified as it can be seen in Figure 58. The general renewable energy policy strategy and the existence of a reliable renewable energy support scheme are clearly considered as the most important factor across all technologies (median = 9). Interestingly, this sub-determinant is rated even higher than the actual level of remuneration (media = 8). The revenue risk and access to finance are rated similarly high (median = 8) but the responses show a higher variety in scores. Most notably, individual stakeholders even considered access to finance as "not relevant at all". Generally, this factor has the largest variance in scores indicating that significant differences between the actors exist. However, the variance for the technology experts is generally lower than for the non-experts. The existence and reliability of the RES policy framework is considered as being more relevant by wind energy experts than by PV experts. This might be explainable by the higher capital requirements related to wind projects entailing a higher risk for the investor in cases of unforeseen policy changes. Regarding access to finance the picture is less clear. PV and wind experts attribute a similar relevance to this issue 8median = 7). Non-experts partly awarded higher points to this aspect. This might be due to them having other, less mature, technologies in mind when awarding the weights or due to a lack of expertise. However this aspect cannot be clarified based on the available data. For the final indicator we will refer to the experts' assessments.

The results for the other three sub-determinants are included in Annex III.

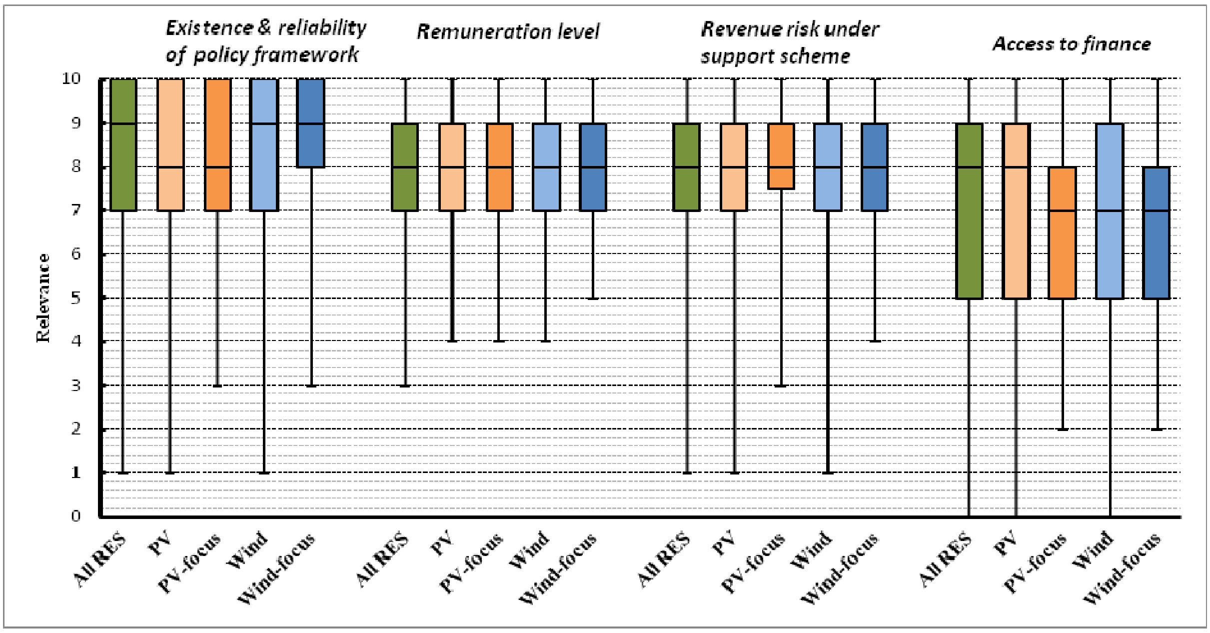

**Figure 58 Weights for sub-determinants of the composite indicator component 'political and economic framework'**

For the final weight of each sub-determinant in the overall composite indicator, we use the median values derived from the survey. The median provides a better representation of the general tendency of a dataset as, e.g. the average values would do, as it is less susceptible to extreme values and potential skewness of datasets, respectively. The final values, i.e. the weights, used for weighting the components of the composite indicator, are presented in Table 5. The weights are derived from a sample comprising 210 datasets. A weight of 0.9 refers to a mean relevance of 9 points out of 10. The weights are used to scale each sub-determinant of the composite indicator meaning that each sub-determinant score (ranging between 0 and 1) is combined with the weighting exponent (see equation 10) thus leading to values of the Composite Indicator between 0 and 1.

### Table 5 Weights of the indicator components

| **Sub-determinant / Indicator component** | | **Weight[17]** | | |
|---|---|---|---|---|
| | | Total | PV | Wind |
| A I | Existence & reliability of RE strategy & -support scheme | 0.9 | 0.8 | 0.9 |
| A II | Relative remuneration level | 0.8 | 0.8 | 0.8 |
| A III | Revenue risk | 0.8 | 0.8 | 0.8 |
| A IV | Access to finance | 0.8 | 0.7 | 0.7 |
| B I | Fair & independent regulation of the electricity sector | 0.8 | 0.7 | 0.8 |
| B II | Existence of functioning & non-discriminatory short term markets | 0.7 | 0.7 | 0.65 |
| B III | Availability of reliable long-term contracts (PPA) | 0.7 | 0.7 | 0.9 |
| C I | Cost of RE grid access | 0.7 | 0.7 | 0.7 |
| C II | Lead time for RE grid access | 0.7 | 0.6 | 0.7 |
| C III | Predictability & transparency of grid connection procedure | 0.7 | 0.7 | 0.7 |
| C IV | Treatment of RE dispatch (curtailment) | 0.7 | 0.7 | 0.8 |
| C V | Transparent & foreseeable grid development | 0.7 | 0.6 | 0.7 |
| D I | Cost of administrative procedure | 0.5 | 0.6 | 0.5 |
| D II | Duration of administrative procedure | 0.7 | 0.6 | 0.8 |
| D III | Complexity of administrative procedure | 0.7 | 0.7 | 0.8 |
| D IV | Integration of RE in spatial & environmental planning | 0.7 | 0.6 | 0.8 |

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[17] The underlined values refer to assessments of technology experts in cases where these deviated from the non-expert assessments.

## 5.2 RES-E diffusion analysis

### 5.2.1 Presentation of the diffusion model

Figure 59 shows a schematic illustration of how the different economic and non-economic factors impact RES technology diffusion. This approach is frequently used in energy models to implement the impact economic and non-economic parameters for the implementation of a diffusion curve. Thereby the resulting market penetration represents the possible (maximum) penetration rate for a certain technology over time (given in MW/a or as % of total available potential). According to general diffusion theory the diffusion of new technologies or products into a market frequently follows an s-curve pattern. This implies a steep (nearly exponential) growth rate at the beginning of the diffusion process followed by linear growth in the mid-term and a saturation of the market (resulting in a relatively slower growth) in the long-term (see, e.g. (Rogers 1995)(Grübler, Nakićenović, and Victor 1999)(Geroski 2000)(Kemp and Volpi 2008)(Rao and Kishore 2010)). In the following we will present an approach how to adapt the diffusion curve for different framework conditions by taking account of the predominant economic and non-economic influence factors introduced before.

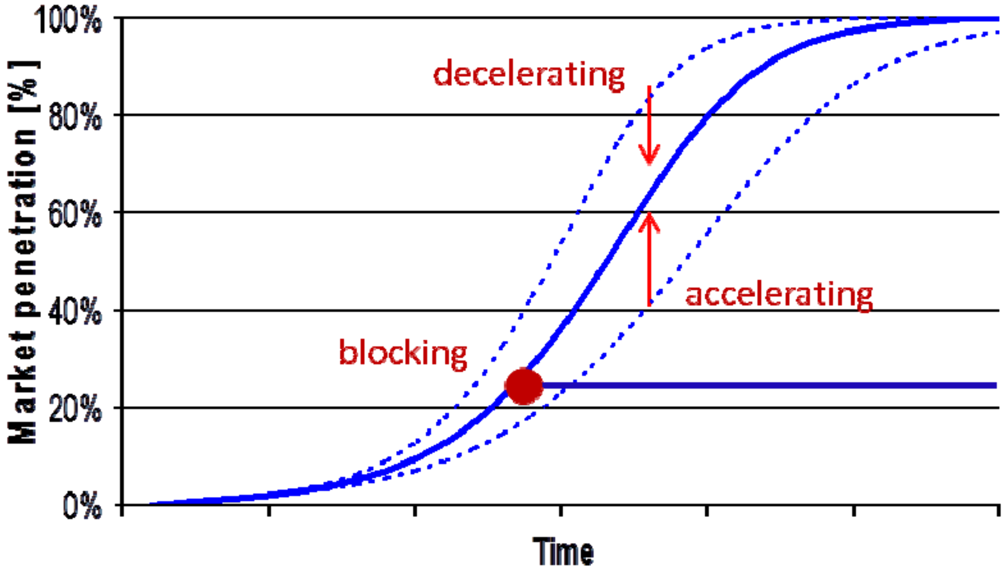

**Figure 59 Schematic, s-shaped diffusion curve indicating the utilized percentage of the total available potential; the dotted lines display accelerated and decelerated diffusion, respectively**

The mathematical representation of the s-shaped logistic function is given in equation 1 below.

$$P(t) = \frac{a}{1 + \exp(-c * (t - t_0)}$$

equation 1

Where: P(t): Penetration over time

e: Euler’s number

Thereby the parameter „a“ represents the saturation level of the s-curve (or the curves maximum value) and can therefore be interpreted as a long term potential of a technology, the parameter "$t_0$" represents a shift on the time axis and impacts therefore the time for which the sigmoid’s midpoint occurs. The parameter "c" is responsible for the actual shape of the curve and therefore for the speed of technology diffusion. It is also called the "steepness" of the curve or "growth rate". Therefore accelerating or decelerating factors for renewable energy diffusion will determine this parameter "c".

The logistic function shown in equation 1 is the solution of the logistic differential equation:

$$\frac{dP}{dt} = c * P * \left(1 - \frac{P}{a}\right)$$

equation 2

This logistic differential equation can then be represented in discrete terms:

$$\Delta P = P_{n+1} - P_n = c * P_n * [1 - \frac{P_n}{a}]$$

equation 3

Therefore the additional penetration is a function of the growth parameter "c" and the long term potential "a". In case of an undistorted diffusion of a technology the growth parameter "c" will be interpreted as the maximum growth that can be achieved if no non-economic barriers exist and economic and financial framework conditions are favorable. The case of a fully undistorted diffusion will hardly exist in real praxis, but best practice cases could be observed in the past, where one might assume, that non-economic barriers were reduced to a minimum and the economic conditions were sufficient to allow for an attractive rate of return. Such a situation was achieved for example in Spain in the period 1994-2004 and in Germany between 1990 and 2002. In both cases a classical logistic growth could be observed for a limited period of time. This is shown in the Figure

60 below for Germany for the period 1990 to 2002 and in Figure 61 for Spain for the period 1990 to 2004. Parameters determined by the fit are c= 0.37, $t_0$ = 19 for the German example and c= 0.36, $t_0$ = 21 for Spain (the long term potentials "a" used for this analysis are given in Table 6 below.

In both countries the effective growth of wind generation after 2004 has been substantially slower than suggested by the logistic curve based on the growth parameter observed in the early years. The classical interpretation of this observation is that non-economic and economic barriers decelerate the undisturbed diffusion. Therefore, the effective growth parameter is diminished by the diffusion constraints characterized by the different economic and non-economic factors limiting an unconstrained diffusion of the technology. This phenomenon has already been observed and discussed by Lund (2006) for a wide range of energy technologies. Lund shows that the growth parameter c often decreases with increasing market penetration. In the case of RES-technologies, an interpretation for this observation may be based on the fact that some constraints and limitations like grid constraints, budget constraints or administrative capacity will only become limiting factors once a certain market share of the new technology is reached.

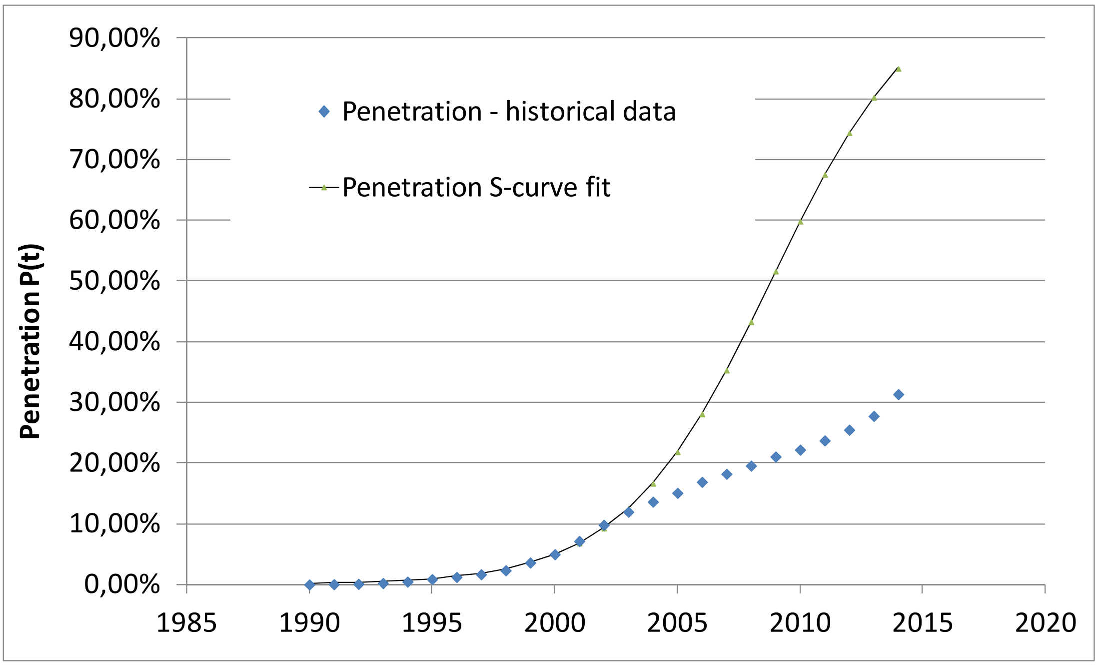

**Figure 60 Optimal fit of a logistic curve to the time series of wind energy penetration in Germany (period of fit 1990-2003).**

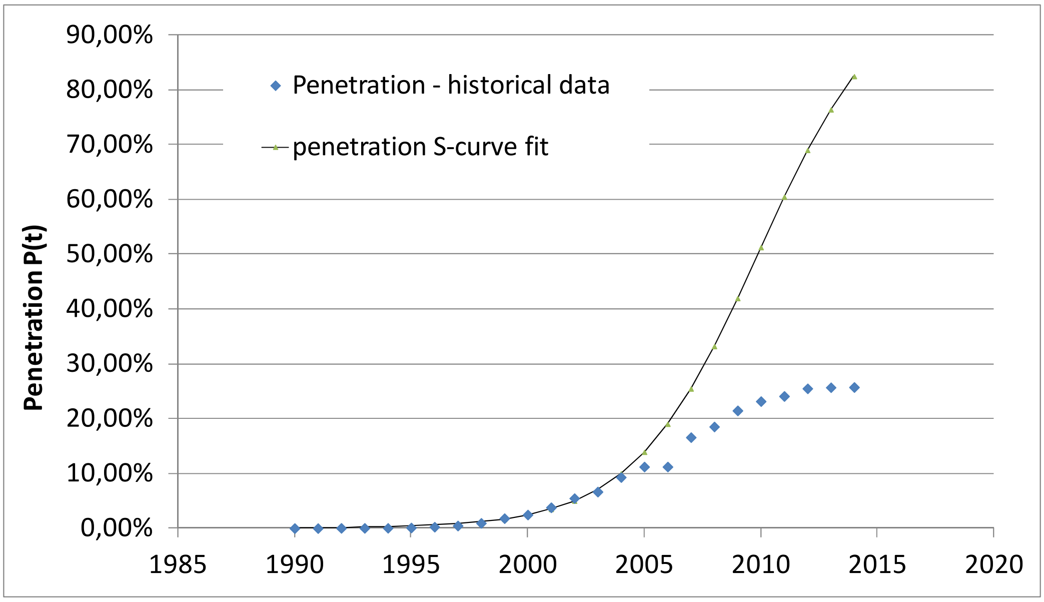

**Figure 61 Optimal fit of a logistic curve to the time series of wind energy penetration in Spain (period of fit 1990-2003).**

Similar as Lund (2006) we have assessed the development of the growth parameter c with increasing the fitting period for the three case study countries Spain, Germany and UK for the case of wind onshore. This is shown in Figure 62 below for a fitting period starting from 1990-1996 and reaching the period 1990-2014 for the case of wind onshore and in Figure 63 for PV.

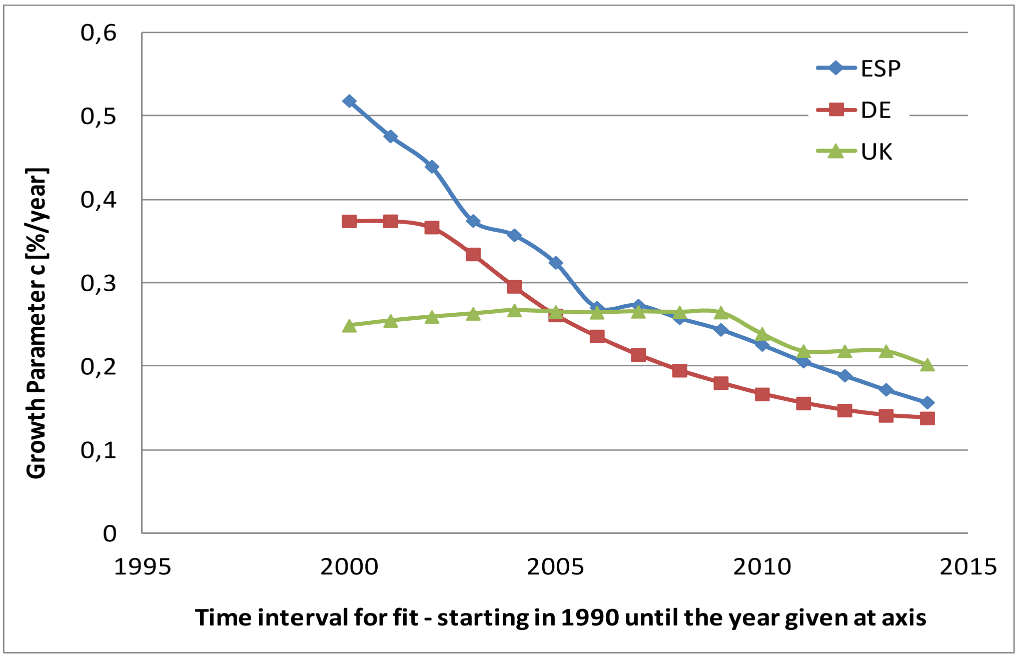

**Figure 62: Temporal behavior of the growth parameter c by increasing the fitting period starting from 1990-1996 to 1990-2014 for the case of wind onshore in Spain, Germany and UK.**

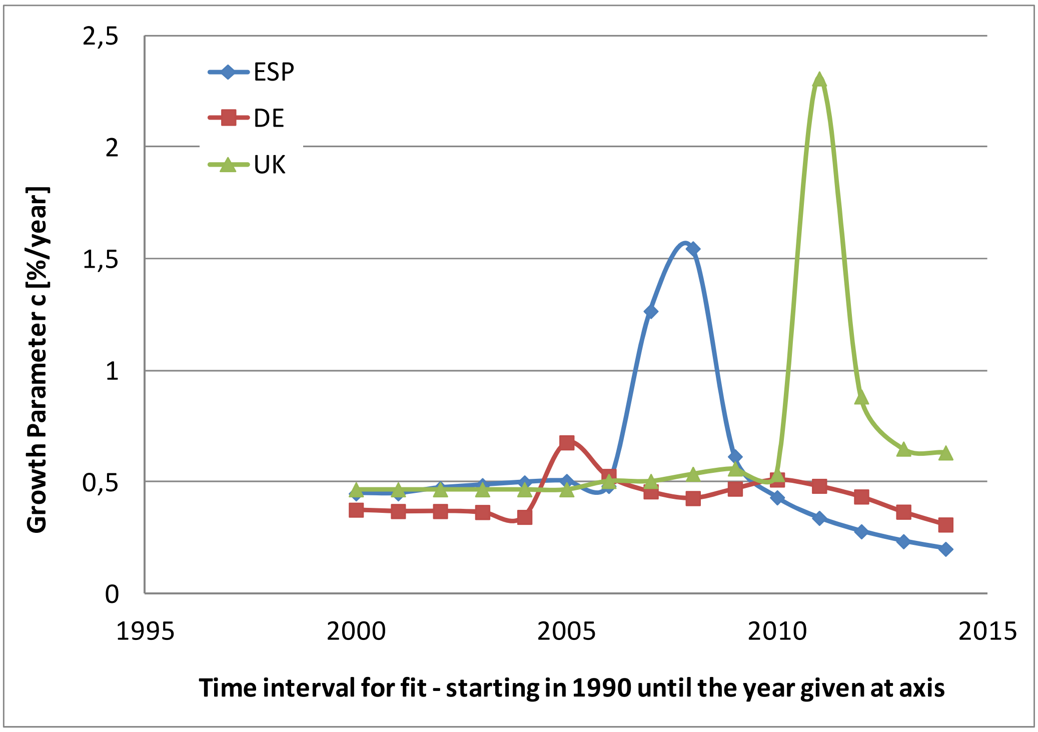

**Figure 63: Temporal behavior of the growth parameter c by increasing the fitting period starting from 1990-1996 to 1990-2014 for the case of PV in Spain, Germany and UK.**

We observe a similar behavior of decreasing growth parameters as a function of the fitting interval as shown by Lund (2006). Therefore the growth parameter "c" is not constant but a function of time "c(t)". Lund assumed that c(t) might take the form of a power curve $c(t)=a * t^{-b} + c$ but could not show clear evidence for the validity of this particular assumption.

Therefore, we will follow a different approach by assuming that the time dependent growth parameter $c_n$ (in a time discrete representation) is the product of the growth given for an unconstrained diffusion "$c_0$", a time dependent Composite Indicator $CI_n$ and a country specific constant $\alpha_{country}$, which contains other country specific aspects which are not covered by the Composite Indicator and which are assumed to be constant, e.g. cultural aspects.

$$c_n = c_0 * CI_n * \alpha_{country}$$ equation 4

Based on equation 3 we can then determine the maximum growth and compare it with the actual growth that was observed in a given country.

$$\Delta P_{\max,n} = c_0 * P_n * [1 - \frac{P_n}{a}]$$

equation 5

$$\Delta P_{act,n} = c_n * P_n * [1 - \frac{P_n}{a}]$$

equation 6

Therefore, we can compute the product of the ratio of the actually observed growth rate and the maximum growth rate of a technology.

$$\frac{\Delta P_{act,n}}{\Delta P_{\max,n}} = \frac{c_n}{c_0}$$

equation 7

Figure 64 below shows the ratio between the time dependent growth parameter $c_n$ and the constant unconstrained growth parameter $c_0$ for wind onshore in Spain, Germany and UK for the period 2000 to 2015 under the assumption $c_0$ = 0.7 (i.e. the largest growth parameter observed for the three countries, namely in the Spanish case).

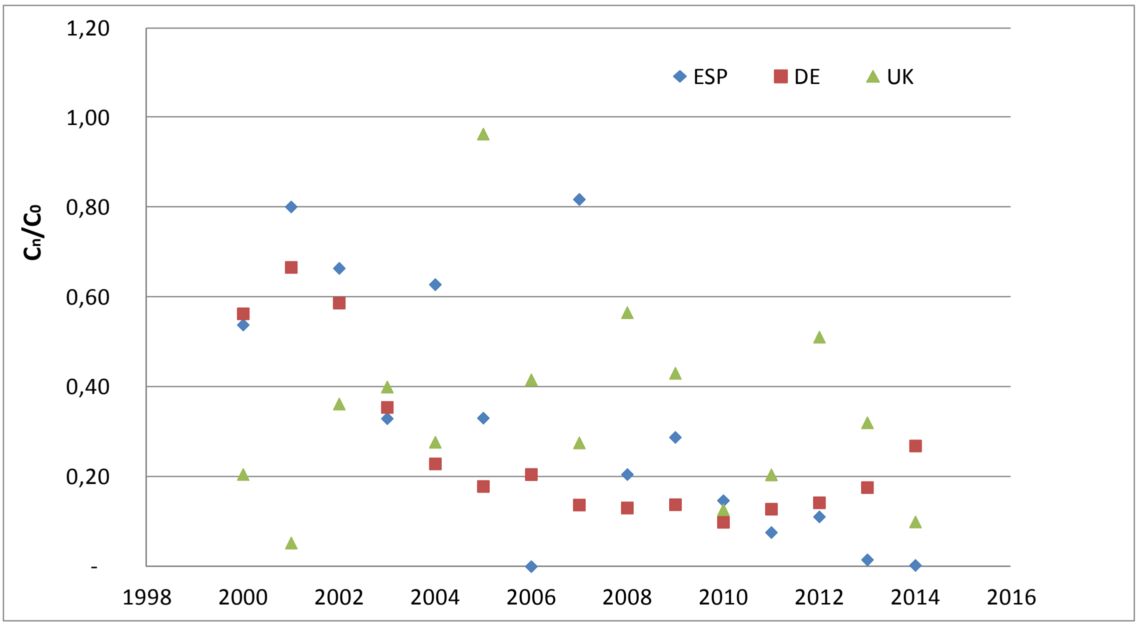

**Figure 64 Ratio between the time dependent growth parameter $c_n$ and the constant unconstrained growth parameter $c_0$ for wind onshore in Spain, Germany and UK for the period 2000 to 2015 under the assumption $c_0$ = 0.7.**

Figure 65 shows the ratio between the time dependent growth parameter $c_n$ and the constant unconstrained growth parameter $c_0$ for PV in Spain, Germany and UK for the period 2000 to 2015 under the same assumption of $c_0$ = 0.7 as for wind onshore.

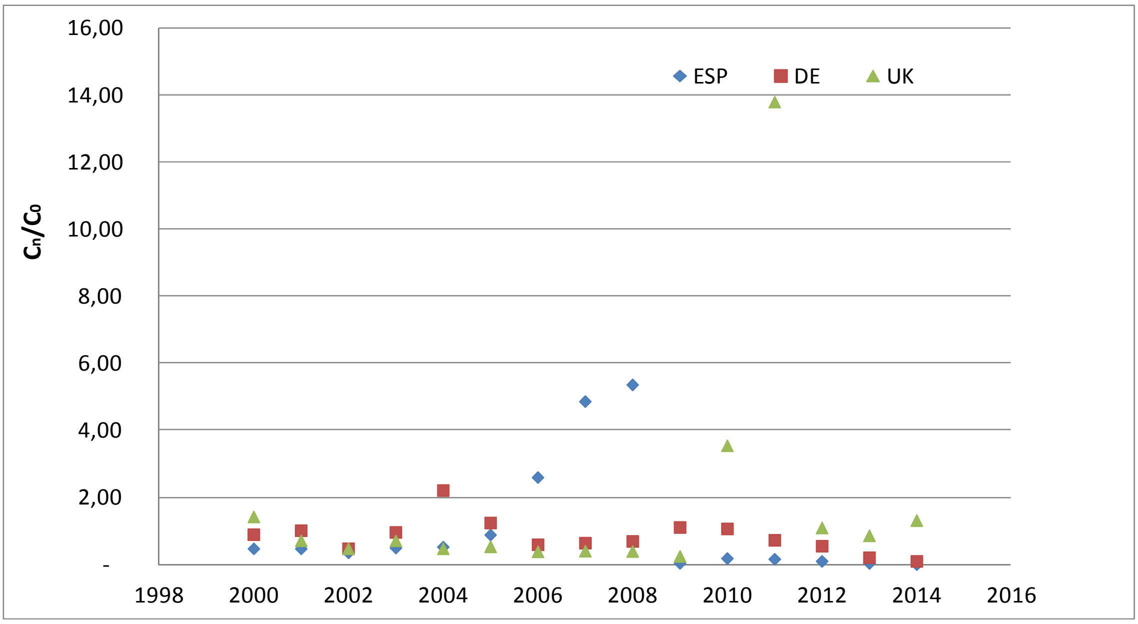

**Figure 65: Ratio between the time dependent growth parameter $c_n$ and the constant unconstrained growth parameter $c_0$ for PV in Spain, Germany and UK for the period 2000 to 2015 under the assumption $c_0$ = 0.7.**

Based on the calculation of the Composite Indicator (CI) we can then, in a last step, determine the country specific constant $\alpha_{country}$. When interpreting the Composite Indicator $CI_n$ we will argue that a time delay between the investment decision and the actual installation of RES capacities needs to be considered. This is caused by the fact, that the barriers measured through bottom-up analysis relate to the moment of the investment decision. However, the growth given in equation 6 relates to the date of installation. For wind energy projects we assume a typical time gap of one year between the investment decision (financial closure of the project) and the date of installation. For PV projects, however, no time gap is assumed, as PV projects typically have much shorter realization time frames than wind projects. Thus it is assumed that they can usually be realized within the same year.

The procedure is presented in further detail in the section below.

The following steps will be carried out for the diffusion analysis:

1. Determination of the saturation level a (achievable long term potential).
2. Estimating the growth parameter "$c_0$" of an unconstrained diffusion in order to determine a maximum growth of the technology.

3. Calculation of the ratio between the time dependent growth parameter $c_n$ and the constant unconstrained growth parameter $c_0$.
4. Calculation of the Composite Indicator (CI) based on the quantification of sub-determinants and weightings as shown before.
5. Calibration of the residual term $\alpha$ based on the assumption of no time delay for PV and a time delay of one year for wind as typical period between final investment decision and installation (i.e. for wind onshore the actual growth in 2014 will be calibrated with the Composite Indicator of the year 2013).

In the following, the individual steps will be discussed in more detail.

### 1. Determination of the saturation level a

The saturation level will be interpreted as the long term potential of a technology. Different literature sources could be used in this respect. Because the Green-X database of mid-term and long-term potentials is continuously updated and consulted with Member States based on a range of national sources we consider this database as best estimate for our purpose. Table 6 presents the figures for the long term potential of wind energy and photovoltaic that are used for the present analysis.

**Table 6: Long term potential for wind onshore and PV for Germany, Spain and UK**

| | DE | ESP | UK |
|---|---|---|---|
| **Long term potential wind power [TWh]** | 177 | 227 | 345 |
| **Long term potential photovoltaic [TWh]** | 139 | 130 | 88 |

### 2. Estimating the growth parameter "$c_0$" of an unconstrained diffusion

By definition there is no "unconstrained diffusion" because in a real word context there are always limiting factors and constraints. However, in some cases or periods of RES evolution, respectively, the growth can be considered as nearly unconstrained, following a pure logistic curve. This was the case, for example, for wind power in Spain between 1990 and 2000. Based on the results shown by Lund (2006) and in Figure 62, we use the value of $c_0$ = 0.7 for the maximum growth parameter for wind onshore assuming that no constraints exist.

### 3. Calculation of the ratio between the time dependent growth parameter $c_n$ and the constant unconstrained growth parameter $c_0$

Based on equation 7 we calculate the ratio between the time dependent growth parameter $c_n$ and the constant unconstrained growth parameter $c_0$ based on the ratio between the growth calculated for an unconstrained diffusion and the actual growth observed. The results of this analytical step are given in Table 7 and Table 8 below.

**Table 7: Ratio between the time dependent growth parameter $c_n$ and the constant unconstrained growth parameter $c_0$ for wind onshore**

| | 2010 | 2011 | 2012 | 2013 | 2014 |
|---|---|---|---|---|---|
| **Spain** | 0,15 | 0,08 | 0,11 | 0,02 | 0,00 |
| **Germany** | 0,10 | 0,13 | 0,14 | 0,18 | 0,27 |
| **UK** | 0,13 | 0,20 | 0,51 | 0,32 | 0,10 |

**Table 8: Ratio between the time dependent growth parameter $c_n$ and the constant unconstrained growth parameter $c_0$ for PV**

| | 2010 | 2011 | 2012 | 2013 | 2014 |
|---|---|---|---|---|---|
| **Spain** | 0,19 | 0,17 | 0,10 | 0,04 | 0,01 |
| **Germany** | 1,07 | 0,73 | 0,55 | 0,21 | 0,10 |
| **UK** | 3,55 | 13,80 | 1,10 | 0,87 | 1,32 |

## 4. Calculation of the Composite Indicator CI based on the determinants and weightings

The Composite Indicator is calculated based on a linear weighting of the logarithmic value of the determinants calculated before.

$$\ln CI = \beta * (w_A * \ln D_A + w_G * \ln D_G + w_P * \ln D_P + w_M * \ln D_M) \qquad \text{equation 8}$$

Therefore, **equation 8** can be expressed as:

$$\ln CI = \ln[D_A^{\beta * w_A} * D_G^{\beta * w_G} * D_P^{\beta * w_P} * D_M^{\beta * w_M}] \qquad \text{equation 9}$$

Or

$$CI = D_A^{\beta * w_A} * D_G^{\beta * w_G} * D_P^{\beta * w_P} * D_M^{\beta * w_M} \qquad \text{equation 10}$$

Considering the observation that RES diffusion will reduce to (nearly) zero as soon as one of the main determinants equals zero, e.g. in case that the remuneration level is lower than the generation costs or if grid barriers prevent grid connection, one finds that the multiplicative model is the most realistic representation of RES diffusion. This observation is also confirmed when analyzing the temporal dynamics of the time dependent growth parameter $c_n$ and of the Composite Indicator $CI_n$ for PV and wind onshore in Germany. We will therefore use this model for the actual calculations in the following.

## 5. Calibration of the residual term $\alpha$

The constant normalization factors $\alpha$ and β, which combine all aspects that are not covered by the list of determinants used in this analysis will be determined by calibrating equation 4 and equation 11 for $\alpha$ and β. Thereby the ratio $c_n/c_0$ is determined based on the actual diffusion during the years 2012, 2013 and 2014 and $CI_{n-\Delta} * \alpha_{country}$ is based on the determination of the composite indicator during these years. Thereby, the calibration will be performed by aligning the ratio $c_n/c_0$ and the product $CI_{n-\Delta} * \alpha_{country}$ for the last year of the observation (i.e. 2014 in our case) as given in equation 12 and by solving the least square problem given in equation 11 for the entire observation period.

$$\begin{aligned}
\Delta P_{data} &= P_{n+1} - P_n = [-\frac{1}{a} P_n^2 + P_n] * c_n \\
\Delta P_{cal} &= P_{n+1} - P_n = [-\frac{1}{a} P_n^2 + P_n] * c_0 * CI_{n-\Delta} * \alpha \\
\min_\alpha &= \sum_{year-n} (\Delta P_{data} - \Delta P_{calc})^2 \\
\Delta P_{data} &= additional\_penetration\_real\_data \\
\Delta P_{calc} &= additional\_penetration\_calculatet
\end{aligned}$$

equation 11

$$\frac{c_n}{c_0} = CI_{n-\Delta} * \alpha_{country} \quad \text{for n = 2014}$$

equation 12

## 5.2.2 Exemplary results for Germany

### 5.2.2.1 *Composite Indicator scores*

Based on the data sources and the methodology described in section 5.1.1, the data for Germany was collected with regard to PV and wind energy (onshore). For this purpose, apart from collection of data from the data sources discussed in section 5.1.1, also 11 semi-structured interviews[18] with RES-E sector experts from Germany were conducted. The majority of the interviewees is directly involved in RES-E project development. A characterization of the interviewees is provided in Table 9.

**Table 9 Overview over interviewed stakeholders in Germany**

| Number | Institutional & technological background |
|---|---|
| **Interview 1** | Investor/ Financing institution, all RES |
| **Interview 2** | Research/consultant, all RES |
| **Interview 3** | RE developer / utility (medium scale), wind onshore |
| **Interview 4** | RE developer (medium scale), wind onshore |
| **Interview 5** | RE developer (large scale), wind |
| **Interview 6** | RE developer/ utility (large scale), wind & PV |
| **Interview 7** | RE developer / utility (medium scale), PV & wind onshore |
| **Interview 8** | Research institution, PV |
| **Interview 9** | RE developer/ manufacturer (large scale), PV |
| **Interview 10** | Research / consultant, focus on PV |
| **Interview 11** | RE developer (medium to large scale), wind onshore |

The scores for the composite framework indicator for PV and wind energy in Germany for the period from 2012 to 2014 are presented in Table 11 and Table 12 below. The unweighted scores are shown in the left-hand column for each year (*PV/wind*) with the sum at the bottom. The right-hand column shows the weighted scores (*PV*/wind**) and the product of the factors based on the formula shown in equation 10.

It can be seen that most of the framework indicators have been stable during the observation period. This shows that the general framework regulating the electricity market (determinants B-I, B-II, B-III) and the grid access (C-I, C-III, C-IV) in Germany are well established and stable and constitute a very favourable environment for the development of renewable energies.

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[18] The interviews followed a comprehensive interview guideline requesting information about the relevant indicators, their present manifestation (min., max., average, optimum) as well as the trend over the past three years.

A positive and stable score can also be observed regarding the revenue risk under the present RES-E support scheme (A-III), as the risk under a support system providing feed in tariffs and feed in premiums is very low once a RES-E project became eligible for the support scheme. Also the reliability of the general RES-E strategy and the support scheme itself (A-I) is rated as very high since the EEG provides a highly reliable basis for RES-E support and the overall policy environment in Germany is among the most stable and secure ones across Europe. A slight limitation applies to the score for PV in 2012 as in this year, additional to the regular amendment of the EEG, an unscheduled reduction of the feed in tariff was announced which limited the attractiveness of the framework for PV developers significantly.

Also access to finance (A-IV) was evaluated as being very good throughout the whole observation period. This is partly due to the low interest rates for commercial bank loans and the stable and low-risk financial market conditions in Germany but can also be attributed to the high availability of financial products specifically for RES-E developers. Interviewees consistently stated that German banks are well experienced with financing of RES-E projects and that access to capital does not constitute a bottleneck for the development of wind or solar projects.

However, also substantial room for improvements can be observed with regard to both, economic and non-economic parameters. For example, the remuneration level for RES-E (A-II) becomes a major limiting factor, especially for PV.

The duration of both, grid access (C-II) and administrative processes (D-II), as well as the cost (D-I) and complexity (D-III) of administrative procedures show further room for improvement. Especially for wind energy, the cost for administrative procedures might become a limiting factor as requirements related to, e.g. environmental impact assessments and other impact studies, compensatory measures as well as the securities for project dismantling are reported to show a rising trend over the past years.

Bottlenecks for both technologies were also identified with regard to the integration of RES in spatial planning (D-IV). Here, interviewees mentioned particularly the exclusion of agricultural areas from the remuneration of PV systems (introduced with the amendment of the EEG in 2010) as problematic. In the case of wind, interviewees mentioned the time delays related to the development of regional spatial development plans as particularly unfavourable and stated that authorities on regional/communal level sometimes lack the technical background for defining appropriate areas for definition of suitable sites and for processing the project applications. Nevertheless, a spatial planning on regional or communal level was mostly seen as the best solution which should be further developed. However, it was suggested that local authorities should receive more guidelines and support to be able to perform this function in a more satisfactory way.

Also the transparency and predictability of the grid development (C-III) did not receive full scores, as the announced grid reinforcement projects in Germany are lagging far behind in their implementation and it is not clear when the planned transmission capacity will actually be available.

**Table 10 Determinants of the framework indicator**

| |
|---|
| A-I Existence and reliability of RES-E strategy and -support scheme |
| A-II Relative remuneration level for RES-E |
| A-III RE revenue risk |
| A-IV Access to finance |
| B-I Fair and independent regulation of the electricity sector |
| B-II Existence of functioning and non-discriminatory markets |
| B-III Availability of reliable long-term contracts (PPA) |
| C-I Grid connection cost |
| C-II Duration of RES-E grid connection |
| C-III Predictability & transparency of grid connection procedures |
| C-IV RES-E access regime and regulation for curtailment |
| C-V Transparency and predictability of grid development |
| D-I Administrative cost |
| D-II Duration of administrative procedures |
| D-III Administrative complexity |
| D-IV Integration of RES-E in spatial & environmental planning |

### Table 11 Diffusion indicator scores for PV in Germany (2012-2014)

| | Score 2012 | | Score 2013 | | Score 2014 | |
|---|---|---|---|---|---|---|
| *Det.* | *PV* | *PV*** | *PV* | *PV*** | *PV* | *PV*** |
| A-I | 0.78 | 0.90 | 0.85 | 0.93 | 0.97 | 0.99 |
| A-II | 0.38 | 0.67 | 0.12 | 0.41 | 0.01 | 0.12 |
| A-III | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| A-IV | 0.91 | 0.97 | 0.91 | 0.97 | 0.93 | 0.97 |
| B-I | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| B-II | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| B-III | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| C-I | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| C-II | 0.68 | 0.88 | 0.68 | 0.89 | 0.68 | 0.89 |
| C-III | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| C-IV | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| C-V | 0.50 | 0.80 | 0.50 | 0.80 | 0.50 | 0.80 |
| D-I | 0.73 | 0.90 | 0.67 | 0.88 | 0.67 | 0.88 |
| D-II | 0.77 | 0.92 | 0.81 | 0.93 | 0.81 | 0.93 |
| D-III | 0.50 | 0.78 | 0.50 | 0.78 | 0.50 | 0.78 |
| D-IV | 0.25 | 0.65 | 0.25 | 0.65 | 0.25 | 0.65 |
| | **12.50** | **0.17** | **12.29** | **0.11** | **12.31** | **0.04** |

### Table 12 Diffusion indicator scores for wind energy in Germany (2012-2014)

| | Score 2012 | | Score 2013 | | Score 2014 | |
|---|---|---|---|---|---|---|
| *Det.* | *wind* | *wind*** | *wind* | *wind*** | *wind* | *wind*** |
| A-I | 0.84 | 0.85 | 0.85 | 0.85 | 0.97 | 0.97 |
| A-II | 0.53 | 0.58 | 0.91 | 0.92 | 0.85 | 0.87 |
| A-III | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| A-IV | 0.91 | 0.93 | 0.91 | 0.93 | 0.93 | 0.94 |
| B-I | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| B-II | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| B-III | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| C-I | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| C-II | 0.98 | 0.98 | 0.98 | 0.98 | 0.98 | 0.98 |
| C-III | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| C-IV | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| C-V | 0.50 | 0.59 | 0.50 | 0.59 | 0.50 | 0.59 |
| D-I | 0.43 | 0.64 | 0.39 | 0.60 | 0.35 | 0.57 |
| D-II | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| D-III | 0.50 | 0.55 | 0.50 | 0.55 | 0.50 | 0.55 |
| D-IV | 0.50 | 0.55 | 0.50 | 0.55 | 0.50 | 0.55 |
| | **13.20** | **0.05** | **13.54** | **0.08** | **13.58** | **0.08** |

Furthermore, the value of the normalisation factors $\alpha$ and β were determined based on the least square problem given in equation 11 and subject to the constraint given in equation 12. The result of this procedure is shown in Table 13 below.

**Table 13: Value of the normalization factors $\alpha$ and β for wind onshore and PV in Germany**

| | DE wind onshore | DE PV |
|---|---|---|
| normalization factor $\alpha$ | 3,47 | 2,94 |
| normalization factor β | 13,03 | 5,78 |

Figure 66 shows the results of the calibration described above based on equation 11 and equation 12 for the example of PV in Germany. The calibration of the Composite Indicator $CI_n$ is performed based on the observations for the growth parameter $c_n$.

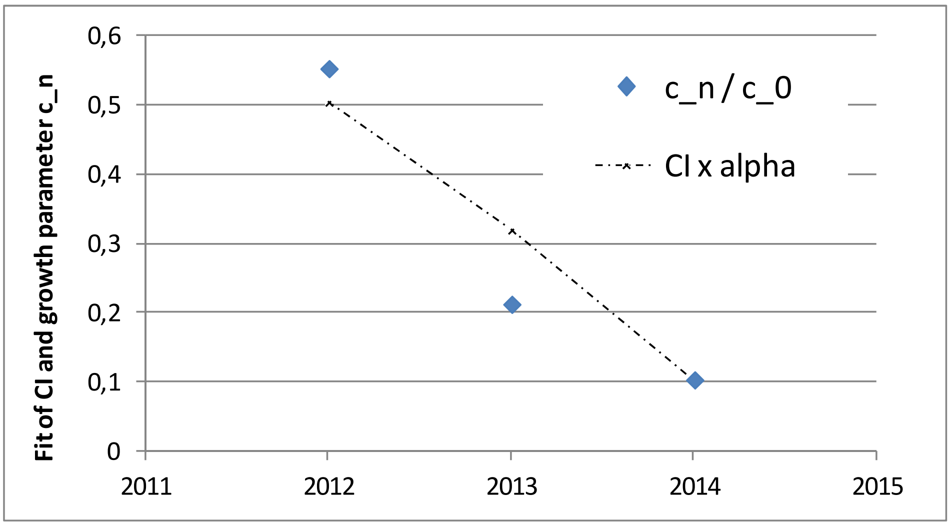

**Figure 66: Calibration of the composite indicator $CI_n$ based on the growth parameter $c_n$**

### 5.2.2.2 RES-E diffusion analysis

Based on the quantification of the normalisation factors $\alpha$ and β, the long term potential "a" and the Composite Indicator CI as shown in section 5.2.2.1, the penetration in year n+1 can be derived from the penetration in year n:

$$P_{n+1} = P_n + c_0 * CI_{n-\Delta} * \alpha * P_n * [1 - \frac{P_n}{a}]$$ equation 13

We start with the case of PV and calculate a short term diffusion outlook for the years 2015 to 2020. Thereby we assess the following three scenarios:

1. **Business as usual**: All framework conditions will remain the same as in 2014 and therefore the Composite Indicator of the year 2014 will be considered as stable in the following years 2015 till 2020.
2. **High Profit**: We assume that the profitability of PV projects after 2014 will be the same as in the year 2013 but all other framework conditions will remain unchanged. Assuming the same profitability as in 2013 means that the difference between remuneration level and generation costs in 2013 is also assumed for the period 2015 till 2020.
3. **Longer administrative procedures**: We assume that the duration of administrative procedures of PV projects after 2014 will be the same as in the year 2012 but all other framework conditions will remain unchanged.

Figure 67 and Figure 68 show the short term diffusion outlook for PV in Germany in terms of the penetration level and the electricity generation for the three scenarios defined above. The following observations can be made from these results:

- Under BAU-assumptions only a moderate growth until 2020 can be expected leading to 34% exploitation of the long term potential and an expected electricity generation of 47.2 TWh and an installed capacity of about 51 GW in 2020. Therefore, the German NREAP target for 2020 is likely to be met under this scenario.
- The assumption of higher profit levels, which are based on the difference of remuneration and costs as realized in 2013, leads to a substantially higher deployment growth after 2014. Under this scenario a penetration level of almost 58% and a generation of about 80 TWh are reached.
- The slight change of the duration of administrative procedures, assuming that the actually achieved reduction between 2013 and 2014 will not be prolonged after 2014, only leads to a very moderate change in the diffusion compared to BAU assumptions. In this case, an electricity generation of 47 TWh is reached by 2020.

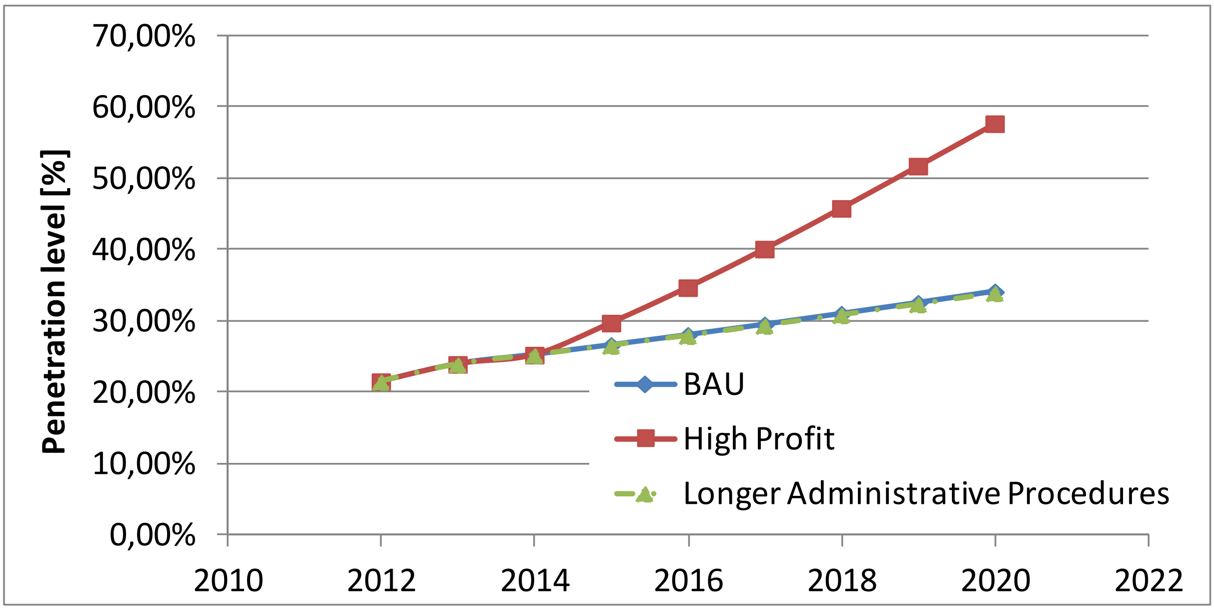

**Figure 67: Short term diffusion outlook for PV in Germany. Shown is the penetration level for the three scenarios defined above.**

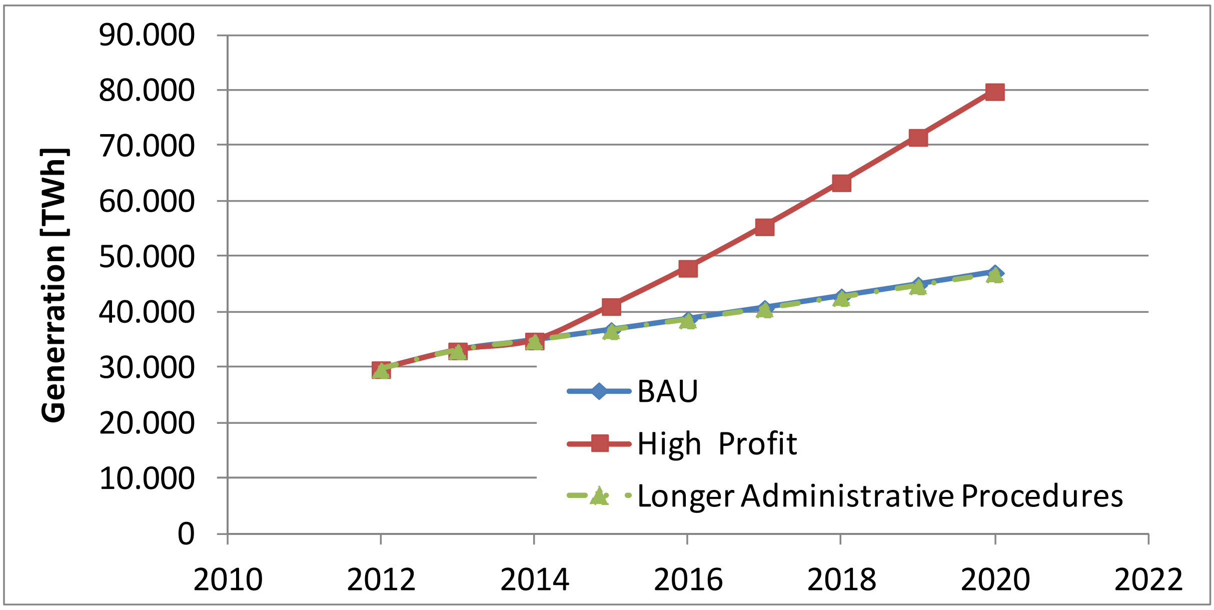

**Figure 68: Short term diffusion outlook for PV in Germany. Shown is the electricity generation for the three scenarios defined above.**

Next we show the case of wind onshore and calculate a short term diffusion outlook for the years 2015 to 2020. Thereby we assess the following three scenarios:

1. **Business as usual**: All framework conditions will remain the same as in 2014 and therefore the Composite Indicator of the year 2014 is also considered for the following years 2015 till 2020.
2. **Lower Profit**: We assume that the profitability of wind onshore projects after 2014 will be the same as in the year 2012 but all other framework conditions will remain unchanged. Assuming the same profitability as in 2012 means that the difference between remuneration level and generation costs as in 2012 is also assumed for the period 2015 till 2020.
3. **Lower administration costs**: We assume that the costs of administrative procedures for wind onshore projects after 2014 will be the same as in the year 2012 while all other framework conditions remain unchanged.

Figure 69 and Figure 70 show the short term diffusion outlook for wind onshore in Germany in terms of the penetration level and the electricity generation for the three scenarios defined above. The following observations can be made from these results:

- Under BAU-assumptions large further growth until 2020 can be expected leading to 59% exploitation of the long term potential and an expected electricity generation of 104.6 TWh in 2020. Therefore, the German NREAP target for 2020 will be substantially overachieved.
- The assumption of lower profit levels, which are based on the difference of remuneration and costs as realized in 2013, leads to a substantially lower growth after 2014. Under this scenario, a penetration level of only 49% and a generation of about 80 TWh are reached.
- The change of the costs of the administrative process, assuming that the lower administrative costs as in 2012 can be achieved also after 2014, leads to a moderate increase of the growth of onshore wind deployment compared to the BAU assumptions. In this case, an electricity generation of 110.5 TWh is reached by 2020.

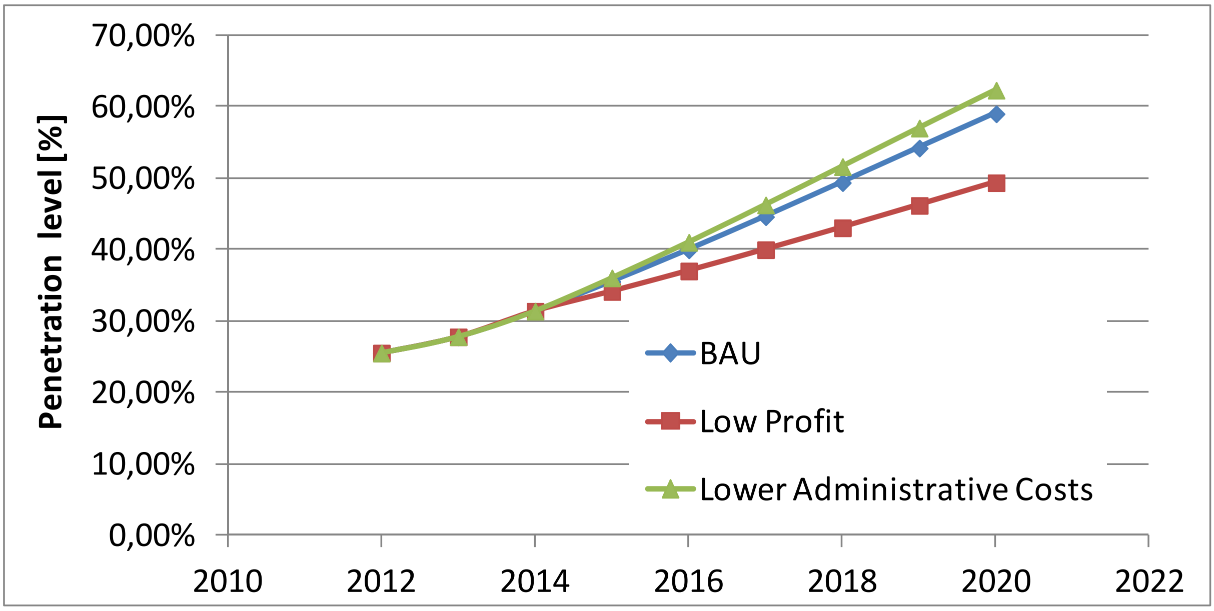

**Figure 69: Short term diffusion outlook for wind onshore in Germany. Shown is the penetration level for the three scenarios defined above.**

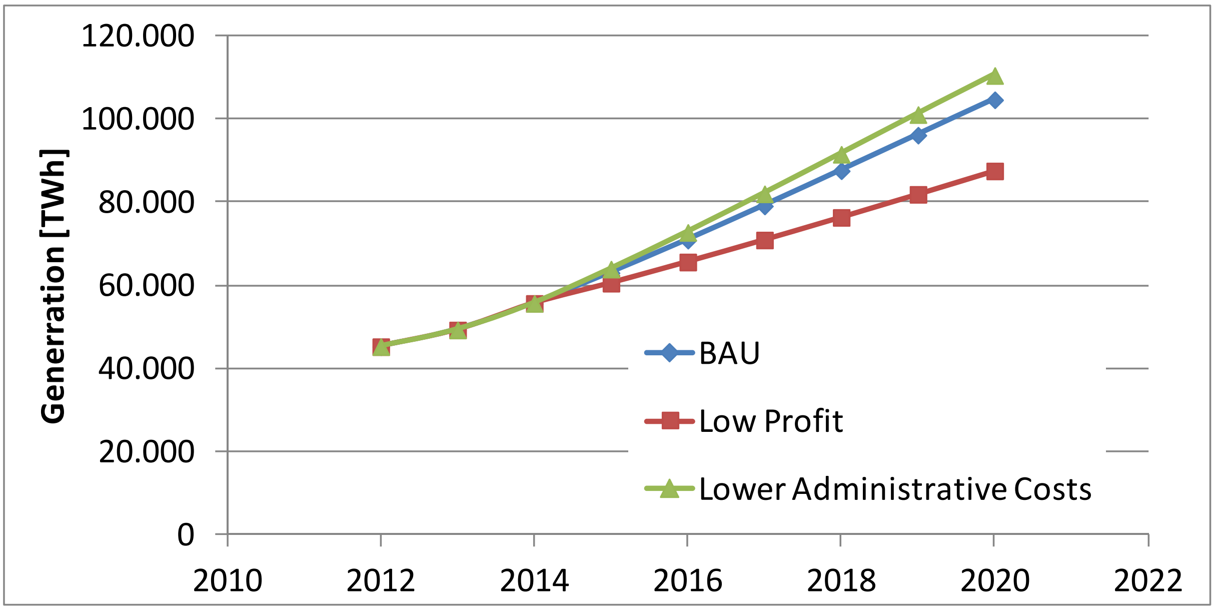

**Figure 70: Short term diffusion outlook for wind onshore in Germany. Shown is the electricity generation for the three scenarios defined above.**

## 5.3 Outlook and next steps

Following the approach described in the foregone sections *5.1.1, 5.1.2* and 5.2.1*,* further country case studies will be performed. Analogue to the initial results for Germany (presented in section 5.2.2), the data for at least one more European country (Spain) will be collected and analyzed to be able to present contrasting results and to test the presented methodology for its transferability.

Furthermore, the impact of individual policy measures will be investigated further by performing additional scenario analyses on country level. To this end, individual parameters of the indicator will be varied and the impact on the overall indicator score and the expected effect on the future RES-E diffusion will be analyzed.

Based on these initial case study results, the approach will be consolidated and e.g. data sources and normalization methods will be refined or additional data will be included. In the medium term, the approach shall be developed further to allow for an application to a broader range of countries (including non-EU countries) and possibly to additional RES technologies. This way the methodological framework of the composite indicator could be used for benchmarking purposes as well as for detailed policy analyses and RES technology diffusion forecasts. Also, the underlying conceptual framework could be used for regular updates of the indicator. It could thus serve as a transparent frame to compile an extensive database of indicators for the major determinants for RES diffusion on country level.

# 6 Key messages and policy recommendations

In the context of this report, we assessed the policy performance of the individual Member States in recent years. Depending on the data available at the time of compiling this report, the time horizon between 2010 and 2012 or 2011 and 2013 was considered. The analysis is based on a set of quantitative indicators that have partly been developed in precedent projects and in this project. *The Policy Effectiveness Indicator* is calculated to evaluate the effectiveness of the support policies. To be able to explain potential differences in the policy effectiveness related to differences in the stage of deployment of a specific RET in a Member State, we have developed the *RET Deployment Status Indicator.* Economic incentives resulting from the support of RET have been compared to energy conversion costs in order to evaluate whether the support level is well adapted to the requirements of a technology. In this context we also calculated the ranges for profit levels enabled by the support schemes. With regard to the electricity sector one further indicator, the *Electricity Market Preparedness Indicator* has been developed in order to monitor the ability of an electricity market to integrate RET.

## 6.1 Key messages

In general, the support policy performance is rather heterogeneous depending on the final energy sector, the renewable energy technology (RET) and the individual Member State. The key messages from the analysis of the policy performance achieved in all EU Member States in recent years are the following:

### Market deployment status and policy effectiveness

The analysis shows a correlation between deployment status and policy effectiveness can be observed: Markets with a higher deployment status often grow faster than markets with a less developed deployment status. However, some countries with a medium deployment status have been catching up with the forerunner countries in terms of policy effectiveness and partly showed even higher policy effectiveness than countries with very advanced markets in case of more advanced technologies, such as wind onshore. Thus, some saturation of more developed markets or reduced policy efforts including Denmark, Spain and Portugal can be observed.

### Relationship between policy effectiveness and support scheme

Past analyses have typically shown a better performance in terms of policy effectiveness of MS using feed-in systems than MS using quota obligations (cf. Steinhilber et al. 2011, Ragwitz et al. 2007). However, this analysis shows that MS using quota obligation including Belgium, Romania and Sweden have gained momentum compared to MS supporting lower cost technologies such as onshore wind power plants by means of feed-in system. Thereby, it should be considered that onshore wind is one of the lower cost technologies and thus stronger benefits from technology-neutral quota obligations as implemented in Romania and Sweden than more costly technologies. For more costly technology, no improvement of policy effectiveness could be observed.

## Relationship between support level and generation costs

As expected, little or no capacity growth can be observed, if support levels are below generation costs. There can be exceptions when investments are motivated by other than economic reasons (e.g. ecologic benefits). Interestingly, there is empirical evidence that high profit levels alone do not result into a strong market growth. Usually this is due to flaws in the support instrument, high risk premiums or non-economic barriers in other parts of the regulatory framework (permitting, grid connection, electricity market structure, etc.). For a policy to be effective, it is crucial to ensure a high stability of policy and a sound investment climate. In general, non-economic barriers for policy design must also be taken into account. Too high support levels are not sustainable on a longer term, since they lead to unnecessarily high support cost and to a lower acceptance of the support scheme by the public.

## Development of the market deployment status

Wind onshore remains the most mature RES-E technology besides hydro. Several Member States have reached advanced deployment and an increasing number of countries have reached intermediate levels. The deployment status of wind offshore is still immature in all Member States except Denmark, which can be considered mature, and Belgium and the UK, with intermediate market status. Photovoltaic technology has experienced very substantial developments in the last years. As a result of technological progress and cost reductions as well as policy incentives, 8 Member States have already reached intermediate deployment status. Some of them already have a sizeable penetration in the power sector and exploit a considerable part of their mid-term potential. With regards to electricity from biomass, 16 Member States reach intermediate development or higher, of which 5 Member States have advanced deployment status and high levels of production as a fraction of their mid-term (2030) potentials. Most Member States remain at an immature or intermediate stage of deployment of biogas plants. The exception is Germany which is by far the most advanced country and produces more biogas electricity than all other Member States combined.

The market of grid-connected biomass heat is fully advanced in the Scandinavian countries with contributions to heat consumption higher than 10% and exploitation of more than 60% of their potential. Estonia, Lithuania, Latvia and Austria are also very advanced markets. The deployment status of biomass heat installations that are not connected to any heating network is generally mature. 18 countries have reached fully advanced deployment status, i.e. they exploit more than 60% of their potential and non-grid biomass covers at least 10% of their heat consumption. Only Cyprus and Malta have reached advanced level of deployment in solar thermal technology, whilst Greece, Austria, Portugal, Ireland and the United Kingdom score intermediate. The markets for heat pumps are still quite immature in the majority of EU Member States. The most advanced markets for geothermal heat are Slovenia, Bulgaria, and Hungary.

## Electricity market status indicator

The requirements for effective electricity market design are evolving with the increasing share of intermittent renewable energy sources (RES). While initially fair remuneration of RES power in the market should be a priority for market design, a more systemic focus on system flexibility should be adopted with a rising share of RES. This will likely comprise increasing shares of demand response and storage – but should also make use of the already existing flexibility in the integrated power system. This can be reflected in how the system matches temporal profiles of different generation and load types and how it accommodates the spatial profile of intermittent RES generation. The Market Preparedness Indicator assesses the openness of the power systems for RES in the EU Member States. The indicator consists of six sub-indicators:

- A: Utilization of transmission capacity,
- B: Allocation of transmission capacity: market coupling,
- C: Flexible transmission use,
- D: Liquidity of spot market,
- E: Gate closure time, and
- F: Liquidity of intraday market.

The results show that particularly Portugal, Spain and the United Kingdom, but also Austria, Belgium, Denmark, Germany, Finland, France, Italy, Latvia, Luxembourg, the Netherlands and Sweden have already relatively prepared electricity markets for a higher share of intermittent RES (this does not automatically mean that they are well integrated into the European electricity market). Other countries are less prepared or lack data availability. EU Member States should take the necessary actions to improve their market preparedness for RES and score higher in the respective sub-indicators.

## Forward-looking RES diffusion indicator

The results of a large scale survey among more than 200 RES-E experts across the EU emphasize the role of non-economic factors which play a major role for the diffusion of renewable energy technologies, apart from direct economic factors.

Particularly important are the stability and reliability of the RES policy framework (median score for relevance of 9 out of 10), as this factor received even higher scores than the actual remuneration level (median score of 8) and the revenue risk (median score of 8). Also the duration and complexity of administrative and grid connection procedures are highly relevant aspects from the investors’ perspective (median scores 6-8) as well as the integration of RES planning with spatial planning (median score 7). Grid related aspects received scores between 6 and 8, depending on the RES technology concerned.

Several differences in the relevance of the framework factors could be observed between the RES technologies. For example, the duration and complexity of administrative and grid connection procedures and the integration of RES planning with spatial- and environmental planning have a notably higher relevance for onshore wind compared with PV. Also grid access conditions and the regulation for curtailment as well as a transparent grid development were rated higher with respect to wind.

The diffusion analysis could show that even small variations in the overall RES-E framework conditions (such as the cost or duration of administrative procedures) can lead to significant differences in the expected future deployment of the technologies.

Case study results for Germany show that variations in the support level lead to significant changes in the future deployment of PV (high profit scenario) compared to a business as usual (BAU) scenario. Under the BAU-scenario 34% of the long term potential are exploited until 2020, reaching an installed capacity of about 51 GW. Under a high profit scenario a penetration level of almost 58% can be reached by 2020. A slight change in the duration of administrative procedures only leads to small variations in the 2020 penetration level. For wind energy onshore BAU-assumptions lead to further growth until 59% of the long term potential are exploited by 2020 (80 TWh). A scenario with lower administrative costs leads to a moderate increase of deployment, compared to the BAU scenario. In this case an electricity generation of 110.5 TWh is reached by 2020.

Although these are just preliminary results for one case study, it could be shown that the interplay of various economic and non-economic framework factors has a significant impact on the future growth of RES-E technologies and that a close monitoring of both is required to allow for optimization of RES policy strategies.

## 6.2 Policy recommendations

### Knowledge of generation costs must be improved

The assessment of policy performance indicators underlines that detailed knowledge of generation costs is required when designing renewable support schemes. Profit levels should be kept on a moderate level so that windfall profits and overcompensation can be avoided. With currently still steep cost-potential curves, support for renewables should be implemented in a technology-specific format.

### Carefully design support level close to generation costs and consider non-economic design elements

Interestingly, there is empirical evidence that high profit levels alone do not result into a strong market growth. For a policy to be effective, it is crucial to ensure a high stability of policy and a sound investment climate. In general, non-economic barriers for policy design must also be taken into account.

### Technology-specific versus technology-uniform support

Experiences with technology-neutral support schemes have shown that these may either lead to considerable windfall profits of lower cost technologies or failing to deploy less mature technologies. Provided that the cost differences of the various RES, we still predominantly recommend the application of technology-specific support. This is supported by the development in the MS, where several MS have introduced technology-specific elements in their originally technology-neutral quota systems. However, if the cost-potential curve in a MS is rather flat and abundant potential is available, a technology-neutral support system can be advantageous.

### Constantly monitor technology costs and adapt support payments

This is a solid measure to avoid overcompensation in particular for technologies with a dynamic cost development such as Solar PV. Moreover, experience shows that automatic payment cuts based on transparent criteria are more effective than payment cuts that have to be adopted in a parliamentary process.

### MS with less experience should take into account best practice examples of other MS

Countries with less developed markets should take advantage of experiences made in other MS. In this way, MS can avoid repeating mistakes made in other MS and improve their own policy design by aligning policy design with the best-practices.

### Need to improve Member State preparedness for RES market integration

The Electricity Market Preparedness indicator shows strong differences between EU Member States. Particularly Spain, Portugal and the United Kingdom, but also Austria, Belgium, Denmark, Germany, Finland, France, Italy, Latvia, Luxembourg, the Netherlands and Sweden show already today a high market preparedness to integrate RES. In contrast markets in Bulgaria, Greece, Slovakia and Romania (and despite lacking data probably also Cyprus and Malta) currently lack this market preparedness for RES.

Where Member States scored low, they should take action to improve the respective situation. All Member States (the TSOs and electricity exchanges respectively) need to further support the *development of market coupling*, foremost regarding the implementation of intraday market coupling, flow-based market coupling, the harmonization of gate closure times, etc. *Grid connection regimes* should, where not yet done so, be changed to "shallow" regimes. Member States should *use their PTC more effectively* by improving calculations. *Liquidity of spot markets* should be improved to lower barriers for small RES producers selling on the electricity market. *Liquidity of intraday markets* should also be further improved.

## Need to improve data availability on market preparedness

The analysis has also shown that there is still a lack of data available on electricity market preparedness among Member States. There is general sufficient and up-to-date data on the sub-indicators *A: Utilization of transmission capacity* (NTC-PTC ratio), *B: Market coupling*, *C: Flexible transmission use* (connection charges) and *D: Liquidity of spot market*. The sub-indicators *E: Gate closure time* and *F: Liquidity of intraday market* however lack data for several Member States. With more data available, also the potential indicators for electricity market preparedness described in section 2.4.2 and the Annex could be assessed and deliver an even more comprehensive overview on market preparedness in EU Member States.

## Need to support diffusion of best practices with regard to non-economic framework factors for RES diffusion

The results of the stakeholder survey and the diffusion analysis have emphasized the outstanding role of a stable and reliable RES policy framework and the diffusion of best practices especially with regard to the various administrative processes and spatial planning for RES. Regional authorities responsible for RES-E project authorisation and spatial planning could be further supported through provision of best practice guidelines. Also stricter time limits for permit approval were mentioned by many stakeholders as a suitable measure to improve the predictability of the planning procedures and to reduce risks and costs for the developers.

# 7 Annex I: Potential additional indicators

The following indicators have been identified in section 2.4.2 but left out due to missing data availability:

## RES value to power system

### Integration of energy and transmission markets

Indicator: Redispatch costs

Redispatch costs are a strong indication of too large bidding zones, and create incentives for TSOs to limit additional RES connection. If transmission constraints occur in a meshed network between zones, but no redispatch costs are incurred within zones, this indicates discrimination against international flow patterns. In contrast, if redispatch costs increase significantly, increasing needs for short-term interventions can raise concerns about system security. One could check if redispatch costs are increasing significantly, by for instance surveying TSOs on behalf of COM.

### Integration of energy, transmission, and system services

Indicator: Qualitative expert review

An effective energy market design needs to enable conventional inflexible generation assets to reflect physical constraints (like start-up, part-load and ramping constraints) in bids, to allow for full use of flexibility of such assets and full remuneration of such flexibility. Moreover, an effective power market needs to allow for a determination of reserve and response requirements based on system configuration. Together this reduces must-run needs of the system. The integration of energy and ancillary service markets, including across national and TSO boundaries, will be of increasing value with rising shares of intermittent renewable resources and the resulting increase of flexibility requirements. One could measure, for instance, to what extent different bid formats allow for flexible participation, or the possibility of joint energy and system service bids.

## Effective use of intra-day updates

### Avoiding penalty in mechanisms

Indicator: Size of pooling units

Balancing market design can create artificial penalties for deviation from earlier schedules. If these exceed cost to system, then they discriminate against smaller players and RE. As the objective of market integration focuses on enhancing the revenue stream while limiting imbalance costs, balancing mechanisms without imbalance penalty are important.

### Interzonal or international integration of balancing markets

Indicator: Share of neighbouring countries with which the balancing market is integrated

Integration of balancing markets will allow for sharing of resources, thus limiting resource needs and costs. As currently a network code is under discussion, this indicator would need to be suited to the design structure evolving in the code.

### Market concentration in generation

**Indicator:** Number of companies with more than 5% share in generation capacity

A competitive market (or very close market monitoring) is essential to ensure fair prices for all players and system efficiency. The competition level can be approximated by the market concentration in the wholesale market.

# 8 Annex II: Data used for sub-indicators

**The data for the six sub-indicators was taken from the following sources:**

*Sub-indicator A*

*NTC values:*

Data source for hourly day-ahead NTCs 2012 for most borders:

ENTSO-E. (2014). Transparency platform: Day-ahead NTC for 2012. Retrieved from http://www.entsoe.net/transmission-domain/ntcDay/show?name=&defaultValue=false&viewType=TABLE&dateTime.dateTime=03.04.2013+00:00|UTC|DAY&border.values=CTY|CZ!BZN_BZA_10YCZ-CEPS-----N_BZN_BZA_10YAT-APG------L&border.values=CTY|CZ!BZN_BZA_10YCZ-CEPS-----N_B

- Direction: From respective country to other countries

Data source, NTC means 2012 for DE>CH, DE>NL, DE>CZ&PL, NL>DE:

Bundesnetzagentur Bundeskartellamt. (2014). Monitoringreport 2013.

- NTC, 2012, mean

Data source, NTC means 2012 for DE>AT, AT>DE, PL>DE, PL>CZ, CZ>DE, IE(SEM)>GB:

Axpo. (2014). Internal update (estimation with experts) based on NTC values 2010 published by ENTSO-E and considering network expansions

*PTC values:*

ENTSO-E. (2013). Yearly Statistics & Adequacy Retrospect 2012. Retrieved from: https://www.entsoe.eu/publications/statistics/yearly-statistics-and-adequacy-retrospect/Pages/default.aspx

Both cumulative PTCs and NTCs account for lines to non EU countries as stated by ENTSO-E.

*Sub-indicator B*

ENTSO-E. (2014). Transparency platform: Daily explicit auction.

Retrieved from http://www.entsoe.net/transmission-domain/dayExplicitAuctions/show?name=&defaultValue=false&viewType=TABLE&dateTime.dateTime=05.07.2012+00:00|UTC|DAY&border.values=CTY|AT!BZN_BZA_CTA_10YAT-APG------L_BZN_BZA_CTA_10YCH-SWISSGRIDZ&direction.values=Export&di

*PTC values:*

ENTSO-E. (2013). ENTSO-E Interconnected Network System Grid Map. Retrieved from: https://www.entsoe.eu/news-events/announcements/announcements-

archive/Pages/News/the-2013-entso-e-interconnected-network-grid-maps-are-now-available.aspx

ENTSO-E. (2012). ENTSO-E Ten-Year Network Development Plan. Retrieved from: https://www.entsoe.eu/fileadmin/user_upload/_library/SDC/TYNDP/2012/TYNDP_2012_report.pdf

*Sub-indicator C*

ENTSO-E. (2013): Overview of transmission tariffs in Europe: Synthesis 2013. June 2013.

Retrieved from https://www.entsoe.eu/about-entso-e/market/transmission-tariffs/

*Sub-indicator D*

Eurostat. (2012): Eurostat Database: Energieendverbrauch von Elektrizität. 24 April 2014. Retrieved from http://epp.eurostat.ec.europa.eu/tgm/table.do?tab=table&init=1&language=de&pcode=ten00097&plugin=1

APX power spot exchange. (2013): Market results. Retrieved from: http://www.apxgroup.com/market-results/cweanduk/

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GME. (2014): Electricity Market: Excel historical data. Retrieved from: http://www.mercatoelettrico.org/En/Tools/Accessodati.aspx?ReturnUrl=%2fEn%2fdownload%2fDatiStorici.aspx

NordPool Spot (2014): Elspot volumes. 02 Mai 2014. Retrieved from: http://www.nordpoolspot.com/Market-data1/Elspot/Volumes/ALL1/Hourly11/

OMEL (2014): Resultados Mercade. Retrieved from: http://www.omel.es/files/flash/ResultadosMercado.swf

European Commission. (2013): Quarterly report on European electricity markets, Volume 6, December 2013.

*Sub-indicator E*

ENTSO-E (2012): Working Group Survey on Ancillary Services Procurement & Balancing market design, September 2012. ENTSO-E Working Group Survey on Ancillary Services Procurement & Balancing market design, ENTSO-E, September 2012

*Sub-indicator F*

ACER/CEER (2013): Annual Report on the Results of Monitoring the Internal Electricity and Natural Gas Markets in 2012, November 2013.

# 9 Annex III: Background to forward-looking indicator

Please specify the general relevance for RES-E technology diffusion:

1. Start here by allocating points to each category according to its relevance for the diffusion of one RE technology.

2. Continue with the same procedure for each sub-category group.

10 = Extremely relevant
5 = Moderately relevant (indifferent)
0 = Not relevant at all

The Rating shall not reflect the current country situation but the general relevance!

Technology: ____

| Category | ☐ | Sub-category | ☐ |
|---|---|---|---|
| Grid regulation & infra-structure | ☐ | Treatment of RES-E dispatch (curtailment) | ☐ |
| | | Cost of RES-E grid access (charging approach) | ☐ |
| | | Duration of RES-E grid access | ☐ |
| | | Predictability / transparency of grid connection procedure | ☐ |
| | | Transparent & foreseeable grid development | ☐ |
| Administrative processes | ☐ | Duration of administrative procedure | ☐ |
| | | Cost of administrative procedure | ☐ |
| | | Integration of RES-E in spatial & environmental planning | ☐ |
| | | Complexity of administrative procedure | ☐ |
| Political & economic framework | ☐ | Access to finance | ☐ |
| | | Existence & reliability of general RES strategy & support scheme | ☐ |
| | | Revenue risk under given support scheme | ☐ |
| | | Remuneration level for RES-E | ☐ |
| Market structure | ☐ | Availability of reliable long-term contracts (PPA) | ☐ |
| | | Existence of functioning & non-discriminatory short term markets for RES-E | ☐ |
| | | Fair & independent regulation of RES-E sector | ☐ |

Figure 71 Questionnaire for assessment of the relevance of the components of the forward-looking indicator (weighting questionnaire)

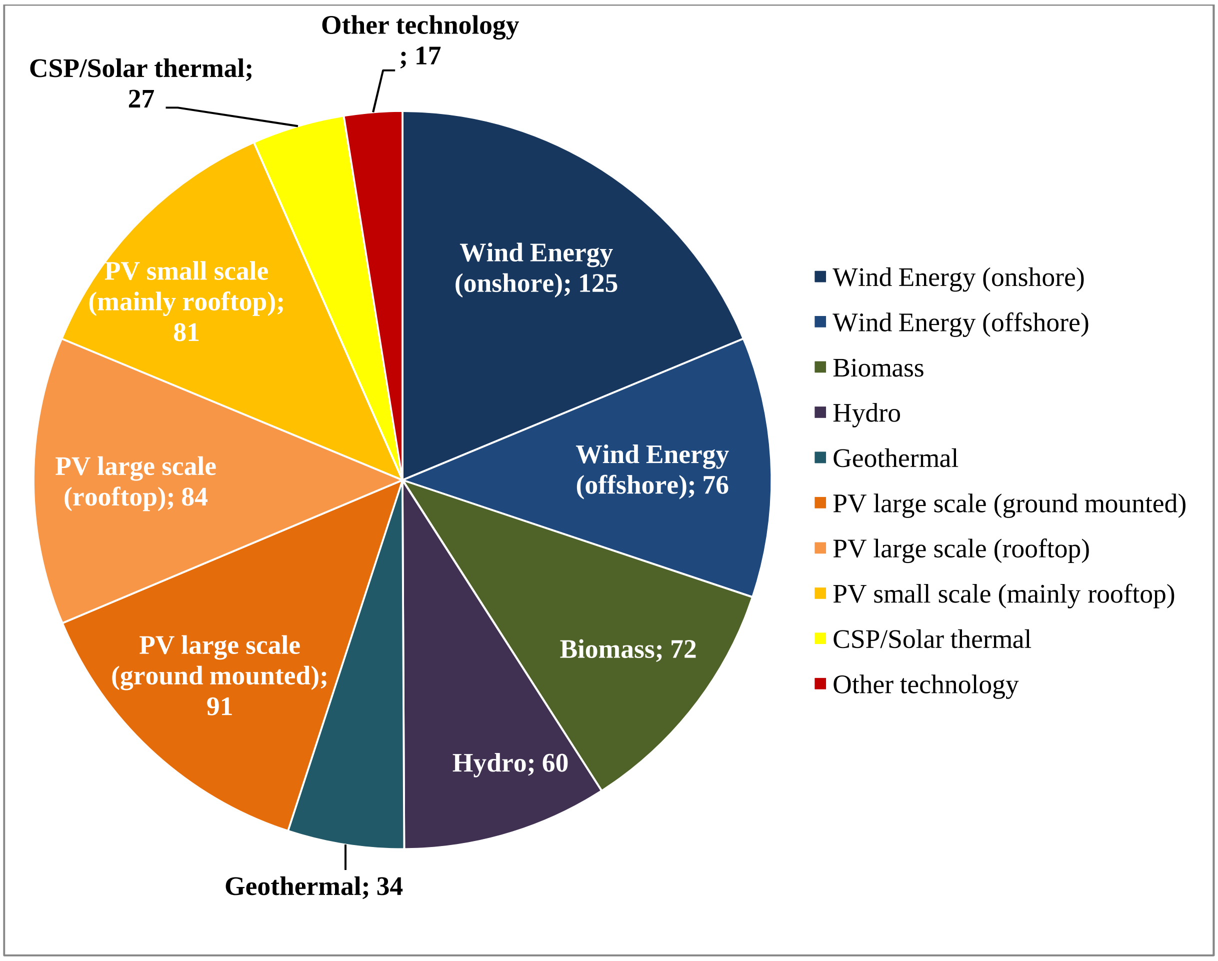

**Figure 72 Technological background of the respondents to the weighting exercise**[19]

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[19] Please note that multiple answers were possible

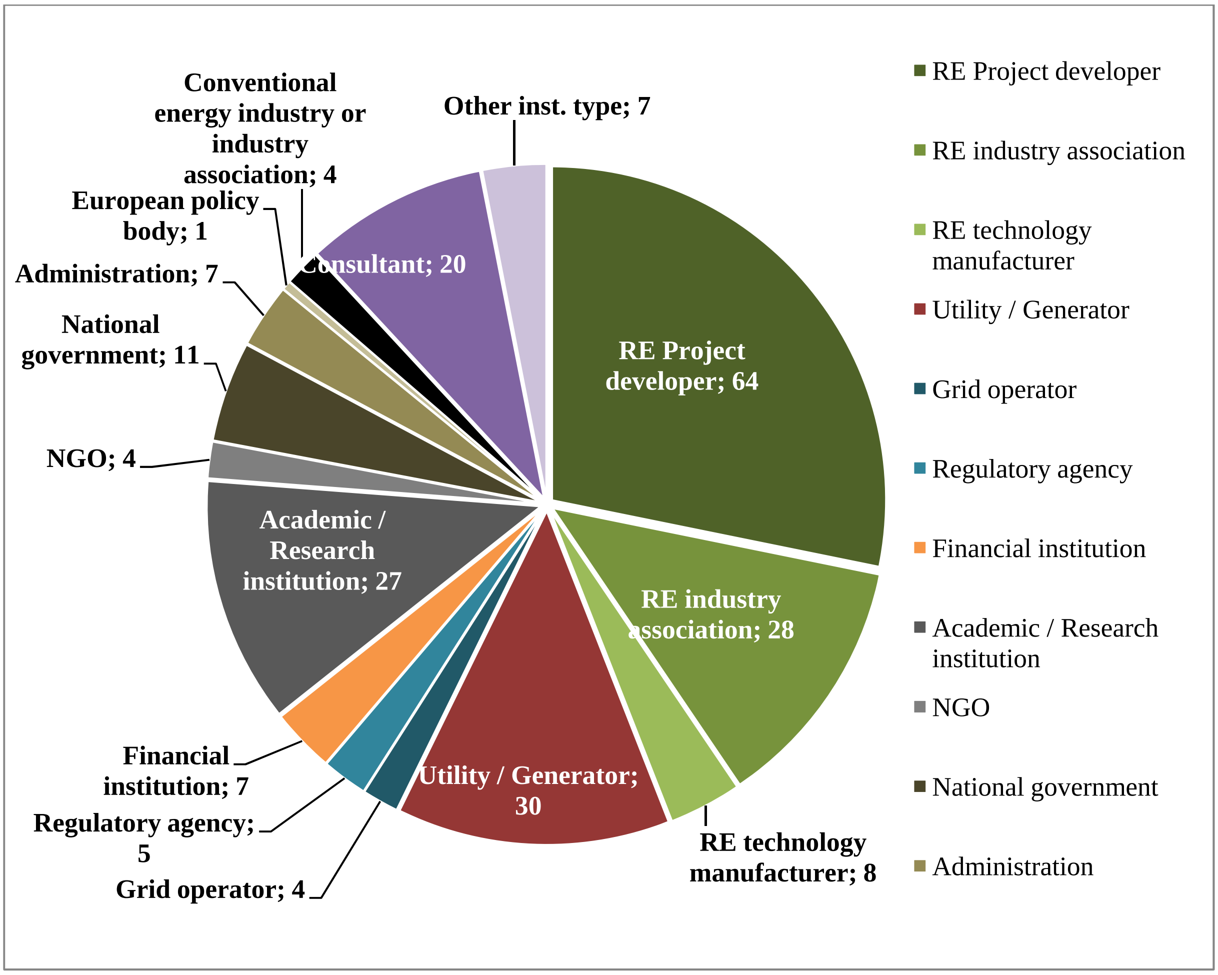

**Figure 73 Institutional background of the respondents to the weighting exercise**[20]

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[20] Please note that multiple answers were possible

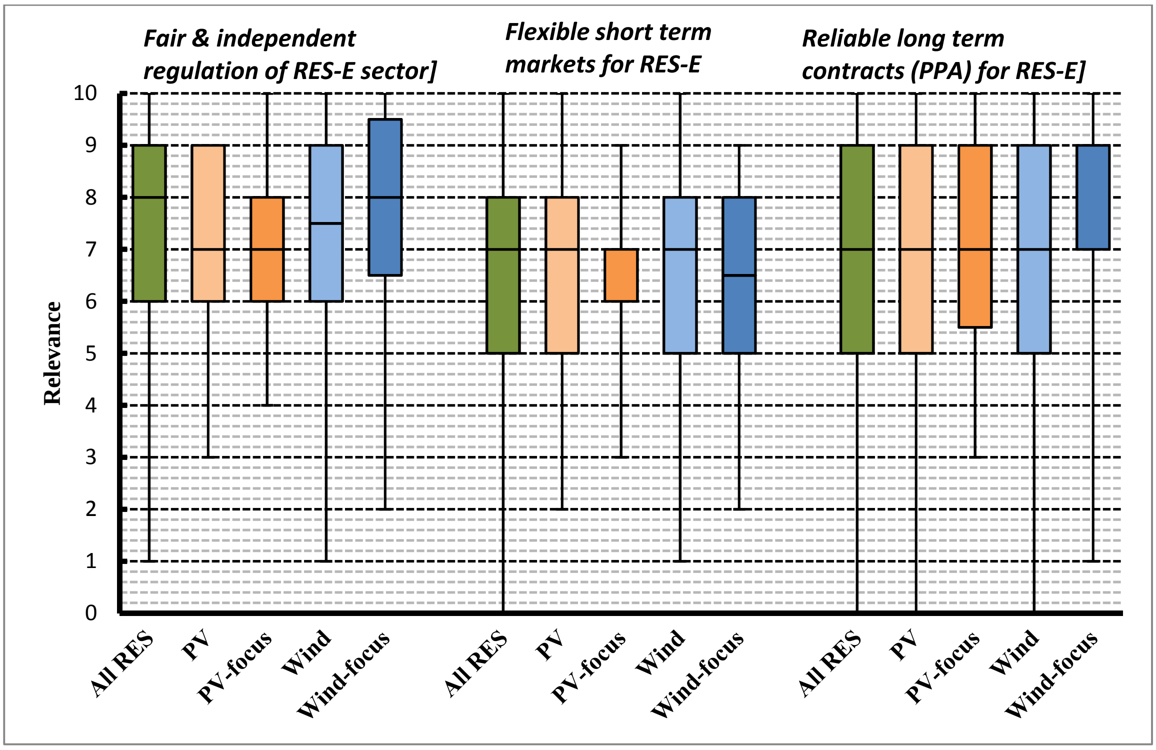

**Figure 74 Weights for sub-determinants of the composite indicator component 'market structure and market regulation'**

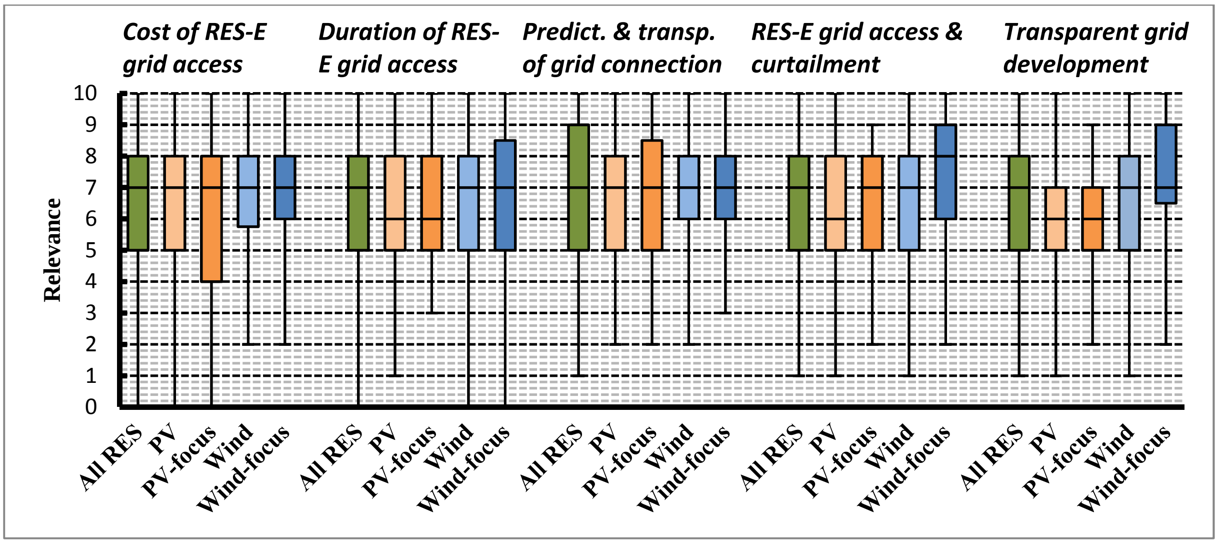

**Figure 75 Weights for sub-determinants of the composite indicator component 'grid infrastructure and grid regulation'**

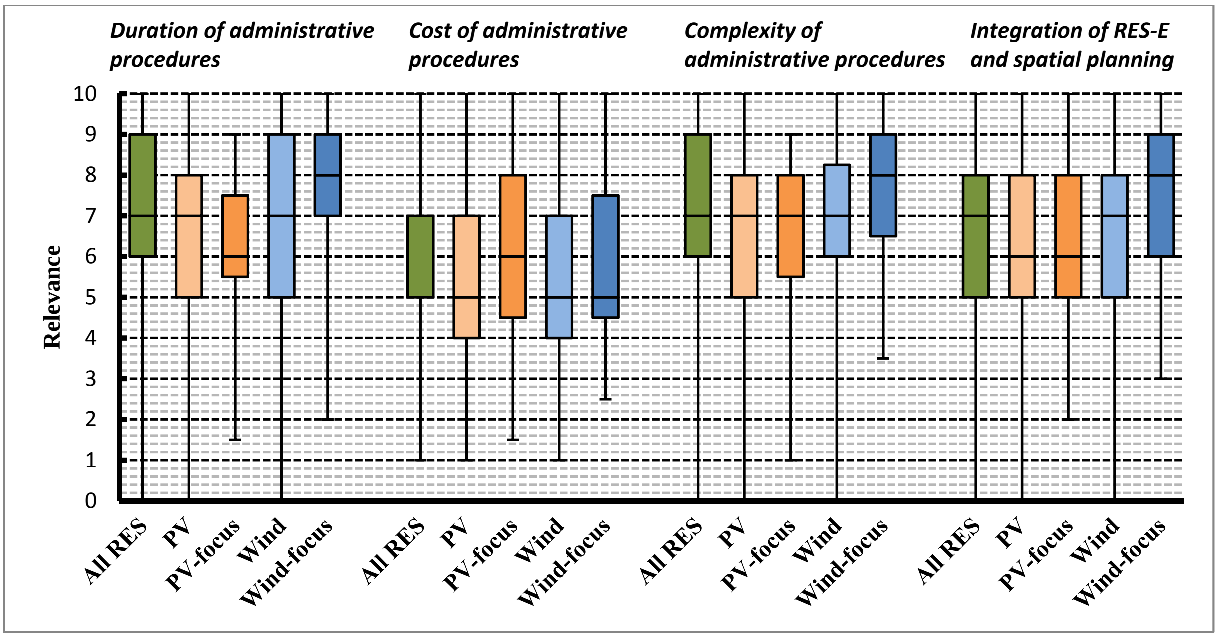

**Figure 76 Weights for sub-determinants of the composite indicator component 'administrative procedures'**

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