Dialogue on a RES policy framework for 2030

towards2030

Task 3.2.3 Report:

Phasing out economic support to mature renewables?

Drivers, barriers and policy options

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About the project

The aim of **towards2030-*dialogue*** is to facilitate and guide the RES policy dialogue for the period towards 2030. This strategic initiative aims for an intense stakeholder dialogue that establishes a European vision of a joint future RES policy framework.

The dialogue process will be coupled with in-depth and continuous analysis of relevant topics that include RES in all energy sectors but with more detailed analyses for renewable electricity. The work will be based on results from the IEE project beyond 2020 (www.res-policy-beyond2020.eu), where policy pathways with different degrees of harmonisation have been analysed for the post 2020 period. **towards2030-*dialogue*** will directly build on these outcomes: complement, adapt and extend the assessment to the evolving policy process in Europe. The added value of **towards2030-*dialogue*** includes the analysis of alternative policy pathways for 2030, such as the (partial) opening of national support schemes, the clustering of regional support schemes as well as options to coordinate and align national schemes. Additionally, this project offers also an impact assessment of different target setting options for 2030, discussing advanced concepts for related effort sharing.

Who we are?

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This report

explores the necessary conditions for a potential 'phase-out' of economic support for mature renewable technologies that is compatible with the levels of deployment required to reach the defined EU target of at least 27% renewables in 2030.

The main 'drivers and barriers of RES-E competitiveness' - both on the cost and revenue side - are identified and analysed in detail. Possible policy measures to enhance drivers and/or overcome barriers are discussed.

We conclude that in the medium term it may be possible to increase the share of RES-E without providing dedicated economic support. Such phase-out of economic support requires that two main conditions are met: firstly, expected future revenues from power markets are sufficiently high to cover generation costs; secondly, the risk tag attached to those revenues has to be acceptable for investors in the energy sector.

Nowadays, these conditions are not met yet, despite falling generation costs. RES targets and support schemes will still be needed for a transitional period until power markets provide sufficient and sufficiently predictable revenues for RES developers. The level of support needed during this transitional period will strongly depend on how policies affect the 'drivers' and 'barriers' of competitiveness described in this paper.

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Executive Summary

The increased deployment of renewable energy is a key element of the European climate and energy policy, intended to improve EU competitiveness, boost economic growth and create jobs. In October 2014 the European Council agreed on a renewable energy target of at least 27% of final energy consumption for 2030. Thus, further investments in renewable electricity (RES-E) generation technologies are needed to meet this target and eventually decarbonise the power sector. At the same time, there is a discussion on whether renewables support can be phased out for mature RES-E technologies beyond 2020, assuming that the electricity and carbon markets will be sufficient to trigger the needed RES-E investments.

This report takes a closer look at the business case of variable RES-E, particularly for wind and solar PV, and explores ***under which conditions support to mature RES-E can be phased out in the future without endangering the needed RES investments.***

Our analysis is focused on the future competitiveness wind and solar PV in the wholesale markets, not the retail markets, which follow different market dynamics.

Preconditions for phasing out economic support for RES-E: market revenues need to cover generation costs and correspond to investors' risk tolerance

The notion of competitiveness for RES-E has traditionally been based on the comparison of the Levelised Cost of Electricity (LCOE) of RES-E technologies with those of conventional power sources, which used to be 'price-setting' technologies in wholesale markets. While LCOEs of mature renewables are quickly approaching those of conventional technologies, this definition of competitiveness may be too narrow. A more relevant question is when will the revenues from the electricity market be sufficient to refinance the LCOE of new investments in RES-E?

The main components of LCOE are: investment costs, costs of capital and operation and maintenance costs (see Figure 3). Revenues from RES-E developers come mainly from electricity sales in the wholesale electricity market. Other sources of revenue from e.g. balancing, capacity or ancillary markets are in principle possible although mostly negligible to this day.

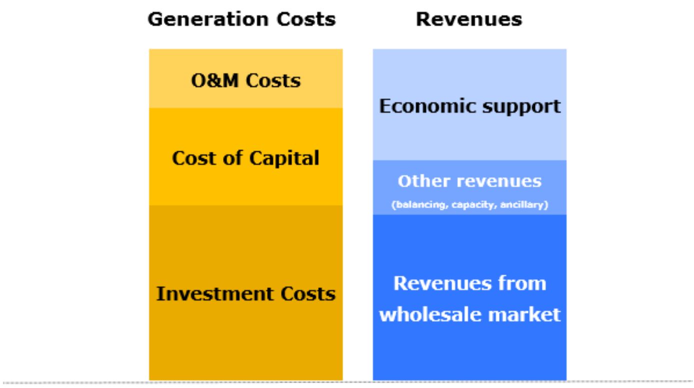

Figure 1 Generation cost (levelised cost of electricity- LCOE) and revenue components

Currently, revenues from electricity markets are in most cases insufficient for RES-E generators to cover the generation costs. Therefore, economic support from RES-E support schemes are used to close that gap.

In the medium or long-term it may be possible to phase-out economic support for RES-E technologies to the extent that two main conditions are met: firstly, expected future revenues from power markets are sufficiently high to cover generation costs; secondly, the risk tag attached to those revenues is acceptable for investors in the energy sector.

Nowadays, these conditions are not yet met, **and it is unclear whether they will be widely met before 2030**. RES targets and support schemes will still be needed for a transitional period until power markets provide sufficient and sufficiently predictable revenues for RES developers. The level of support needed during this transitional period will strongly depend on how policies affect the *'drivers'* and *'barriers'* of competitiveness described in this paper.

The phase-out of RES-E support can be accelerated by several drivers but also hampered by a number of barriers

Adequate policies and regulations can mitigate the effect of existing *barriers* for RES competitiveness as well as enable the positive effects of identified *drivers* (see Figure 2)***.*** As a result, these policies and regulations can bring reduction in generation costs and increase in revenues for RES plants with reduced - and ultimately no - economic support.

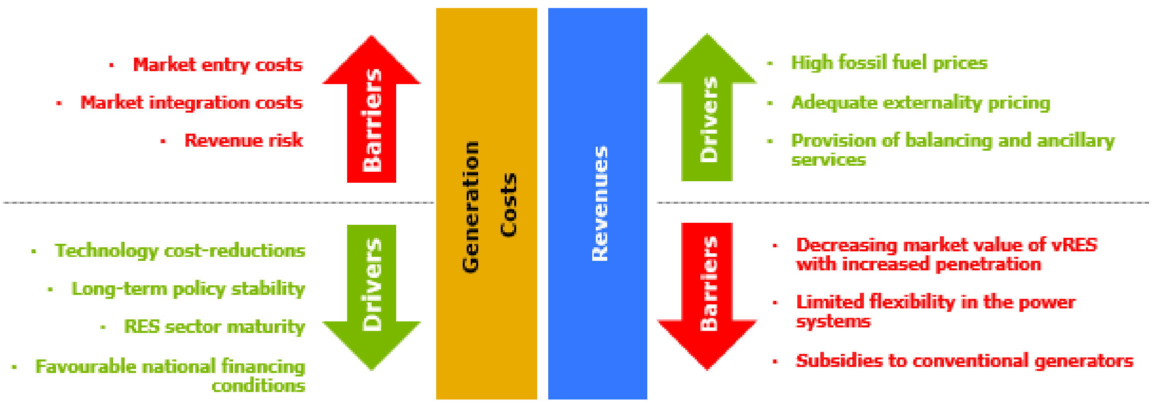

Figure 2 Barriers and drivers of RES-E competitiveness

Drivers for reduction of the generation cost

Technology cost reduction. Progressive technology cost reduction has been one of the key levers to reduce power generation costs for any technology, in particular relevant for wind and PV. As deployment of renewable energy technologies continues, it is expected that technology costs will continue to decrease in the future by ca. 20% for wind onshore and ca. by 30% by solar PV by 2030 (Fraunhofer et al. 2014).

Long term stability and credibility of RES- and climate policies. Stable, reliable and predictable policies and regulatory frameworks are important to provide a planning horizon for project investors and a project pipeline for component and service providers and thus – reduce the cost of capital.

RES sector maturity. In general, wind turbines and PV systems are subject to global competition. However, the specific maturity of the national renewable energy sectors may have an effect in the actual generation costs, due to high competition among specialised companies, availability of qualified professional, adaptation of regulations, more advanced and customised financial mechanisms and lower risk premiums for developers, as well as knowledge transfer and best institutional practices for permitting procedures.

Favourable financing conditions. National credit rating and the interest rate can have a considerable impact on the cost of capital. While policy and revenue uncertainty impair the availability of credit and cost of capital for of RES-E plants, specific financing solutions, such as soft loans and loan guarantees, can help.

Barriers for reduction of the generation cost

Revenue risk. Since RES-E plants are highly capital intensive, high revenue risks from the electricity markets result in substantially higher generation costs, reducing the available financing options. Existing support schemes mitigate revenue risk for RES-E project developers to different degrees. Without any support or remuneration scheme, RES-E plants are fully exposed to market risks.

Market entry costs. Market entry costs are usually related to grid access and administrative barriers, such as lengthy and complex permitting procedures, lack of information of grid capacity, intransparent assessment methods, etc. Securing actual grid capacity, assuring availability of information on grid connection capacity, transparent assessment methods, as well as eliminating land ownership disputes issues shorten project development time and decrease its cost. Information about future grid development and an increased transparency of the grid connection procedure can also drive cost reductions. Finally, the costs of connecting to the grid can be reduced by adopting a shallow grid connection charging regulation where grid upstream reinforcement costs are socialized via the network tariffs and no or little costs are charged to the connecting entity.

Market integration costs. Current power market rules are not always fully prepared to incorporate increasing volumes of variable RES-E generation (vRES), where the actual power output of the generation plants is uncertain until the time of delivery, while predictability increases towards this time. The costs for balancing solar PV and wind uncertainty in the system can be significantly reduced with appropriate market design options, e.g. through reducing the scheduling or dispatch periods and gate closure times.

Drivers increasing RES-E market revenues

High fossil fuel prices. Fossil fuel prices are a key cost component of fossil-fuel-based electricity production and their price developments have a direct impact on the competitiveness of RES-E. At the moment fossil fuel prices are relatively low and there is no evidence to expect that fossil fuel prices will reach unprecedentedly high levels in the period 2020-2030.

Adequate externality pricing. Climate change and depletion of energy resources form the largest externalities of fossil energy use but externalities include also particulate matter, ozone depletion, water depletion, metal depletion and terrestrial acidification and many other. The EU Emission Trading Scheme (EU ETS) is the cornerstone of EU climate policy and the main instrument aimed at internalising negative externalities in the EU by setting a market price for carbon. However, current carbon prices fail to appropriately reflect the negative externalities related to fossil energy sources, estimated at €50/tonneCO_2 or more. The degree to which the carbon price approaches these real externality costs in the future will be a determinant factor of RES-E competitiveness and thus of the possible phase-out of economic support; however, most analysts do not expect such carbon price increase over the 2020-2030 period.

Balancing and ancillary services. Balancing and ancillary services could constitute an additional source of revenues for RES-E if the right regulatory framework is set.

Barriers decreasing RES-E market revenues

Decreasing market value with increased RES-E penetration. Wind and solar technologies are characterised by high investment costs and very low relative operational costs. In practice, this means that they can offer electricity in the power market at prices close to zero, preceding most conventional generation technologies in the merit order. This means that windy and sunny periods tend to be the low price periods in systems with large penetration of wind and solar PV technologies. Additionally, wind and solar PV are driven by their resource availability, so they tend to operate precisely in those periods of low prices, undermining their own revenues. This has been known as the 'cannibalism' effect and it has strong implications for energy policy makers as higher penetrations of vRES in the power markets can result in an increased relative need for net support payments to bridge the gap between decreasing revenues from the wholesale market and the LCOE of these technologies. Future increases in carbon prices could partially mitigate this effect by 'flattening' the merit-order curve; however, a long term and sustainable solution to this issue is to achieve increasing levels of flexibility in the power system and market.

Limited flexibility of power systems. Limited flexibility of power systems is an important barrier for further deployment of vRES generators such as wind and PV plants. Future systems and markets with increasing shares of vRES will need additional flexibility to maintain system reliability as the variations in supply and demand will be larger and faster. Future power market regulations should be designed to provide sufficient economic incentives for all market actors to contribute to the flexibility of the system. Flexibility in the power systems can be improved by increasing the flexibility of generators and consumers, but also by implementing energy storage solutions, increasing interconnection capacity with other systems, adapting power market rules and/or expanding market size.

Subsidies for conventional technologies. Conventional generation largely benefits from various (historical) interventions and subsidies, often much less obvious than renewable energy support. Examples of interventions are certain energy tax structures and exemptions, financial government participation in oil and gas extraction and the (partial) coverage of risks by governments related to nuclear accidents and transport, to name a few. From an economic perspective, a socially responsible and progressive phase-out of policy support to conventional generation will result in improving competitiveness of renewables, thereby reducing the need for support.

Shifting from dedicated economic support to an enabling market framework for RES-E

The transition towards the phase-out of dedicated economic support will require **a shift in focus in (renewable) energy policies**. RES policy (for mature technologies) should progressively move away from a narrow notion of dedicated RES-E economic support to one in which **policies are aimed at providing the right conditions for renewables to recover their costs from the electricity markets**.

This means, on the one hand, **creating an adequate regulatory environment to trigger investment in new RES-E generation**. The level of long-term ambition and reliability of policy frameworks are two critical elements to achieve this. Likewise, policies can greatly improve the business case for renewables by reducing market entry barriers e.g. costly grid connection or administrative procedures, where these barriers still prevail. Last but not least, **phasing out support for emission intensive conventional sources will contribute to create a level playing field**.

On the other hand, it means **reforming the markets to ensure that they are adapted to the special characteristics of (variable) renewables** and that they provide sufficient economic incentive for RES investors. Along with an appropriate **pricing of carbon**, the key element to achieve this will be the creation of the appropriate regulatory incentives to **increase the levels of flexibility** in the power markets. This is critical to ensure that long term revenues for renewables will be able to cover investment costs with increased levels of penetration.

The success in accelerating the phase-out of economic support for mature RES-E technologies will go hand in hand with the progress made in the transition in renewable energy policy and power market transformation.

Table of contents

Figures

Tables

List of Abbreviations

CSP: Concentrated Solar Power

EC: European Commission

EU ETS: European Union Emissions Trading System

IEA: International Energy Agency

LCOE: Levelised Cost of Electricity

LNG: Liquefied Natural Gas

PV: Photovoltaics

RES: Renewable Energy Source

RES-E: Renewable Energy Source - Electricity

vRES: Variable Renewable Energy Sources

1 Introduction

1.1 Background

The increased deployment of renewable energy sources (RES) is a key element of the European climate and energy policy, intended to mitigate climate change, improve EU competitiveness, boost economic growth and create jobs[1].

The EU has made substantial progress towards meeting its 20% renewable energy target set for 2020 (Ecofys et al., 2014); however, it is widely accepted that a new policy framework for the period up to 2030 is needed to ensure regulatory certainty for investors. In January 2014, the EC put forward its proposal, including a renewable energy target of at least 27% of final energy consumption for 2030. The European Council reached an agreement in October 2014 confirming an EU-wide target of at least 27%. The European Commission is now tasked with working out the specifics of the 2030 framework in order to reach this target in a cost-efficient manner.

National support schemes have been key drivers of the growth experienced by renewable electricity (RES-E) markets across Europe in the recent years. Renewable energy technology costs have significantly decreased. However, as the share of renewables in the electricity system rises, so have the total costs of support schemes. As a result, national governments are looking at ways to lower costs of support schemes. A trend towards a gradual lowering of support levels and higher exposure to the market has emerged in the recent years. The European Commission has repeatedly called for increased market exposure of RES-E producers[2], with the aim to reduce market distortions. Similarly, it has also called for increased economic efficiency of support instruments - e.g. by the introduction of competitive mechanisms[3]- and an eventual phase-out of economic support for mature technologies, that is - capable of competing in the market, allowing power and carbon markets alone to drive (renewable) energy production and investment decisions.

1.2 Scope of this paper

Economic support for renewable energy has been historically justified as a required policy incentive to trigger deployment of new low-carbon technologies, compensating for incomplete internalisation of environmental externalities, decreasing dependency on energy imports, and increasing the diffusion of immature technologies, in turn decreasing their costs.

In this paper we discuss the necessary conditions for a potential 'phase-out' of economic support for RES-E that is compatible with the levels of RES deployment required to reach the defined EU RES target of at least 27% in 2030.

Thus, the aim of this paper is to analyse the following research question:

- Under which conditions can support to mature RES-E be phased out without endangering the ***needed RES investments***?

[1] (COM (2012) 271) and earlier EC documents.

[2] (SWD (2013) 439 final) Delivering the internal electricity market and making the most of public intervention

[3] In 2014, the European Commission released new Environmental and Energy Aid Guidelines that provide guidance to Member States as to which support schemes are compliant with EU state aid rules.

We carry out a qualitative analysis of market conditions and policy options that could enable a progressive phase-out of financial support for RES-E. Detailed techno-economic calculations fall out of the scope of this study.

We focus primarily on onshore wind power and solar photovoltaics (PV), since both technologies have achieved substantial reductions in costs, and high levels of deployment across Europe in recent years. They are thus increasingly considered mature RES-E. Furthermore, their observed growth trends indicate that they are likely to be dominant RES-E technologies in the power sector after 2020.

Both PV and wind are variable renewable sources (vRES). As it will be discussed later, this is a determinant feature when analysing the competitiveness of the technologies in the power market; however, many of the arguments and discussion in this paper could be extended to other RES-E technologies.

Our analysis is focused on the future competitiveness of RES-E generators in the wholesale markets. Distributed RES-E generation is also becoming increasingly competitive in many European retail markets - i.e. self-consumption of PV electricity is in some cases already cheaper than buying electricity from a supplier - and may play an important role in achieving the EU RES-E 2030 target; however, the market dynamics, distributional effects and the portfolio of policy options to support further and faster deployment are fundamentally different from those for wholesale markets, and worth of a specific study of its own.

In chapter 2 we define in broad terms what we mean by “phase-out of economic support” and identify the key elements of RES-E competitiveness. Subsequently, in chapters 3 and 4 we discuss in more detail the elements of RES-E competitiveness previously identified as well as policies that potentially reduce economic support needs and eventually phase out economic support. In chapter 5 we draw conclusions for policy-makers from our analysis in the previous chapters.

2 Necessary conditions for phasing-out economic support

2.1 Defining the pre-conditions for the 'phase-out' of economic support

The Levelised Cost of Electricity (LCOE) is the metric often used to compare the competitiveness of generation technologies. It is the present value of the total cost of building and operating a plant over its financial life, converted to equal annual payments and amortised over the expected annual generation (Klessmann et al., 2013).

The notion of competitiveness for RES-E has traditionally been based on the comparison of the LCOE of RES-E technologies with those of conventional power sources, which used to be 'price-setting' technologies in wholesale markets. While LCOEs of mature renewables are quickly approaching those of conventional technologies, this definition of competitiveness may be too narrow. A more relevant question is when will the revenues from the electricity market be sufficient to refinance new investments in RES-E?

The specific time and place when RES-E technologies reach a point of competitiveness in the power markets is highly dependent on the specific market context and is influenced by a number of factors besides the technology cost reduction, such as wholesale market prices, administrative costs, financing conditions, taxes and the renewable resource availability, among others.

Figure 3 below shows the two sides of the business case for RES projects, breaking down the main components of generation costs and revenues for developers. Generation costs are composed of investment costs (cost of developing the project and building the generation plant), costs of capital (the cost of raising sufficient funds to cover investment costs) and operation and maintenance costs. Revenues from RES-E developers come mainly from electricity sales in the wholesale market and additional economic support when available. Other sources of revenue from e.g. balancing, capacity or ancillary markets are in principle possible although mostly negligible to this day.

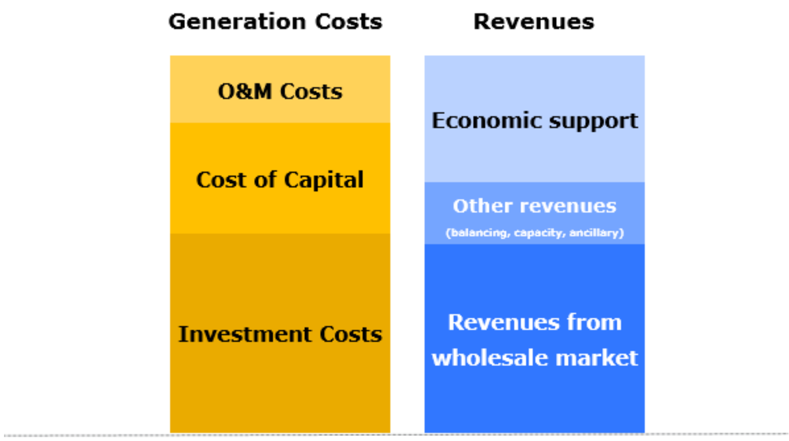

Figure 3 Generation cost[4] (levelised cost of electricity) and revenue components

[4] Fuel costs are an additional component of the generation cost breakdown for (RES-E) technologies other than wind or PV.

In the current situation, revenues from power markets are in most cases insufficient for RES-E project developers to cover the generation costs. Therefore, economic support is still needed. A model-based assessment of future renewables deployment at national and EU level assuming achievement of the 27% target by 2030 shows that the necessary remuneration for renewables is expected to decline over time (Resch et al.2015); however, some degree of support is expected to be needed in the period 2020-2030.

It will be possible to progressively phase-out economic support for mature RES technologies when RES developers can build business cases for their generation projects counting exclusively on revenues from the power markets. This, in turn, requires that the two following main conditions are met:

1. The level of revenues expected from power markets is sufficient to cover the generation costs (including a certain economic return on investment, reflected in the cost of capital).

2. The level of risk associated with investments in RES-E, which strongly influences the generation costs, is in line with the expected levels of return on investment.

The second element is of particular importance for RES-E generators, since wind and solar are characterised by a high share of capital costs compared to their (very low) operating costs. This means that the largest share of the generation costs for these plants is incurred already at the time of investment. Once the investment is done there is little margin for optimisation of generation costs to adapt to power price changes.

2.2 Elements of RES Competitiveness: Drivers and barriers

It is generally perceived that the potential phase-out of economic support for renewables (in particular for PV and onshore wind installations) should happen along with technological improvements that bring LCOE of renewables sufficiently low to compete on price with conventional generation technologies; however, renewable technology costs are only part of the picture. While technology costs are a key element of RES competitiveness, there are several other key influencing factors that need to be considered.

As a matter of fact, generation costs can also be reduced e.g. by tackling existing administrative and market barriers that result in higher overall required investment costs for RES-E developers. Likewise, risk-mitigating policies can substantially reduce the cost of capital, which is typically a main component in the cost structure of RES-E generation projects.

Expected future revenues for RES developers can also be affected by a large number of factors. These include power market design and regulation issues, the demand profile of the particular market where renewables operate, the existing generation portfolio, among many others. In addition to electricity sales on the wholesale market, RES-E producers could potentially obtain additional revenues participating in the balancing and ancillary services markets.

Besides the level of revenues, the risks associated to those potential revenues also influence RES-E competitiveness, playing a key role in the final investment decisions. The predictability of project costs and revenues plays a similar role.

All the factors mentioned above determine the potential business case for RES-E technologies (both from the revenue side or the cost side) and therefore their potential for increased penetration in the future power markets. We identify all these aforementioned elements as *'drivers and barriers of RES-E competitiveness'*.

An overview of these elements can be found in Figure 4 below:

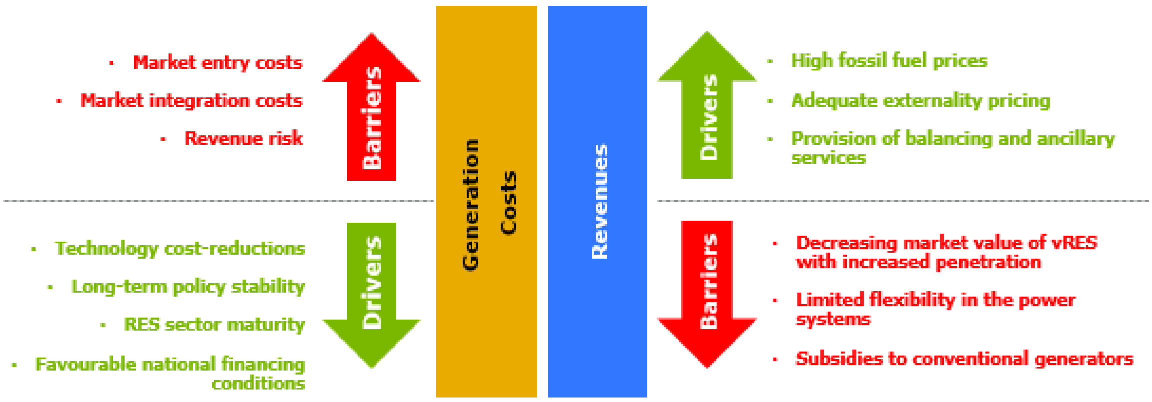

Figure 4 Elements of RES-E competitiveness. Barriers and drivers

Adequate policies and regulations can mitigate the effect of existing *barriers* for RES competitiveness as well as enable the positive effects of identified *drivers.* As a result, these policies and regulations can bring reduction in generation costs and increase in revenues for RES plants with reduced - and ultimately no - economic support.

In the following sections we discuss in depth the *elements of RES competitiveness* identified above as well as the possible policy instruments and measures that can be implemented to act upon them.

3 Elements determining RES-E generation costs

An analysis of the elements composing the Levelised Costs of Electricity (LCOE) of RES-E offers insights into the major levers to reduce RES-E generation costs and ultimately phase out economic support.

The LCOE reflects all costs needed to build a plant, operate it throughout its technical lifetime, and decommission it. These costs are then normalized over the total net electricity generated. The use of LCOE allows for comparisons of costs across different generation technologies, with different unitary investment costs, capacity installed, operation and maintenance costs and other characteristics such as technical lifetime. Figure 5 below shows the main elements determining the LCOE of power generation technologies.

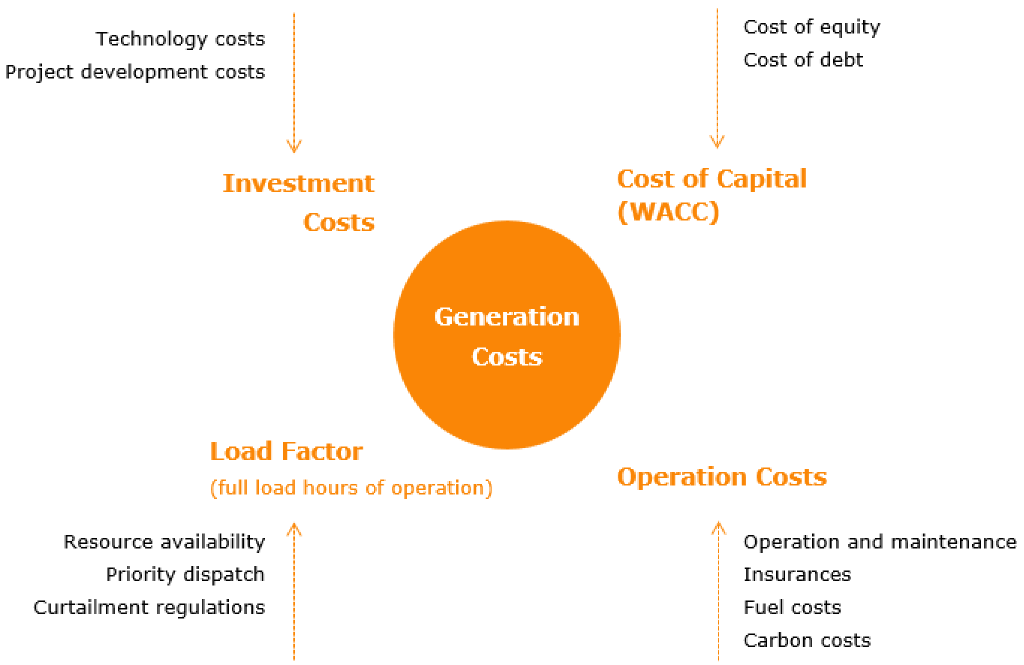

Figure 5 Main elements determining electricity generation costs

Investment costs include costs for land, engineering, technology, project development and construction of the RES-E plant. While technology costs are a major component of the investment costs, the "soft" costs for project development for RES-E technologies may also represent a substantial part of total costs.

The **cost of capital** is determined by the interest rate paid for debt, the expected return on equity, the debt/equity ratio, the period for which debt and equity need to be committed as well as fees paid (Klessmann et al., 2013). The Weighted Average Cost of Capital (WACC) is often used as a measure of the cost of capital taking into account the debt/equity ratio of different project costs. It represents the minimum return that a generation project must earn to satisfy its creditors, owners, and other providers of capital.

The cost of capital of RES-E projects is highly dependent on national financial conditions, e.g. on the macroeconomic rating of a country, but also on the national energy policy framework and power market regulations and their stability.

Operation costs include the costs for operation and technical maintenance of the generation plant, costs for guarantees and insurances as well as fuel and carbon costs. As wind and solar-PV plants do not have fuel nor carbon costs, their operating costs are significantly lower – in relative terms - than those of conventional energy sources.

Finally, the total electricity generation of the plant is determined by the **load factor** (full-load hours of operation vs 8,760 total hours/year). All else equal, the larger the load factor, the smaller the generation costs expressed in EUR/MWh. For solar PV and wind plants this element is mainly determined by the availability of the renewable resource and the efficiency of the technology. However, it may be (negatively) influenced by market and/or system regulations if these allow for the (uncompensated) curtailment of RES-E generators.

Table 1 below shows a list of drivers and barriers for the reduction of generation costs of RES-E technologies. In the following subsections we analyse how these influence the generation cost components described above. For each of them we discuss the possible options available for policy-makers to enhance and capitalise on the drivers and address the barriers in order to create the right conditions for further investments in RES-E generation.

Table 1 Drivers and barriers for reduction of generation costs for RES-E

	Drivers (+)	Barriers (-)
Generation Costs	• **Technology cost reductions** (reduces investment costs) • **Long-term stability of RES (and overall energy) policies** (reduces cost of capital) • **RES sector maturity** (reduces both investment and operation costs) • **Favourable financing conditions** (reduces cost of capital)	• **Revenue risk** (increases cost of capital) • **Market entry costs** (increases investment costs) • **Market integration costs** (increases operation costs)

3.1 Driver 1: Technology cost reductions

Technology costs account for a very significant share of the overall investment costs for RES-E projects. Progressive technology cost reduction has been one of the key levers to reduce power generation costs for any technology. It is particularly relevant for wind and PV since the weight of the capital costs in the total costs is higher than for other power market participants.

The significant reductions in the cost of wind turbines and PV modules and inverters have resulted in a substantial reduction of generation costs in recent years. These reductions are expected to slow down but continue in the future, following a phenomenon well-known for emerging technologies: the experience curve or learning curve (Arrow, Kenneth J. 1962). Among the reasons driving costs down and explaining the learning curve we include: increased experience; economies of scale derived from larger markets, organisational and process improvements, etc.

Solar PV

In the past, module prices decreased by roughly 22% every time the cumulative installed capacity doubled. As a result, in the past 20 years, the cost of PV modules and systems has been reduced very significantly. Figure 6 below shows the learning curve for PV modules and the main drivers behind the cost reduction.

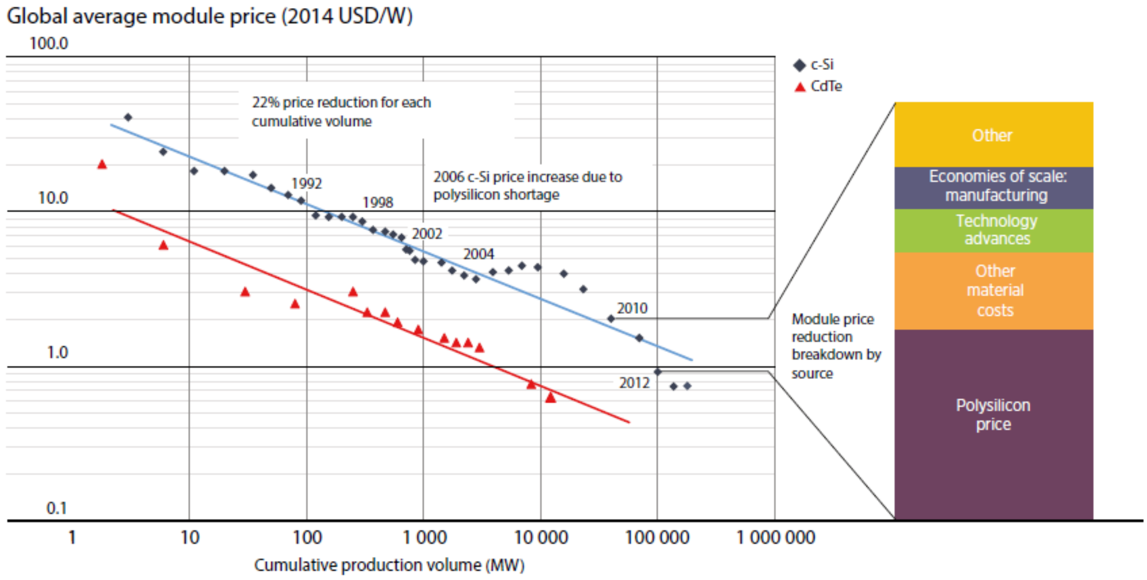

Figure 6 Global average module price (2014 USD/Watt). Source: IRENA, 2015

Wind

Historical learning rates[5] for wind power were roughly 10% until 2004 when wind turbine prices grew strongly, partially explained by supply/demand imbalances and increase in component prices. After 2009, manufacturing overcapacity, the reduction in raw materials costs caused by the financial crisis and increasing competition created downward pressure on prices again (JRC, 2015). Figure 7 below shows the evolution of wind turbine prices in recent years.

[5] Learning rate: % of reduction in costs when installed capacity is doubled.

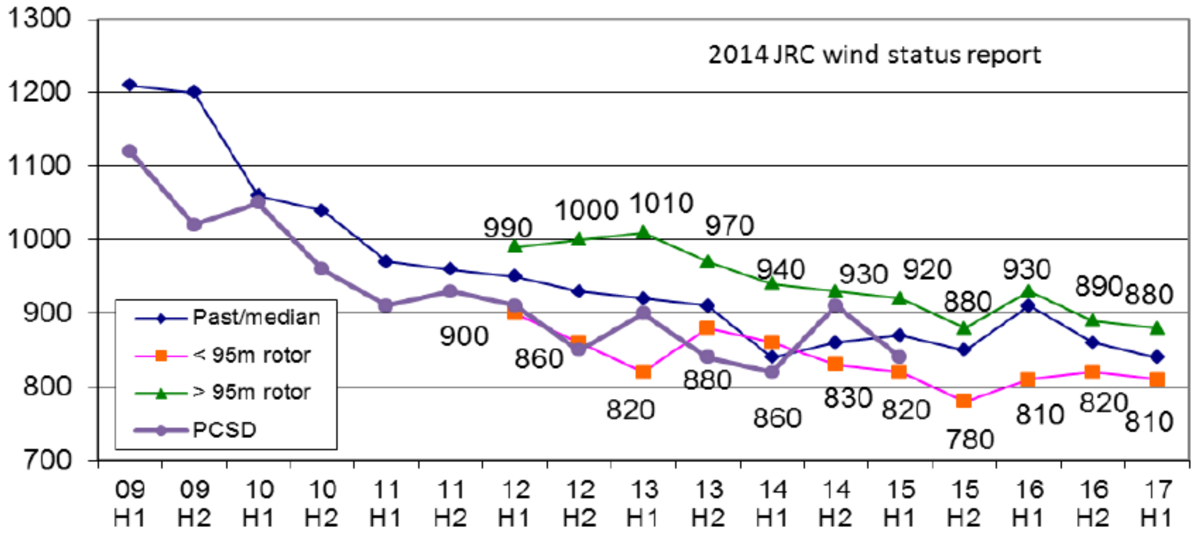

Figure 7 Evolution of wind turbine prices in EUR/kW based on the year of delivery and per year of contract signature (PCSD) Source: JRC, 2015

As deployment of renewable energy technologies continues, it is expected that technology costs will continue to decrease in the future, even though the cost decrease is usually less pronounced the more technologies mature. Figure 9 and Figure 8 below show projections for the development of investment costs up to 2030. According to these, wind onshore investment costs could decrease by around 20% and solar PV costs by around 30% by 2030 (Fraunhofer ISI et al. 2014).

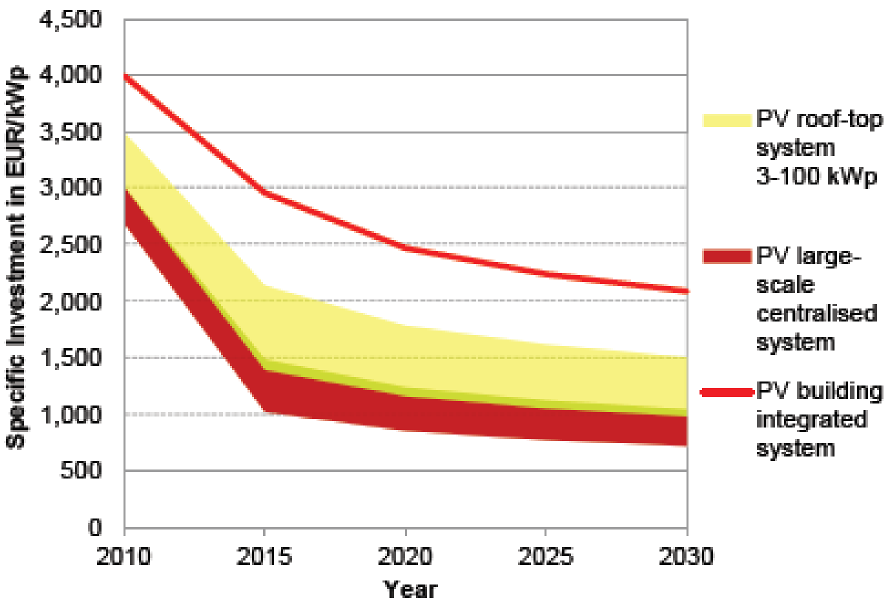

Figure 8 Future specific investment costs for PV power. Source: Fraunhofer ISI, et al. 2014

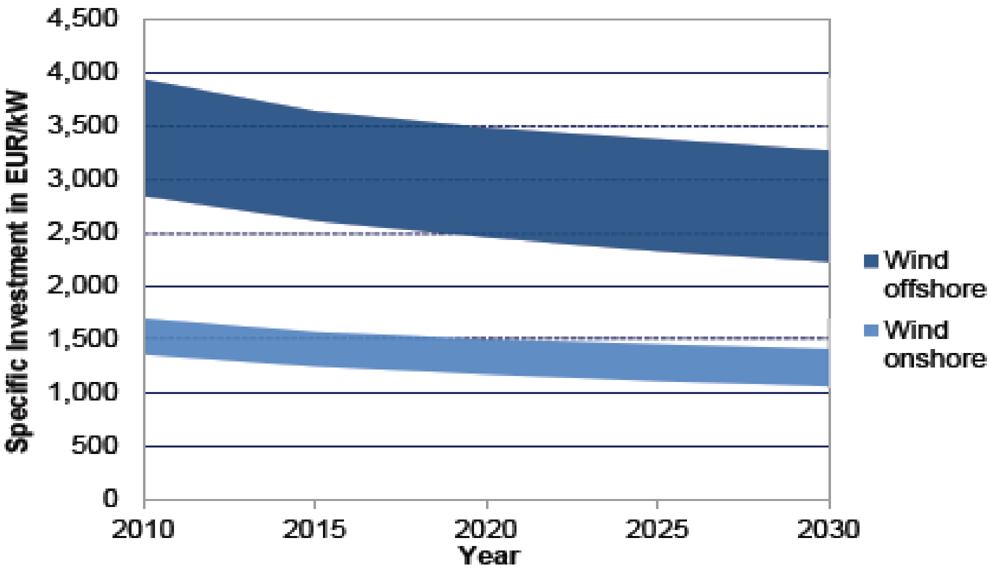

Figure 9 Future specific investment costs for wind power. Source: Fraunhofer ISI, et al. 2014

3.2 Driver 2: Long-term stability and credibility of RES and climate policies

Credible renewable energy and climate policies can contribute to reducing generation costs without necessarily providing dedicated economic support.

Providing policy stability is a key element to reduce the cost of capital. Stable, reliable and predictable political targets and regulatory frameworks are important to provide a planning horizon for project investors and a project pipeline for component and service providers. For instance, quantitative RES-E targets express a commitment to encourage investments not just into RES-E and its supply chain, but also into the necessary transmission and distribution grids (Piria et al., 2013).

Credible RES targets contribute to the credibility of the policy support framework and therefore they may have a substantial positive impact in the cost of capital. Interviews with financing experts carried out over the course of the RESHAPING[6] project shown that LCOE of RES-E projects are assessed to be up to 10% lower if market actors do not expect abrupt changes in the regulatory or support framework (Rathmann et al. 2011).

In the period while economic support for RES is still required, a key lever to provide political stability is to avoid retroactive support scheme changes. Retroactive changes are changes that are announced and negatively impact projects and their financial viability when investments have already taken place (i.e. projects that are under construction or in operation). Retroactive policy changes in economic support to RES have been implemented in several EU countries[7].

The motivation behind these changes is often to cut costs immediately, but the short-term policy cost saving may be outweighed by the increase of policy costs that come with higher risk premiums for RES-E projects at a later stage. The negative effects of retroactive policy changes in the investment environment in the RES sector may persist in the medium-term. The resulting high risk premiums for developers are a serious barrier to build business cases without the need for economic support.

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[6] http://www.reshaping-res-policy.eu/

[7] See e.g. EPIA, 2013

3.3 Driver 3: RES sector maturity

In general, wind turbines and PV systems are subject to global competition. However, the specific maturity of the local renewable energy sectors may have an effect in the actual generation costs, in the competiveness of RES technologies in specific power markets and therefore in the outlook for a phase out of economic support in those countries. This is the case for the following reasons:

Firstly, advanced RES markets are characterised by the presence of a larger number of specialised companies (equipment manufacturers and distributors, developers, installers, etc.) and increased access to qualified and specialised professionals. These two factors typically result in increased competition, streamlined manufacturing and installation processes and therefore reduced generation costs.

Secondly, the experience accumulated by public and private institutions in mature RES markets may contribute to a reduction in investment costs. This may happen e.g. by means of adaptation of regulations and technical codes to the new technologies, which in turn reduces the amount of time and resources that developers need to spend to comply with administrative and permitting procedures. Similarly, experience accumulated by financial institutions may result in more advanced and customised financial mechanisms and lower risk premiums for developers.

Public policies may speed up the process to market maturity by implementing training programmes for professionals, incentivising knowledge transfer and adopting best institutional practices for permitting procedures.

Again, a key element is policy stability. ‘Stop and go’ policies typically create excessive long-term risks for the consolidation of domestic RES industries.

The European market for wind and PV can be considered relatively mature, but there are significant differences among Member States. Renewable generation technologies have achieved substantial reductions in costs and increased levels of penetration in the European power markets in recent years. In particular, wind and PV are by far the predominant renewable technologies being installed in the EU markets nowadays. Figure 10 shows the net installed capacity for all non-fossil generation technologies in Europe from 1990 to 2013. Solar PV and on-shore wind are the two RES technologies with the highest growth in recent years.

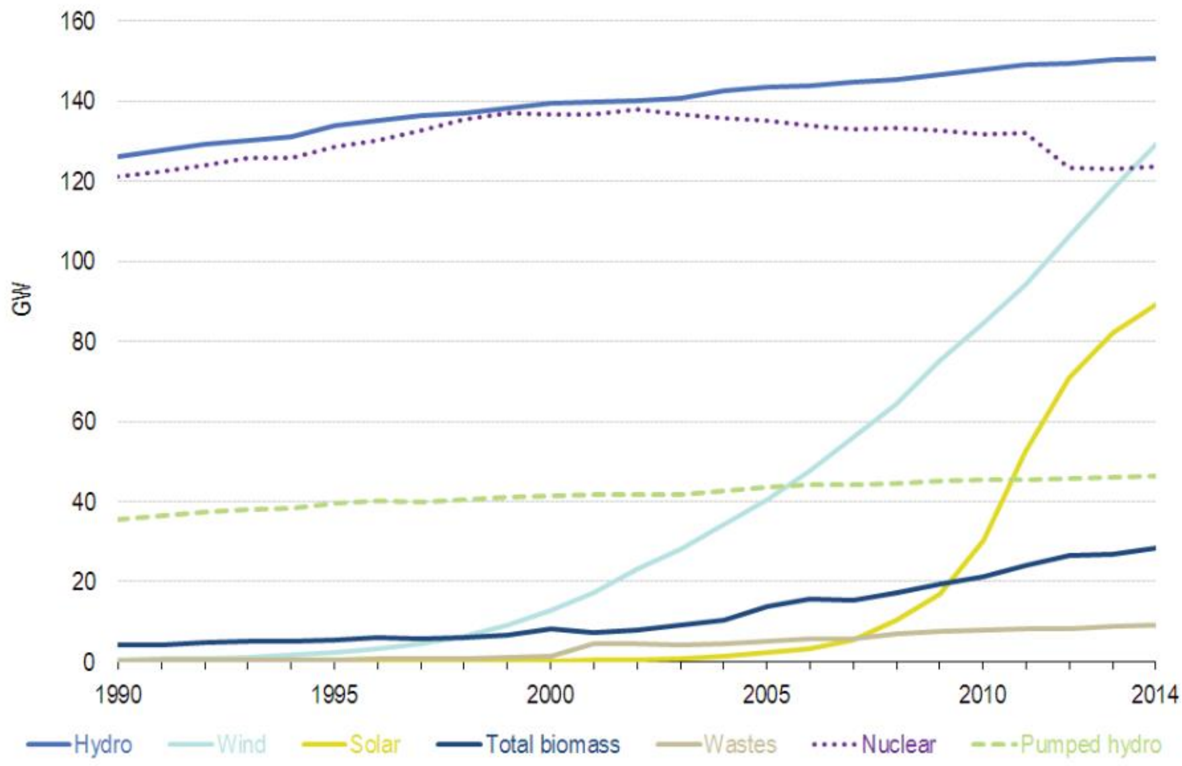

Figure 10 Evolution of generation capacity in the EU 28. Source: Eurostat

While it is clear that both wind and solar are quickly advancing to technological maturity and achieving increasing levels of penetration in the European power markets, the situation varies substantially depending on the technology and Member State considered. Figure 11 and Figure 12 below show the *deployment status indicator*[8] for wind onshore and PV respectively for the EU-28 Member States. Both graphs show substantial differences in RES market maturity across EU Member States. This means that there is still potential for decreasing RES investment costs by increasing market maturity, especially in the Member States with less developed markets.

[8] The *Deployment Status Indicator* aims to quantify how advanced the market for a specific renewable technology is in a specific Member State. Source: Held et al. 2014 DIA-CORE D2.1: Assessing the performance of renewable energy support policies with quantitative indicators – Update 2014.

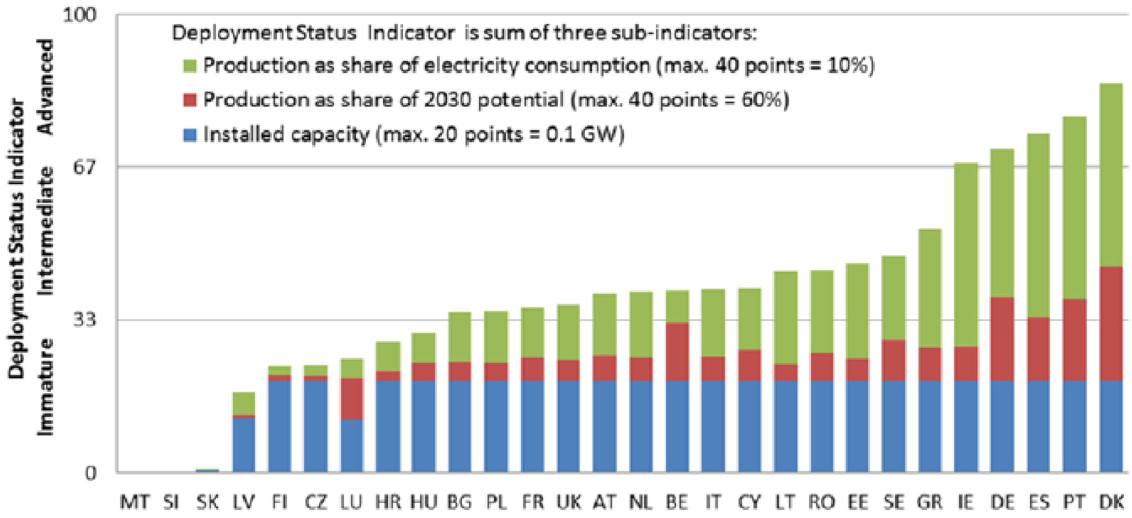

Figure 11 Deployment Status Indicator for onshore wind in the EU-28 in 2012. Source: Held et al. 2014

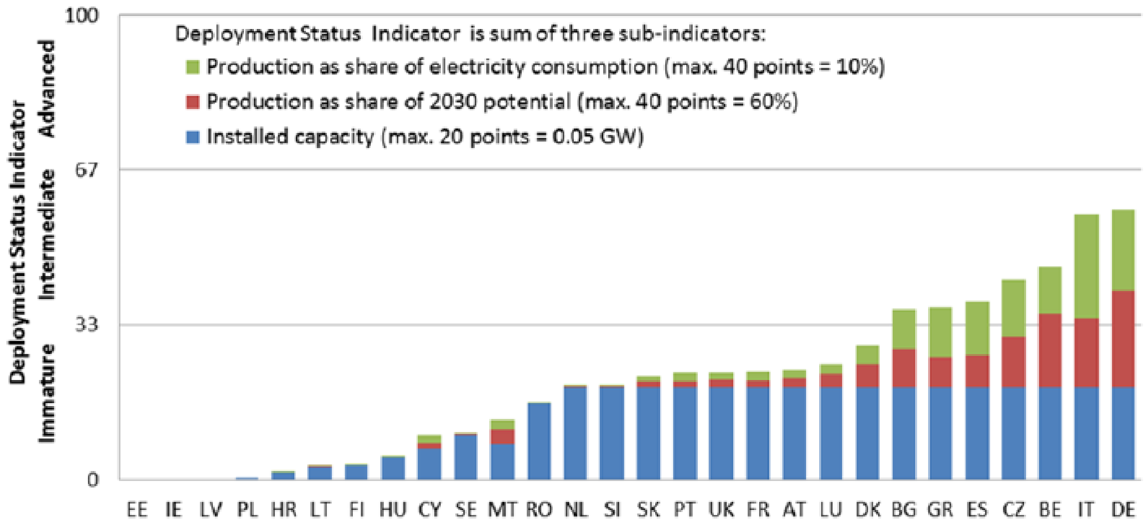

Figure 12 Deployment Status Indicator for PV plants in the EU-28 in 2012. Source: Held et al. 2014

3.4 Driver 4: Favourable national financing conditions

National credit rating and the national interest rate can have a considerable impact on the cost of capital. The availability of finance is however not only a result of the domestic macroeconomic conditions, but also on the ease of getting credit for RES-E projects in particular. While policy and revenue uncertainty impair the availability of credit and cost of capital for of RES-E plants, specific RES-E financing solutions could help. These could include soft loans with low interest rates or grace periods, but also loan guarantees where the government underwrites debt for a project or provides guarantees for the case a project defaults. Such financing support reduces the risk exposure of lenders and thereby reduces the cost of capital of RES-E projects (Rathmann et al. 2011).

3.5 Barrier 1: Revenue risk

Uncertainty about future revenues increases the level of risk for RES-E projects, resulting in an increase in risk premiums and therefore in higher costs of capital. Since RES-E plants are highly capital intensive, high revenue risks result in substantially higher generation costs, endangering the business case for RES-E project developers. In addition to increased generation costs, the higher risk premiums imply that investment in RES-E projects becomes unattractive for the more risk averse spectrum of investor profiles, reducing the financing options available for RES-E developers.

Existing support schemes mitigate revenue risk for RES-E project developers to different degrees: quota schemes expose the operator to both wholesale market revenue and green certificate price risks (in some cases limited); feed-in premium schemes also expose RES-E to wholesale market revenue risk, but guarantee a level of support payments. Fixed feed-in tariffs (FIT) and sliding feed-in premiums (i.e. contracts for difference) provide the highest level of revenue stability as they provide a fixed payment (in the case of FIT) or a stable combination of support premium and market price (in the case of the sliding premium).

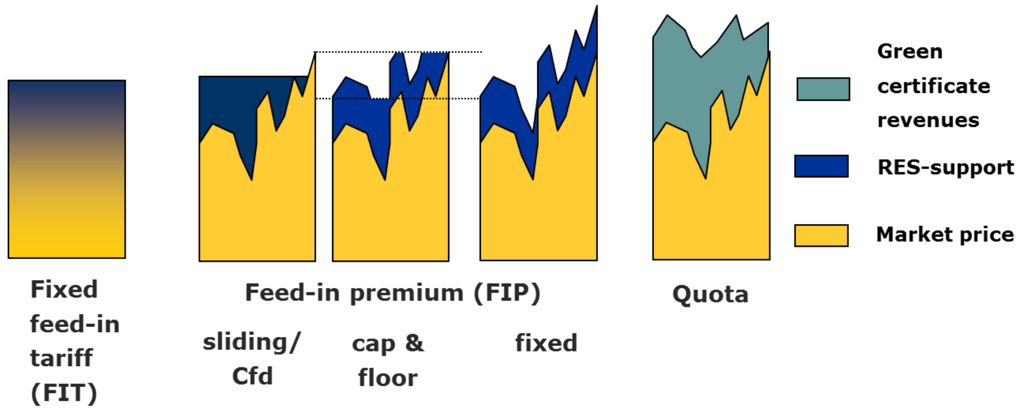

Figure 13 Payments by support scheme type (Source: Ecofys)

A number of Member States has shifted from fixed feed-in tariffs to feed-in premium schemes that further the market integration of RES-E by gradually exposing them to market prices (even though the associated revenue risk differs strongly from a sliding to a fixed feed-in premium scheme). Through participation to the wholesale market, RES-E producers have an incentive to optimise their production according to market prices. In markets without economic support, the revenue for RES-E generators is not protected by the design of the support scheme. RES-E plants are fully exposed to market risks.

In this situation, the revenue risk can be split into two main elements, namely: **price risk** and **volume risk**.

Price risk refers to the uncertainty and variability of the future power prices that RES-E developers will obtain from the markets.

Market prices evolve due to a combination of a large number of factors e.g. level of electricity demand, fossil fuel prices, capacity availability, market design elements such as the availability of capacity mechanisms, changes in the weather, among many others.

In the last few years, wholesale power market conditions across the EU have become very difficult for prospective investors in new generation. Power prices are in most cases insufficient to cover life-cycle generation costs, not only for renewables, but also for mature conventional technologies. Among the reasons for this situation is the excess generation capacity present in some Member States as a result of stagnated demand following the economic crisis as well as the increasing volumes of renewable generation.

Future power prices in wholesale markets are difficult to predict for all market actors; however, RES-E developers are particularly vulnerable to this uncertainty due to its capital intensive cost structure characterised by large initial investments.

However, market revenues for RES-E developers depend not only on the average wholesale market price but also on the relative market value[9] of RES-E technologies in a specific wholesale market. As it will be discussed later in section 4.4, the market value of variable, almost zero marginal cost technologies like solar PV and onshore wind decreases with the level of penetration of the technology in the market.

In the absence of sufficient predictability of future power prices, potential investors will be very reluctant to invest in RES-E projects; however, future price risk may be mitigated by entering into long-term contracts. The availability of a long-term contract may reduce generation costs for RES-E generators by ~20% through a combination of increased possible leverage and reduced costs of capital (Weiss et al. 2013). However, the financial terms of the long-term contract will be influenced by the RES market value and the market price risk.

The long-term predictability of revenues for RES-E can be improved with the implementation of functioning, transparent and liquid forward power markets; while this is already the case in some parts of Europe, others still struggle with barriers for the participation of RES-E generators in these markets, including: lack of transparency of market rules; high cost of guarantees to formalise contracts; non-availability of forward products suitable for RES-E generators.

Volume risk refers to the amount of energy that the RES-E generator is able to sell in the market. In this paper we mainly focus in wind onshore and solar PV. Both these technologies are resource-driven (vRES) and therefore 'non-dispatchable'. Current power systems and markets were designed primarily with dispatchable technologies, resulting generally in low levels of system flexibility. The availability of wind and solar resource determines the time at which power can be generated and the power output. When wind and solar power are curtailed at times of congestion in the grid, this results in energy generation lost and revenues foregone.

Levels of curtailment can be reduced by increasing system flexibility (e.g. through increased demand response grid reinforcement, power storage, larger control areas – regionalisation of power system as well as use of more grid friendly vRES technologies). Another measure that has been used so far is granting priority dispatch to renewable generators. Curtailment risk can be lowered with clear, precise and transparent grid management and dispatch rules, so that revenue losses linked to curtailment can be predicted up-front by RES-E operators. Nevertheless, risk of curtailment will likely increase with increasing shares of vRES. Curtailment could be interpreted as a system service in situations when the power system simply cannot absorb the amount of power fed into the grid during high-resource-low-demand moments. It should be priced in a structured way by a well-designed ancillary services market.

Some countries compensate RES-E generators for curtailment, in order to limit the related volume and financial risk and this compensation rules may constitute the starting point for the ancillary services debate.

[9] Ratio of the average price per MWh received by a specific technology and the average wholesale market price

3.6 Barrier 2: Market entry costs

Grid access

Improving grid access holds also the potential to strongly reduce investment costs of RES-E plants in countries with high grid access barriers. A lack of information on available grid connection capacity insufficiently transparent assessment methods, or a lack of actual grid capacity as well as land ownership issues prolong project development and increase its cost. Also here, streamlined administrative procedures, faster administrative processing times and a standardization of grid codes can help to address the issue (EWEA, 2010). Further information about future grid development and an increased predictability and transparency of the grid connection procedure could also improve the situation. Finally, the costs of connecting to the grid can be reduced by adopting a shallow grid connection charging regulation where grid upstream reinforcement costs are socialized via the network tariffs and no or little costs are charged to the connecting entity.

Administrative barriers

Administrative barriers such as lengthy and complex permission processes are a cost element of RES-E that can be reduced as a “no-regret option”, as this will reduce costs without shifting them to society. Lacking coordination between authorities on permissions that are required for building RES-E plants is an example of such a barrier. Interviews conducted with RES-E financing experts in the course of the EU-funded RESHAPING research project show that providing stable and transparent administrative procedures can reduce LCOEs of wind and PV projects by ~10% (Rathmann et al. 2011).

This can be achieved by improving and streamlining the administrative procedures, for instance introducing “one-stop” shop approaches for project applications and defining maximum response periods for the responsible authorities (Klessmann et al., 2013). The latest progress report of the European Commission on the implementation of the Renewable Energy Directive shows that while there has been substantial progress in recent years, in a majority of Member States there is still a need for further improvements in their administrative procedures applicable to renewable energy producers (EC, 2015).

3.7 Barrier 3: Market integration costs

Current power market rules are not always fully prepared to incorporate increasing volumes of variable RES-E generation (vRES). The extent to which existing power markets adapt to facilitate the operation of vRES generators is a key element determining generation costs.

One of the key characteristics of supply-driven renewables like solar PV and wind onshore is that the actual power output of the generation plants is uncertain until the time of delivery, while predictability increases towards this time. The deviation between the programmed and actual generation (forecast errors) of these technologies needs to be balanced through the balancing market. This represents a cost for the system. In the case of wind power, IEA estimates that in the EU the system costs increase by 1 - 4.5 EUR/MWh due to wind variability and uncertainty for wind penetrations of up to 20% of gross demand (IEA, 2013).

In view of the increased penetration of variable renewables, many EU Member States have started to attribute system balancing responsibilities to wind and solar PV installations and established (economic) penalties for their production programme deviations. In many cases, balancing rules for wind and PV are the same as for other generators.

Given the variability and limited predictability of wind and solar generation, exposure to balancing responsibilities can result in high balancing costs for RES-E, depending on the design of the market rules applied. When power market rules do not allow adaptation to changing wind and solar forecasts during the day, (intraday markets) large volumes of real-time balancing are required and actual costs of balancing are larger than needed.

The uncertainty about wind and solar power output decreases very substantially from day-ahead predictions as compared to forecasts just a few hours before physical delivery of energy, so the costs for balancing solar PV and wind uncertainty in the system can be significantly reduced with appropriate market design options.

Most power systems develop a schedule of supply and demand for each hour. Because the deviation from forecasts grows over time, the deviations over shorter time periods are less than over longer ones. Reducing the scheduling or dispatch periods to e.g. five to fifteen minutes can significantly reduce the deviations from plan, and hence, the need for reserve generation to cover those deviations.

Similarly, reducing the “gate closure” times - i.e. minimising the time between the end of the trading period and the delivery of electricity – also reduces deviations and reserve needs. “Gate closure” times can be as long as two hours. Reducing the gate closure periods to less than an hour may help decrease costs for renewables. This however should be combined with measures that address intra-day market liquidity, to allow that intra-day markets actually provide enough opportunities to take actions upon updated forecasts (Ecofys, 2015).

4 Elements determining revenues for RES-E

A scenario of progressive phase-out of economic support for RES-E technologies means that these should get an increasing share of their revenues from the power markets. Ultimately all revenues should come from the market. The question that immediately arises is: ***will future power market prices be a sufficient incentive to guarantee the required investments in RES-E generation in order to meet the EU 2030 renewable targets?***

The main elements determining future revenues for power market participants are shown in Figure 14 below. We distinguish three main sources of revenue: firstly, revenues from electricity sales, which are determined by the future average wholesale market price and the specific value of the technology in the market considered; secondly, revenues from the provision of balancing and/or ancillary services; thirdly, revenues from the provision of firm capacity in those power markets where this is remunerated.

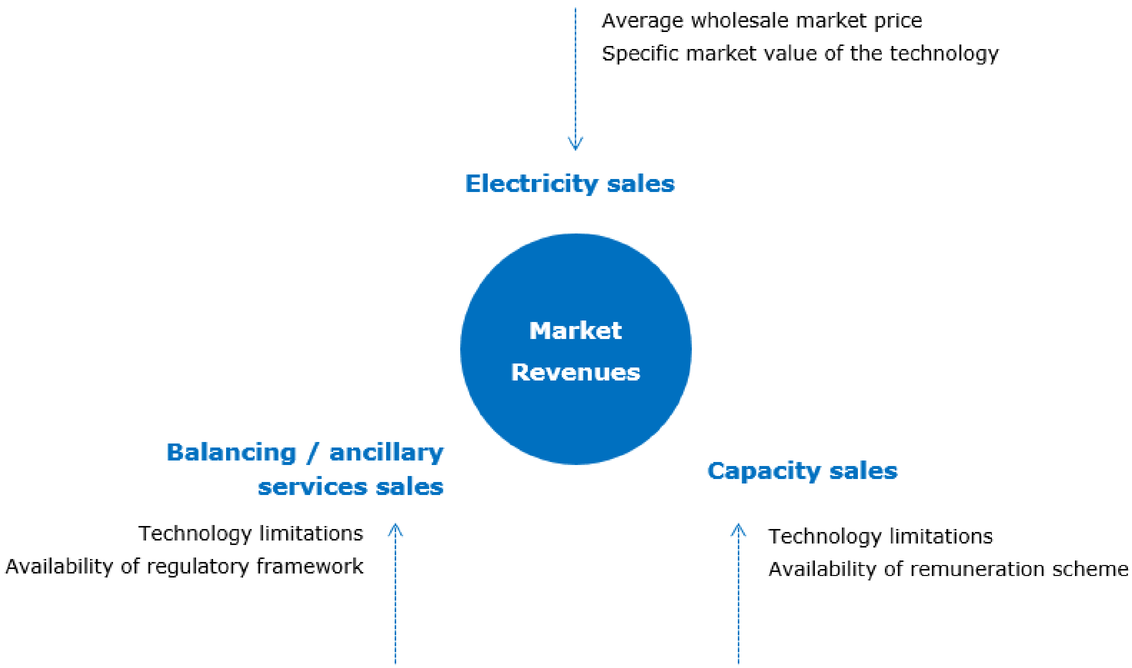

Figure 14 Factors determining future revenues for RES-E projects (I)

In this chapter we focus on analysing the factors determining future revenues for RES-E developers from electricity sales. As it will be discussed later, with appropriate regulatory frameworks, (variable) RES-E technologies could obtain some additional revenues from the provision of balancing and/or ancillary services in the market. However, these are expected to be just a small fraction of the revenues from electricity sales. Finally, as it was discussed earlier, in this paper we focus on supply-driven technologies (solar PV and onshore wind). Therefore, with current technologies the potential to obtain revenues from capacity sales can be neglected.

Table 2 below shows a list of identified drivers and barriers influencing the future evolution of power market revenues for RES-E developers. In the following subsections we discuss in detail these drivers and barriers and the associated policy options that would facilitate the progressive phase out of dedicated economic support for RES-E generators.

Table 2 Revenues for RES-E developers in wholesale markets. Drivers and barriers

	Drivers (+)	Barriers (-)
Power Market Revenues	• **High fossil fuel prices** (increases generation costs for conventional plants, increases average wholesale market prices) • **Adequate externality (carbon) pricing** (increases generation costs for polluting/carbon-intensive plants, increases average wholesale market prices) • **Provision of balancing and ancillary services** (opens up new sources of revenue for RES-E)	• **Decreasing market value of RES-E with increased penetration** (reduces average market prices received by RES plants) • **Subsidies to conventional generators** (artificially reduces wholesale market prices) • **Low flexibility of power system** (limits further integration of vRES and decreases its market value)

4.1 Driver 1: High fossil fuel prices

Fossil fuel prices are a key cost component of fossil-fuel-based electricity production and their price developments has a direct impact on the competitiveness of RES-E. Fuel costs are volatile and strongly depend on the depletion of traditional and the availability of new fossil fuel sources, the integration of fossil fuel markets, geopolitical developments in supply and transit countries as well as general macroeconomic developments.

In the past, arguments for the increasing competitiveness of RES-E compared to electricity from fossil-fuel sources were partly based on expectation of increasing fuel prices due to the depletion of fossil sources ("peak oil")[10]. The increasing exploration of unconventional fuel sources that has induced a downward trend on regional, if not global, gas prices has however shown that the development of future fossil fuel prices depends on a more complex set of drivers.

Availability of fossil fuel reserves

In the major European gas-producing countries (e.g. United Kingdom, the Netherlands and Norway) domestic gas production is declining, but globally unconventional gas resources, e.g. shale gas in the United States, are increasingly explored. The availability of new sources reduces global gas prices as countries either consume cheaper domestic sources or gas is redirected to new consumers, e.g. through transport of liquefied natural gas (LNG). While there are still serious environmental concerns in Europe on the exploitation of unconventional fossil fuels and the scale of these reserves is not as significant, still Europe benefits from reduced global gas prices caused by the exploitation of unconventional sources in other regions. Large European and global reserves and good access to the global coal market make coal-based electricity production in Europe generally cheap. The competitiveness of coal-based generation is further increased by the low carbon allowance prices in the EU ETS (see next chapter). With coal being the energy source with the highest specific greenhouse gas emissions (FEE, 2010), there are however strong climate implications of coal-based electricity production.

Integration of market and supply routes

With higher capabilities of Western European LNG hubs, European gas prices could fall with decreasing global gas prices. LNG gas is however increasingly redirected to East Asia where prices for LNG are higher. Lacking infrastructure to transport gas from the Western European LNG hubs to Central and Eastern European consumers

[10] See e.g.: http://www.renewableenergyworld.com/rea/news/article/2011/01/the-peak-oil-catastrophe-in-waiting

also hinders that all European Member States profit from cheaper gas prices. A further obstacle is the predominance of long-term take-or-pay gas contracts which avoid that developments on the global gas market are faster reflected in the domestic gas production costs (EC, 2014).

Geopolitical risk and general economic development

The geopolitical risk of unstable supply and transit regions for fossil fuel sources also impacts the price of fossil-fuel-based electricity production. One of the strongest impacts on fuel prices is caused by the state of the global economy. The global recession and subsequent decrease in fuel demand in 2008 resulted in a strong drop of the oil prices (IEA, 2009). After a period of recovery, prices started to drop again. In 2014 and into 2015 oil prices fell dramatically, as a further acceleration of supply, notably from North America, coincided with slower than expected global demand growth. Prices of other fuels moved in tandem in many parts of the world (IEA, 2015).

Figure 15 below shows the past evolution of different fossil fuel prices in different markets over the last 25 years.

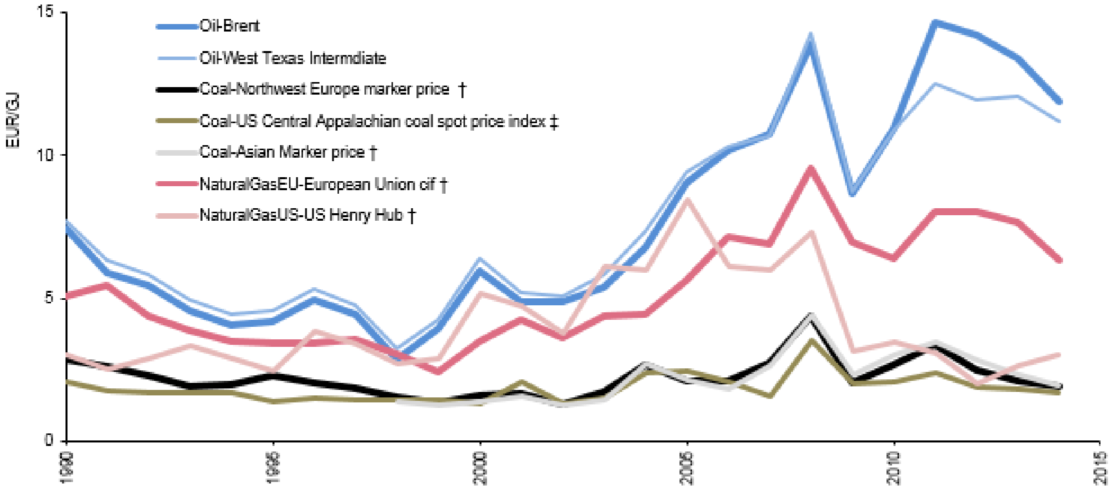

Figure 15 Evolution of fossil fuel prices in different markets. Source: Ecofys (source data: ENERDATA).

Future prospects

Predicting future fossil fuel prices is a very complex task; however, the latest downward movement for most fossil fuels has opened a deeper debate about the possible fundamental long-term price trends. According to the IEA, a more prolonged period of lower oil prices cannot be ruled out (IEA, 2015).

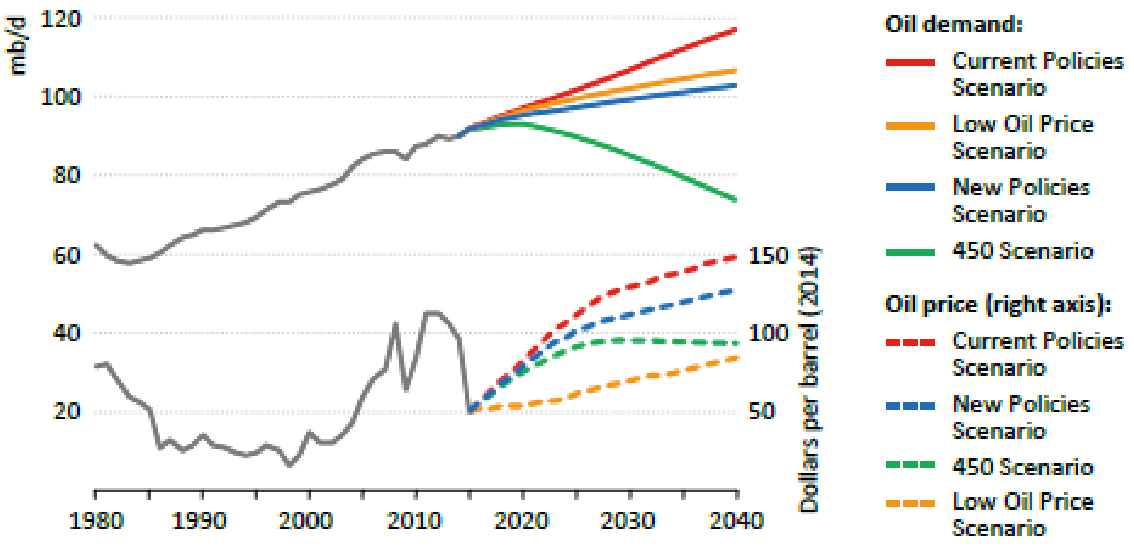

Figure 16 Global oil demand and price scenarios. Source: IEA, 2015

Figure 16 shows IEA projections of global oil demand and prices under different policy scenarios (IEA, 2015). These show a progressive increase in prices over the period 2020-2030; however, highest historic price levels are not reached again until the mid-2020s. Besides, under certain conditions (low oil price and 450 scenarios), prices would remain below the 100$/barrel mark for the whole 2015-2040 period.

In sum, at this point there is no evidence to expect that fossil fuel prices will reach unprecedentedly high levels in the period 2020-2030. While current levels of fossil fuel oversupply could be corrected in the near term, in the long term the global progress in energy efficiency, renewable energy, and climate action create a considerable downward push in fossil fuel demand, which could contribute to longer periods of relatively low fossil fuel prices.

4.2 Driver 2: Adequate externality pricing

Economic externalities represent the impacts of production and consumption on entities other than those producing and consuming, which are not reflected in prices. Externalities can be either positive or negative. The classic example of a negative externality is that of the private owner of a coal power plant paying for coal, labour and other inputs and charging for the energy sold, but not bearing a cost for the damages to health and the environment caused by, for example, the CO2 and particulate matter the power plant emits. These costs are borne by society as a whole, so that the outcomes for private and social welfare do not necessarily match. Other externalities besides CO2 and particulate matter may include ozone depletion, depletion of energy resources, water depletion, metal depletion and terrestrial acidification, to name a few.

In a perfect market, which maximises social welfare, private costs would be equal to societal costs, with no externalities to the price mechanism and all the costs and benefits to society of economic activity reflected in the price. Without policy intervention this is rarely the case in practice, with the most common result of lower prices and higher consumption than is desirable for society as a whole (see Figure 17).

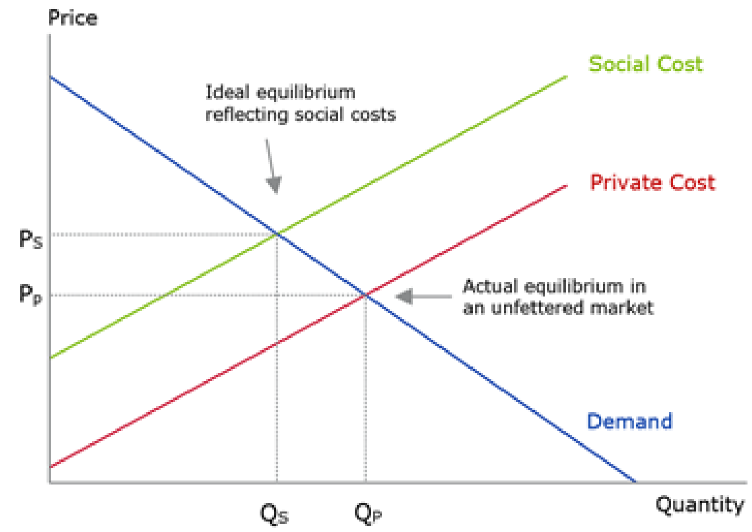

Figure 17 Externalities – result from the difference in private and social costs

In a major study for the European Commission (Ecofys et al., 2014b), the externalities related to the production and consumption of energy for heating, cooling and electricity production were assessed. This study shows that climate change (e.g. CO_2) and depletion of energy resources form the largest externalities. These are the highest for fossil fuel based heat and power generation technologies and significantly lower for renewables. Total external costs (or: non-internalised costs) in Europe are in the range €$_{2012}$ 150-310 billion in 2012, with a central value of €$_{2012}$ 200 billion. Regarding climate change damages, the report shows that there are large differences in methodologies and the monetary values that the literature gives to (the social cost of) climate change. A carbon price of €50$_{2012}$/tonneCO_2, is on the lower end of the range that is provided in literature.

From a societal perspective it is therefore desirable to 'internalise' the externalities, through policy interventions such as taxes, regulations, subsidies and other measures. These modify the prices and incentives for private production and consumption decisions so that they better account for the full impact on social welfare.

The EU Emission Trading System (EU ETS) is the cornerstone of EU climate policy and the main instrument aimed at internalising negative externalities in the EU by setting a market price for carbon and thereby giving a financial value to each tonne of emissions saved. The EU carbon market has suffered from an oversupply of CO_2 emission allowances since 2009. The surplus of allowances in the EU ETS can be attributed to several factors including the economic crisis and high imports of international credits, among others.

This has led to low carbon prices and thus a weak incentive to reduce emissions. Current carbon prices within the EU ETS are well below the €50$_{2012}$/tonneCO_2 mentioned above and therefore they do not reflect the level of climate change costs properly. In fact, between 2011 and 2015, EU ETS carbon spot prices dropped from above €15/tonneCO_2 in 2011 to around €8/tonneCO_2 in September 2015. Carbon Taxes in several EU countries are attempting to further internalise social costs to compensate for (low) EU ETS allowance prices[11].

The above illustrates well that current carbon prices fail to appropriately reflect the negative externalities related to fossil energy sources. This has a decisive negative effect in the competitiveness of renewable electricity generation by keeping generation costs for conventional technologies artificially low. This, in turn, drives wholesale power market prices down – failing to reflect true social costs of electricity generation – and makes it more difficult for RES-E plants to recover their generation costs exclusively from market revenues.

The European Commission has started to address this problem with the adoption of short-term and long-term measures. As a short-term measure, a decision was taken in February 2014 to postpone the auctioning of 900

[11] Carbon taxes are implemented in Finland, Denmark, France, Sweden, and a carbon price floor in the UK.

million allowances until 2019-2020; however, this 'back-loading' of auction volumes does not reduce the overall number of allowances to be auctioned during phase 3 (2013-2020), only the distribution of auctions over the period[12]. The structural correction of the chronical oversupply of allowances requires deeper measures in the long term. In October 2015 the Council approved the implementation of a 'Market Stability Reserve', which shall be established in 2018, with inclusion of allowances in the reserve from 1 January 2019.

The degree to which these reforms are successful in delivering a carbon price as close as possible to the real externality costs in the period 2020-2030 will be a determinant factor of RES-E competitiveness and thus of the possible phase out of economic support; however, most analysts do not expect that the carbon price will rise to the level of externality costs over the 2020-2030 period[13].

4.3 Driver 3: Provision of balancing and ancillary services

In section 3.7 we discussed the importance of adequate market rules to reduce system balancing costs with increased penetrations of variable RES-E plants; however, under certain conditions RES-E could also obtain revenues from the market by providing balancing or ancillary services.

Already today, some RES-E technologies, as for example biomass and hydropower and to some extent geothermal and CSP with thermal storage, are dispatchable and can provide balancing and ancillary services to the power system. While resource conditions limit the generation of wind and solar PV plants, they are also partially dispatchable in the sense that they can always provide downward balancing by reducing output if the right economic incentives are present.

Several studies investigating ancillary and balancing services in future power systems largely dominated by renewable energy point out that v-RES also have the potential to provide such services and therefore earn additional revenues to those of energy sales (Dena, 2014; Fraunhofer IWES, 2014a; Fraunhofer IWES, 2014b). The participation of vRES to ancillary markets is possible under certain conditions.

These include, first, that v-RES installations must be remotely controlled, in order to curtail or ramp up their production when needed. Second, expanding grid control areas in continuous improvement of communication between the grid and generation units in various geographical locations mitigates variability and consequently increases their ability to provide ancillary and balancing services. Fraunhofer IWES (2014b) tested the capacity of RES to ensure system stability, and concluded that a mix of dispatchable RES combined with v-RES can provide all required balancing needs, while using only current technologies. Nonetheless, changes are needed in the regulatory frameworks of balancing markets in order to lift the barriers that prevent the participation of RES. Prequalification requirements, tender periods, bidding sizes and lead times between the tender and provision period will have to be adapted to allow new providers of balancing energy from decentralised energy units and flexible electricity loads to enter the market.

More grid-friendly solutions in vRES could be promoted with the regulatory framework. Creating more demand in more –grid friendly vRES will also drive investments in technology, that will also be required to make sure that RES-E units are equipped with the necessary hardware and software to provide ancillary services. In particular, participation of distributed generation will also require coordination and upgraded information exchange mechanisms between system operators.

Balancing and ancillary services could constitute an additional source of revenues for RES-E if the right regulatory framework is set.

[12] http://ec.europa.eu/clima/policies/ets/reform/index_en.htm

[13] In the impact assessment of the EU ETS revision for phase 4, an average value of €25 for the period 2021-2030 is assumed (EC, 2015b)

4.4 Barrier 1: Decreasing market value with increased penetration

There are two intrinsic characteristics of wind and solar PV technologies that define the way in which they operate in the power markets:

Firstly, wind and solar technologies are characterised by high investment costs and very low relative operational costs. Additionally, the largest fraction of operational costs is independent of electricity production, so wind and PV can be considered almost 'zero marginal cost' technologies. In practice, this means that they can offer electricity in the power market at price zero, preceding most conventional generation technologies in the merit order[14].

Secondly, wind and solar are variable renewable energy sources (vRES). Their electricity output curve is *'supply-driven'* i.e. it is determined by the availability of the renewable resource at all times.

Joskow (2011) defined the 'market value' of vRES as the revenue that generators can earn on the power markets. The market value of a generation technology can be measured as the ratio of the average price per MWh received by that technology and the average wholesale market price. The two characteristics described above are key to understand the effect that wind and PV generators have in the power markets and in turn the impact on their own market value.

Wholesale market prices are set by the marginal generation costs of 'price-setting' technologies (usually gas plants and/or coal plants). In systems with low penetration of zero-marginal cost, supply-driven technologies in the power market, the hourly electricity price obtained by a few supply-driven, zero marginal cost generators is roughly the same as what it would be in their absence. Over a certain period, the average price obtained by vRES generators can be higher than the average wholesale market price when there is a positive correlation between RES production and power demand (e.g. solar power production correlates with air conditioning use, which drives demand – and prices – upward during sunny periods).

However, systems with high penetration of renewables show a completely different behaviour. Figure 18 below shows the effect of the penetration of substantial shares of renewables in the market. Since wind and solar PV have almost zero marginal costs, they enter first in the merit order curve. The share of power demand covered by them is no longer generated by the most expensive plants in the merit order curve (usually gas plants). Because the supply curve is shifted to the right, the marginal generation cost of the last unit needed to meet the demand tends to be lower.

[14] Ranking of available sources of power to meet a certain level of demand in a certain period of time. It is built on ascending order of price reflecting the order of their short-run marginal costs of power production and the amount of energy that each source can generate in the same period.

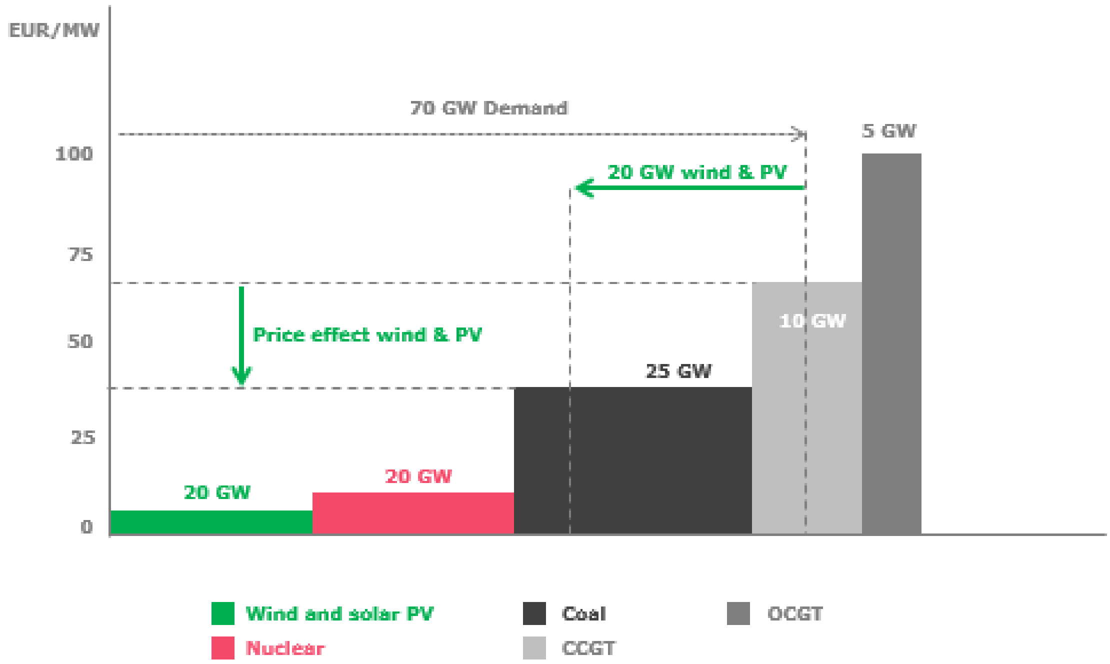

Figure 18 Illustration of the merit order effect. Source: own elaboration

This is known as the 'merit-order effect', and it results in a substantial reduction in the hourly wholesale market price when there is high infeed of wind or solar power. The larger the penetration of zero-marginal cost renewables in the system, the larger the downward pressure on prices.

This means that windy and sunny periods tend to be the low price periods in systems with large penetration of wind and solar PV technologies; however, as it was mentioned earlier, both technologies are supply-driven. Although prices tend to be lower when there is plenty of renewable resource available, it is precisely during those periods that they need to operate.

In a model-based analysis of this effect, Hirth (2013) found that the market value of wind power may fall from 110% of average power price to 50-80% when the market share increases from zero to 30%. In the case of solar PV the decrease in market value is even steeper, reaching similarly low values at 15% market share. In other words, wind and solar electricity are worth 50 to 80% of a constant generation source at penetrations of 30% and 15% respectively (see Figure 19 below).

This phenomenon has been often referred to as the renewables 'cannibalism' problem, in the sense that the more successful vRES are in gaining power market share, the more they undermine their own potential revenues in the current market design.

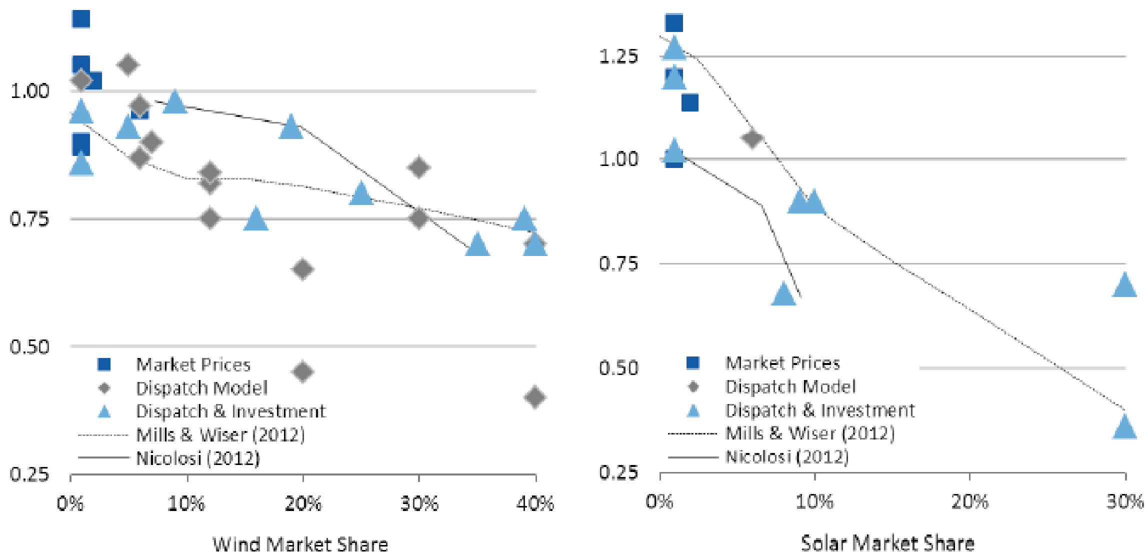

Figure 19 Estimation of market value for wind and PV generation with increased penetration (Hirth, L. 2013)

The 'cannibalism' effect described above has deep implications for energy policy makers as deeper penetrations of vRES in the power markets result in an increased relative need for net policy support to bridge the gap between decreasing revenues from the wholesale market and the LCOE for these technologies. While it can be argued that this may be a transitional effect – i.e. in the long run market actors will need to recover their fixed costs through higher market prices – it is difficult to predict when (or if) power markets will reach such new equilibrium.

Future increases in carbon prices could partially mitigate this effect by 'flattening' the merit-order curve (higher carbon costs for coal plants than for gas plants drive marginal generation cost convergence between both technologies).

Renewable project developers may also be able to mitigate this effect in the short term - to a limited extent - by adapting the design of generation plants to markets with high penetration of renewables. For instance, an increase in relative wind rotor size vs generator size increases the load factor of the plant, potentially increasing the average price obtained per MWh generated.

However, a long term and sustainable solution to this issue is to achieve increasing levels of flexibility in the power system and market. This is further discussed in section 4.5.

4.5 Barrier 2: Limited flexibility of power systems

A certain degree of system flexibility is an inherent and necessary feature in the design and operation of all power systems. Power systems need to ensure a spatial and temporal balancing of generation and consumption at all times. System flexibility represents the extent to which a power system can adapt electricity generation and consumption as needed to guarantee system stability, maintaining continuous service in the face of rapid and large swings in supply or demand (Ecofys, 2014).

In traditional power systems dominated by a relatively small number of centralised, conventional power generation plants, flexibility was provided almost exclusively by the generators (supply-side) and the only sources of variability came primarily from the demand side.

The inherent stochastic nature of supply-driven renewables such as wind and solar PV creates a need for power system flexibility by introducing variability on the supply side. At the same time, the increased penetration of these technologies in the power markets reduces the availability of flexible supply-side resources in the system by displacing traditional supply side flexibility providers (*'dispatchable'* plants with higher marginal generation costs). This creates a "flexibility gap" that will need to be covered by new flexibility options.

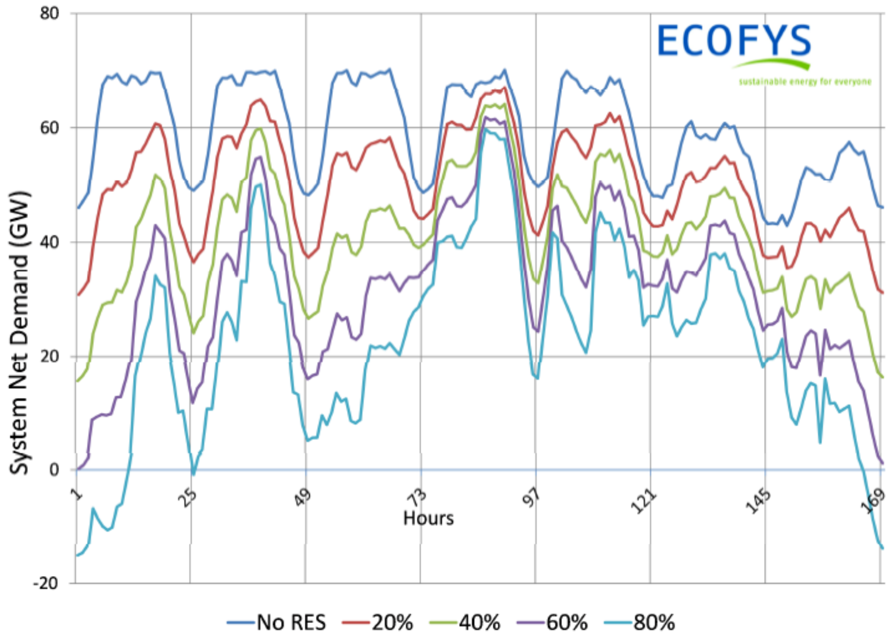

Figure 20 **Daily patterns of electricity demand (No RES) and net electricity demand15 at different vRES penetration levels. Source: Ecofys, 2014**

Current power systems still resemble the traditional power systems described above. The limited flexibility of such systems is an important barrier for further deployment of (more decentralised) variable renewable generators such as wind and PV plants. Firstly, because the lack of flexibility may create short-term technical limitations to deploy more generation capacity. Secondly, because the limited flexibility in the system exacerbates the merit-order effect described in section 4.4, reducing potential revenues.

Future systems and markets with increasing shares of vRES will need additional flexibility to maintain system reliability as the variations in supply and demand will be larger and faster. Figure 21 shows an illustration of the opening of the 'flexibility gap' in future electricity markets and how different options will take shares of the new flexibility demand.

[15] Net demand is the demand minus variable generation.

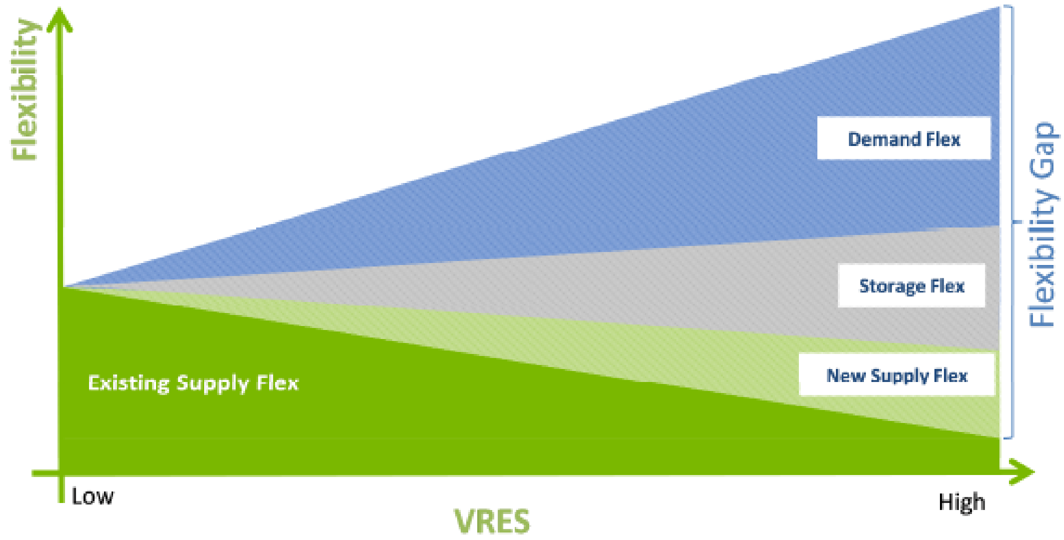

Figure 21 Flexibility gap in electricity systems with increased penetration of vRES. Source: Ecofys, 2014

There are several barriers in place preventing further development of cost-effective flexibility options. Current markets do not provide the adequate regulatory framework to increase system flexibility. For instance, the demand side does not have the mechanisms to participate in the market, responding to price fluctuations. Furthermore, several EU markets currently have excess generation capacity, which reduces price variability and in turn the economic incentives to invest in flexibility.

Future power market regulations should be designed to provide sufficient economic incentives for all market actors to contribute to the flexibility of the system. Flexibility in the power systems can be improved by increasing the flexibility of generators and consumers, but also by implementing energy storage solutions, increasing interconnection capacity with other systems, adapting power market rules and/or expanding market size.

Traditionally, the flexibility in power systems was provided almost exclusively by the supply-side; however, the demand side offers very significant and untapped opportunities to increase system flexibility. The adoption of demand response programmes could enable final consumers (including households, services and industry) to react to market events e.g. by increasing demand at times of abundant wind and PV power supply; however, this requires a reform of current power markets in order to enable the exposure of final consumers to wholesale market price signals. In some countries, district heating systems can facilitate the growth of flexible CHP (equipped with heat storage) to absorb spare vRES power and provide balancing services to the grid in low vRES power supply. Also on the demand side, incentives to accelerate the adoption of efficient heat pumps, electric cars or other forms of inter-sector coupling could improve power system flexibility substantially while achieving the broader policy objective of decarbonising other economic sectors.

Energy storage solutions may also play an important role in the flexible power systems of the future, by time-shifting energy between periods of over- and undersupply from variable renewables. Pumped hydro has been used for decades as a form of electricity storage and is a fully mature technology; however, the potential for growth in the EU is limited. Batteries are a promising storage technology for the medium or long term in terms of cost-reduction and growth trends, as well as in terms of possible synergies with other sectors (e.g. storage provided by batteries in electric cars).

Finally, progressing in the integration of EU power markets can also be an effective measure to improve the availability of flexible resources by increasing market size and profiting from reduced variability of renewable resources due to the greater spatial aggregation.

4.6 Barrier 3: Subsidies to conventional technologies

While renewables receive substantial amounts of (public) economic support, conventional generation still also largely benefits from various (historical) interventions and subsidies. Support for renewables is quite well documented and rather visible - as it tends to come in the form of direct subsidies (for e.g. production or investments); however, support for conventional based generation (fossil and nuclear) is often much less obvious.

Examples of interventions are certain energy tax structures and exemptions, financial government participation in oil and gas extraction and the (partial) coverage of risks by governments related to nuclear accidents and transport, to name a few. Policy support for conventional technologies may artificially reduce their generation costs, distorting the energy market and slowing down the transition towards a low carbon economy.

Ecofys et al. (2014b) provide an inventory of subsidies to different technologies in the EU energy sector. Figure 22 below shows the total value of current interventions in the EU in 2012 for energy production of 14 different technology categories and separately for energy demand and energy savings.

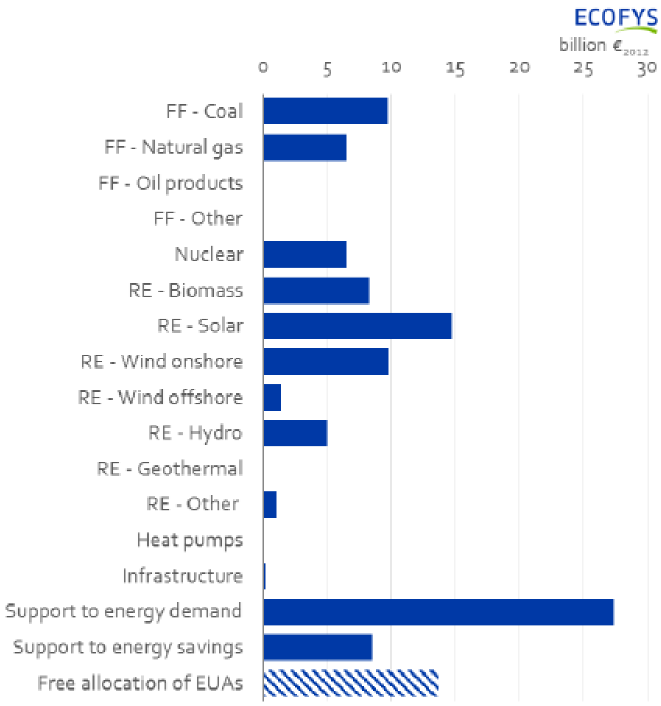

Figure 22 Total support provided in the 28 Member States (in billion €2012) per technology, including EU level support16. Source: Ecofys et al., 2014b

Support to production of electricity or of primary fuels such as coal, gas and oil makes up almost 70% of the total support. Of this, most support is still given to renewable energy technologies, particularly solar, although very significant support is also given to coal and nuclear, including decommissioning and waste disposal (Ecofys et al, 2014b)

From an economic perspective, a socially responsible and progressive phase-out of policy support to conventional generation will result in improving competitiveness of renewables, thereby reducing the need for support in the medium term and contributing to the accelerated phase-out of support for renewables themselves.

[16] Support to energy demand is typically provided in the form of tax exemptions (energy taxes, VAT, other taxes and levies) on the consumption of energy, or as price guarantees.

5 Discussion and conclusions

5.1 Discussion

The trends in terms of progress of RES-E towards technological maturity are clear. Levelised Costs of Electricity for both solar PV and onshore wind plants are increasingly competitive and quickly approaching those of conventional technologies; however, despite the very substantial cost-reductions achieved in recent years, the revenues from power markets alone are in most cases insufficient for RES-E project developers to cover their generation costs. Economic support is still needed and it is likely that it will still be needed to some degree in the period 2020-2030.

Current wholesale power market conditions across the EU provide in many cases little or no incentive for investments in new generation capacity. In many countries power prices are generally too low to cover generation costs, not only for renewables, but also for conventional technologies. Among the reasons for this situation is the excess generation capacity present in several EU power markets as well as the downward effect on prices driven by the penetration of increasing volumes of renewable generation, combined with low flexibility of the power system. Under these market conditions, aggregated market revenues do not cover generation costs at system level. The degree and the way in which this trend in the power markets is corrected in the future will determine to a great extent the future possibilities for RES-E deployment without economic support.

In addition to a sufficient level of future revenues expected from power markets, the second key factor determining the possible phase-out of economic support for RES-E is the level of risk attached to those future revenues. RES-E developers are particularly vulnerable to revenue uncertainty due to the capital intensive cost structure of wind and solar characterised by large initial investments. For this reason, a high risk market environment will increase RES-E generation costs and limit the number of RES-E investors.

In this paper we have analysed a number of drivers and barriers influencing the potential business case for RES-E developers both from the generation cost and revenue sides:

Main factors determining RES-E generation costs

A key driver for the increased competitiveness of onshore wind and solar PV observed in recent years has been the substantial reductions achieved in the costs of the technology. Further costs reductions - to different degrees – for both solar PV and wind onshore are expected in the period towards 2030. This trend will have strong positive effects on RES-E competitiveness.

Credible renewable energy and climate policies can contribute to reductions in generation costs without necessarily providing dedicated economic support. A key element is policy stability. Reliable and predictable long-term political targets and regulatory frameworks have a substantial positive effect on the generation costs by reducing risk premiums and providing clear investment signals to RES-E plant and supply chain investors.

As it was mentioned earlier, a key barrier for RES-E deployment without economic support is the uncertainty about future market revenues. This results in an increase in risk premiums - and therefore in higher generation costs – but also in a reduction in the financing options available, since investment in RES-E projects become unattractive for a wider number of investors. Long-term predictability of prices for RES-E can be improved by the implementation of functioning, transparent and liquid forward power markets, especially in where this is not yet the case. Furthermore, the price risk can be reduced by making public interventions in the power market more transparent and reliable, e.g. through long-term targets. In addition to helping to mitigate price risks, policies should also pay attention to volume risks, which can be mitigated by precise and transparent grid management and dispatch rules, so that revenue losses linked to curtailment can be predicted up-front by RES-E operators. All of these elements influence cost of capital and thus generation costs.

Generation costs for RES-E plants can also be reduced by reducing the costs of connection to transmission and distribution grids and streamlining administrative procedures.

Main factors determining revenues for RES-E

A key existing and future barrier for RES-E technologies to obtain sufficient revenues from the power markets is the 'merit-order effect', which results in a reduction of prices obtained by RES-E generators with their increased penetration in the power systems. The capacity for project developers to mitigate this problem is very constrained by intrinsic technical limitations. However, increasing levels of flexibility in the power system can be considered a long term and sustainable solution to the merit-order effect.

Traditionally, flexibility in power systems was provided almost exclusively by generators; however, the demand side offers very significant and untapped opportunities. The provision of demand response options could enable final consumers to react to market events e.g. by increasing demand at times of abundant wind and PV power supply, when prices drop. Energy storage solutions could also play an increasingly important role in the flexible power systems of the future, by time-shifting energy between periods of over- and undersupply from variable renewables. Finally, progressing in the integration of EU power markets can be an effective and efficient measure to improve the availability of flexible resources by increasing market size and profiting from reduced variability of renewable resources due to the greater spatial aggregation.

Adequate carbon pricing contributes to the competitiveness of RES-E technologies by adding the social cost of carbon emissions to the generation costs of fossil-fuelled plants. This has an upward effect in the marginal power prices set in wholesale markets and thus a positive effect in the potential revenues for RES-E plants; however, current prices in the EU ETS fail to reflect the true externality cost. The European Commission has recently adopted decisions to address this issue. However, carbon prices are expected to stay below the real externality costs up to 2030. The degree to which these reforms are successful in delivering a carbon price close to the real externality costs in the future will be a determinant factor of RES-E competitiveness and thus of the possible phase-out of economic support.

Last but not least, the remaining direct and indirect subsidies to conventional generation technologies in the EU are another potential barrier for RES-E because they artificially reduce generation costs for conventional plants, driving wholesale market prices down. A socially responsible and progressive phase-out of subsidies to conventional generation could result in improved competitiveness for renewables, contributing to accelerate the phase-out of economic support.

5.2 Conclusions

Increasing the share of renewables in the power system is a necessity for decarbonising electricity production and meeting the European energy and climate targets. In the medium term it may be possible to increase the share of RES-E without providing dedicated economic support. Such phase-out economic support for RES-E requires that two main conditions are met: firstly, expected future revenues from power markets are sufficiently high to cover generation costs; secondly, the risk tag attached to those revenues is acceptable for investors in the energy sector.

Nowadays, these conditions are not yet met, and it is unclear whether they will be widely met during the period 2020-2030. RES targets and support schemes will still be needed for a transitional period until power markets provide sufficient and sufficiently predictable revenues for RES developers. The level of support needed during this transitional period will strongly depend on how policies affect the *'drivers'* and *'barriers'* of competitiveness described earlier in this paper.

This transition towards the phase-out of dedicated economic support will require a shift in focus in (renewable) energy policies. These were traditionally designed to compensate RES developers for their higher technology costs. The fact that the Levelised Costs of Electricity for RES-E generators are increasingly comparable to those of conventional plants indicates that this issue will increasingly be less relevant. In turn, the key question to answer is how developers will recover their costs from the electricity markets.

RES policy (for mature technologies) should progressively move away from a narrow notion of dedicated RES-E economic support to one in which policies are aimed at providing the right conditions for renewables to compete in equal footing with other generation sources in the power markets.

This means, on the one hand, creating an adequate regulatory environment to trigger investment in new renewable generation. The level of long-term ambition and reliability of RES targets and regulatory frameworks are two critical elements to achieve this. Likewise, policies and regulations can greatly improve the business case for renewables by reducing market entry barriers e.g. costly grid connection or administrative procedures, where these barriers still prevail. Last but not least, phasing out support for emission intensive conventional sources will contribute to create a level playing field.

On the other hand, it means reforming the markets to ensure that they are adapted to the special characteristics of (variable) renewables and that they provide sufficient economic incentive for RES investors. Along with an appropriate pricing of carbon, the key element to achieve this will be the creation of the appropriate regulatory incentives to increase the levels of flexibility in the power markets. This is critical to ensure that long term revenues for renewables will be able to cover investment costs with increased levels of penetration.

The success in accelerating the phase-out of economic support for mature RES-E technologies will go hand in hand with the progress made in the transition in renewable energy policy and power market transformation described above.

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