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Abstract

This paper analyzes the different renewable support schemes that have been employed by different regulators worldwide, and how renewable energy is being deployed in different regions based on these schemes. The main goal is to estimate the effectiveness of renewable support schemes. In order to do that we relate the support schemes directly to the extent of renewable deployment. Other impacts and effects are also analyzed, including for example costs of feed-in tariffs or societal "cost" like increased electricity price volatility.

Keywords: renewables, renewable support schemes, environmental policy

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1 The necessity of renewable support schemes

Renewable Energy Sources (RES) are of utmost importance for the mitigation of climate change. The Intergovernmental Panel on Climate Change (IPCC) determined in its latest report that significant increases in renewable energy generation are necessary to decarbonize our energy systems and hence to avoid a global average temperature increase of over two degrees Celsius. An increase of two degrees is generally seen as critical threshold above which the detrimental consequences clearly exceed the potential costs and efforts to keep the increase below the two degrees.

In particular, and as pointed out by the IPCC (2014, p. 100) the share of low-carbon electricity supply, consisting of renewable energy, nuclear energy, and fossil generation with carbon capture, will have to increase to 80% of total electricity generation until 2050. The maturity of the carbon capture technology is still incomplete (see for example Bui et al. 2018), and the political support of nuclear energy is dwindling as well in some key countries. As a consequence, the challenges to increase renewable electricity generation (with wind, hydro, solar, other modern bioenergy, and other renewable sources) are large.

This is illustrated by current figures of renewables generation worldwide. As depicted in the following figures, global renewable electricity generation is still far from the figures projected by the IPCC (2014) for 2050.

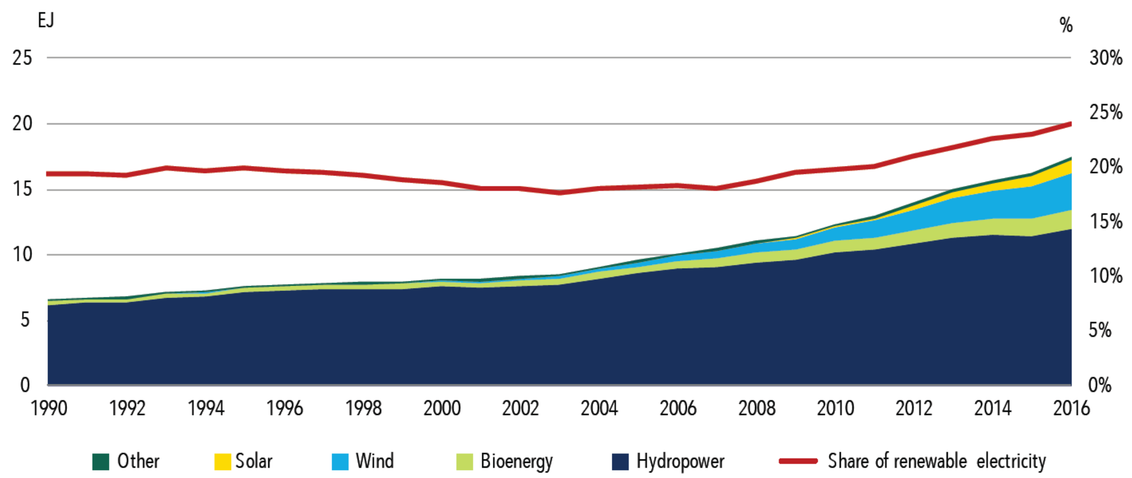


Figure 1 – Global Renewable Electricity Consumption by Technology 1990-2016. Source: IEA et al. (2019, p. 68)

As indicated by the above figure, the global share of renewable electricity consumption was 25% in 2016. And about 2/3 of that was hydro generation. Hoes et al. (2017) estimate that the global potential for hydroelectric generation is 52 PWh/year, which is roughly about 33% of the annually required energy. However, the potential for new hydro capacity is not distributed evenly over the world (see for example Zhou et al. 2015). Many countries will have to reach high participation rates of renewables without additional hydro capacity.

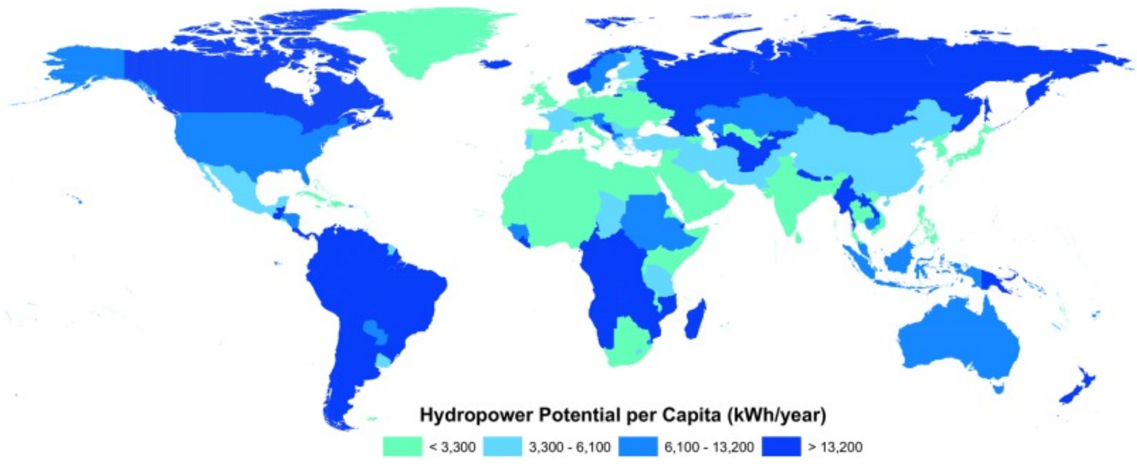


Figure 2 – Hydropower Potential per Capita (kWh/year). Source: Hoes et al. (2017)

This means that a significant share of the necessary new renewable capacity will have to come from wind (onshore and offshore), solar (PV and thermal), modern and clean biomass, or other innovative renewable sources which will still have to be developed.

In many cases these technologies have not yet reached levels of maturity and competitiveness that would ensure the necessary levels of implementation. Significant market barriers, the most prominent of which are the externalities and spillovers in the innovation market, still obstruct the roll-out of renewables. Therefore, support is needed to ensure that the technological development progresses further. This is vital to ensure that GHG reduction costs are not excessive.

The EU, for example, has recognized this. On June 14th 2018, the recast Renewable Energy Directive was agreed between the European Commission, the European Parliament and the European Council. This new regulatory framework includes a binding renewable energy target for the EU for 2030 of 32%, with a review clause by 2023 for an upward revision of the EU level target. Other countries or regions are also considering renewable energy targets and support instruments that may achieve them. The EU has also reformulated its view about support instruments, within the State Aid guidelines. According to the EU, support instruments need to be competitive (thus eliminating the possibility for earlier feed-in-tariff or feed-in-premium systems).

2 Overview of available renewable support systems

Renewable support systems have been used in many different forms and shapes. IRENA (2012) provides an overview of renewable support schemes and defines 18 different categories. In order to simplify and summarize the different support schemes we define the following categories of renewable support schemes:

<u>Price Instruments:</u>

- Investment support (Investment grants)

- Feed-in tariffs (FIT)
- Feed-in premiums (FIP)

Quantity Instruments

- Renewable Tradable Quotas
- Auctions

Voluntary instruments

- Green Electricity

In the following we describe these different options.

Investment support (Investment grants)

In the case of investment subsidies, a financial subsidy is granted to investors developing RES-E capacity. These mechanisms include capital grants, third-party financing, consumers grants and rebates, among many others alternatives.

In the case of fiscal incentives, rebates are granted on investment in RES-E capacity, or on the energy produced. These mechanisms include tax credits, excise and property tax exemptions, and/or many other similar alternatives.

Fiscal incentives such as grants and investment subsidies are the most popular policy mechanisms implemented to promote renewable heating and cooling. For renewable electricity they were used to jumpstart markets, but were later phased out and substituted with feed-in tariffs.

Feed-in Tariffs (FiTs)

FiTs guarantee stable purchasing prices for renewable plant operators for a given period, often between 10 and 30 years. The tariff usually varies by supported renewable technology. Also, the amount of the tariff is often adjusted over time, according to a long-term path to allow for investment security. In some cases the FiT is adjusted according to new installed capacity each year; e.g. if new capacity exceeds a certain threshold, the amount of the FiT is reduced automatically.

The cost for FiT can be funded through tax revenues (i.e. the public budget), or be placed on market participants such as electricity suppliers or network operators, who then socialize these costs among electricity consumers. FiT provide predictability and stability, both for the overall renewable energy landscape from a policy perspective and for the individual producers and investors with regard to their revenue.

FiT have been popular in recent years, with the number of countries using this instrument increasing continuously.

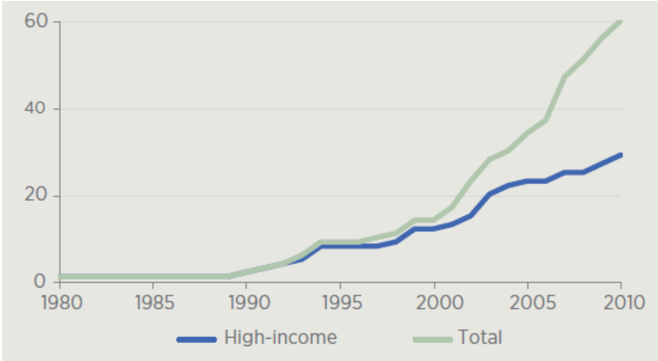


Figure 3 – Number of Countries using Feed-in Tariffs 1980 – 2010. Source: Irena (2012, p. 9)

A thorough analysis of feed-in tariff design options can be found in Klein et al. (2008).

Feed-in premiums (FiP)

In an FiP, plant operators have to market the electricity generated directly at the electricity market and receive an additional payment on top of the electricity market price - either as a fixed payment or adapted to changing market prices in order to limit both the price risks for plant operators and the risks of providing windfall profits at the same time.

Similar to FiT, the premiums are valid for a prescribed long time period. Here, the remuneration is more uncertain than with a FiT, but there is an incentive to produce when the power system needs it most (strongly correlated with higher prices). In some countries this scheme is associated with the obligation to participate in the electricity market. As with the FiT, the amount of the premium may depend on facility characteristics, and also on the electricity market price (in this case, expressed as a cap-and-floor or a contract for differences).

Box 1 – Strength and weaknesses of FIT and FIP	
Strengths: • Investor security • Effective (see Auer et al., 2009) • Low transaction and administrative costs. • Low entry barriers. (Investors do not have to find electricity buyers for their energy) • Government spending is foreseeable (if a cap to total spending exists) • FiT, unlike premiums, do not contribute infra-marginal capacity for incumbent generators that operate both traditional generation assets in the electricity market as	Weaknesses • Incentives must be constantly updated to keep up with technological improvements and other cost factors. • it is very challenging to determine the right remuneration levels, particularly so if technological advance and other factors are to be considered. • If remuneration levels are adjusted over time (which is recommended to represent changing circumstances), this may lead to investor insecurity.

well as renewables, thus reducing their potential market power. • Premiums, unlike FiT, do not suppress market price signals.	• As in any price mechanism, the policy may not achieve the quantitative objectives pursued.

Renewable Tradable Quotas

In comparison to FiT / FiP, tradable quotas mean that governments fix quantities and the market sets the price. A minimum share of the electricity supply has to come from RES, and this share is increasing over time. Suppliers may trade certificates for electricity from RES (RES-E) on a secondary market if they cannot reach the minimum share with own production. In this case, the certificates are usually awarded per unit of electricity produced with renewable sources. In the certificate market, the actors required to comply with the renewable quota (electricity generators, distributors or retailers, depending on the specific scheme devised) buy certificates from renewable energy producers. Since these producers still sell their energy on the electricity market, the price of the certificate tends to be the difference between the marginal long-term cost of the renewable technology (i.e., the total cost of production of the last unit of electricity needed to meet the quota) and the electricity market price. The certificate price can therefore be linked to the premium described earlier.

These systems are usually fitted with safety nets: a penalty is normally envisaged for non-compliance, so the maximum cost of the certificate, and thus the maximum total cost of the system, is known in advance. Sometimes a minimum price is also established to guarantee some degree of profitability for renewable facilities.

The quota can be technology-specific (this is called banding) or include several technologies. The banding provision is set to avoid that all investments happen for the least expensive renewable technology.

Box 2 – Strength and weaknesses of Renewable Quotas	
Strengths: • High compatibility with market principles and the competitive price determination. • The amount of electricity to be produced with renewables is a known quantity (with obvious favourable implications for power system management). • The market is entrusted with achieving efficiency by constantly incorporating technological change, so the target can be reached at a lower cost.	Weaknesses • High risk premiums resulting from the uncertain development of the prices of electricity and the certificates typically increase policy cost. • Price and volume risks must be assumed by producers. (The price depends on market conditions and can be volatile. The quantity is established by the regulator) • Certain practical difficulties and transaction costs are encountered: a market would have to be established for each technology, along with a suitable certification mechanism.

	• Possible appearance of market power in the certificate market when an electricity system has only a few large renewable energy producers.

Renewable Auctions

Another option for RES support is to use tender or auction schemes to allocate financial support to different renewables technologies and to determine the support level of other types of support schemes, such as feed-in systems, in a competitive bidding procedure. There are different ways to design an auction, but the static sealed-bid and the dynamic descending clock auction or a combination of the two have been used the most to support new renewable energy plants. Different mitigation measures exist to ensure that winning bidders effectively implement their project.

Hence, renewable energy auctions constitute another quantity instrument, but with some of the advantages of price mechanisms. These auctions are held at the initiative of the regulator, typically respecting uniform intervals, in which the regulator establishes a demand for a certain amount of renewable energy (usually classified by technology) and the bidders offer energy volumes and prices up to the quantity demanded. The regulator subsequently guarantees the price reached in the auction for the energy to be generated by the winner, usually by signing a long term contract, and provided that the renewable power facilities are installed within the specified time period. The auctions can be restricted to plants of a certain size or technology.

Auctions have been successfully used for renewables procurement in several Latin American countries, where the initial flaws of early attempts in Europe have been corrected by good design and very competitive prices have been revealed, see Batlle and Barroso (2011). Auctions appear to be the right heirs to successful FiT programs for mature enough renewable technologies (Del Río and Linares, 2012).

Box 3 – Strength and weaknesses of Renewable Auctions	
Strengths: • Introduces a competitive element in the allocation of economic incentives. • Technological improvements can be factored into the equation automatically. • Provides financial security to the investor.	Weaknesses • Complexity and high transaction costs. • Market power issues can arise. (But these may be addressed in the design of the auction.) • Require credible non-compliance penalties. • Require connection between the auction and land use planning

3 Renewable penetration in Europe

In this chapter we evaluate which countries have reached the highest levels of renewable generation. The quantification of renewable shares must be done carefully. It can be measured in different ways; and the outcome can change significantly depending on the method chosen. We illustrate this in the following sections, using two different quantification methods for renewable shares:

- Method 1 - Evaluation by renewable shares (Eurostat data)
- Method 2 - Evaluation by renewable generation data (IEA data)

After presenting the two methods and their outcomes, we also provide an intuitive explanation for the different outcomes of both methods.

Method 1 - Evaluation by renewable shares (Eurostat data):

Eurostat provides a database on the renewable share (a percentage) of total energy production and of electricity production in Europe. The figure below shows the results of this data.[1]

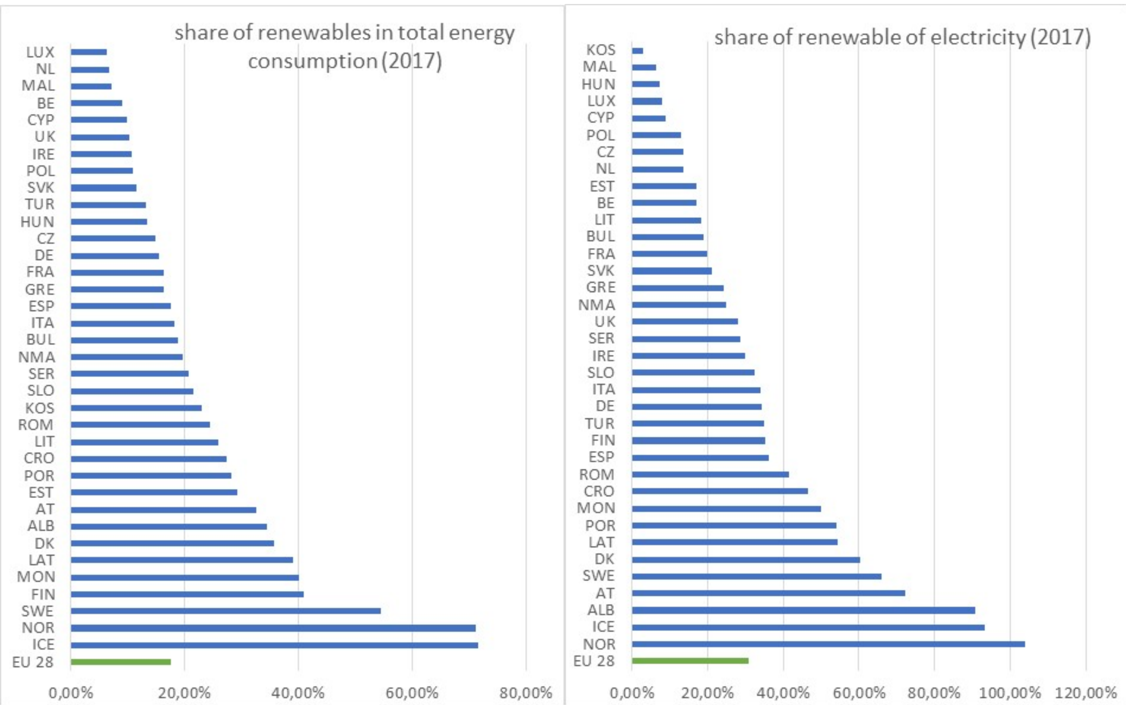
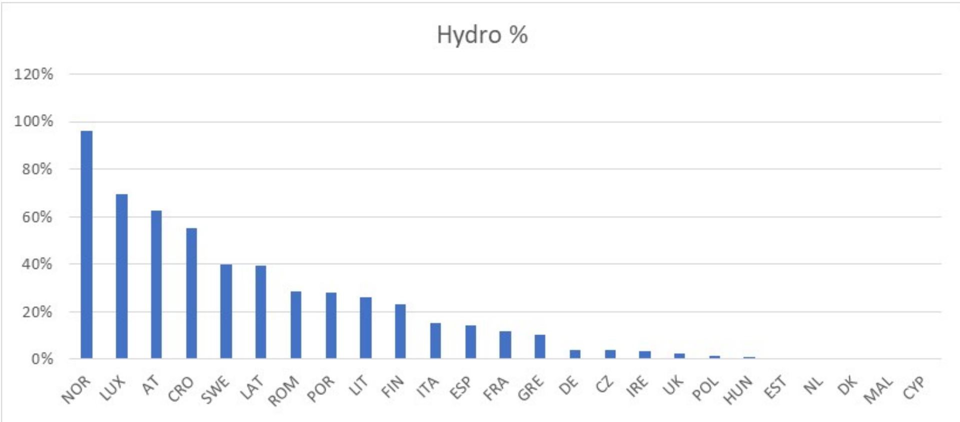


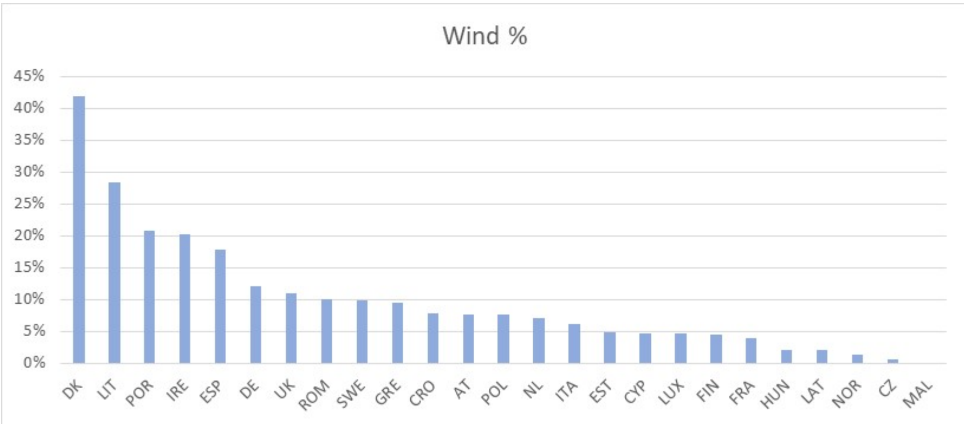
Figure 4 – share of renewables of total energy consumption and of total electricity for different countries. Data for 2017.. Source: Eurostat.

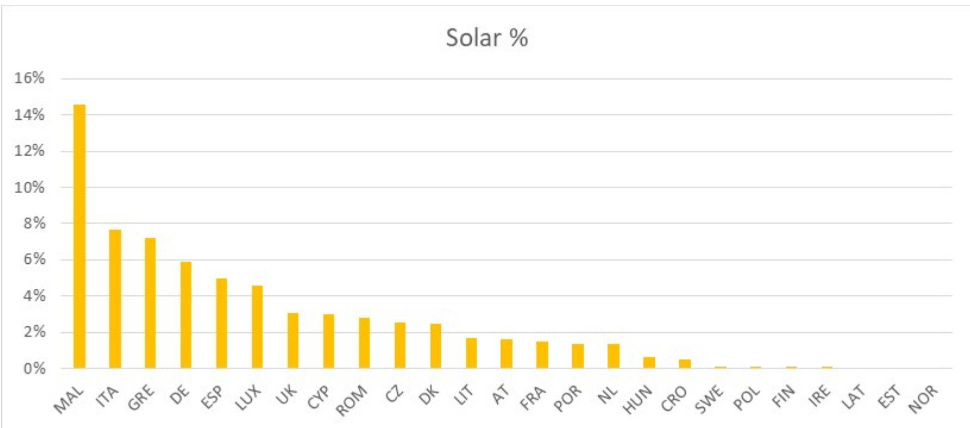
[1] The exact definition of the two renewable shares can be found on the Eurostat webpage. See: "Share of energy from renewable sources (nrg_ind_335a)" https://ec.europa.eu/eurostat/cache/metadata/en/nrg_ind_335a_esms.htm

Method 2 - Evaluation by renewable generation data (IEA data):

The IEA runs a database on renewable generation for most OECD countries. In this case there are also precise figures for different types of renewables.[2] We calculated shares (of total electricity generation) based on the renewable electricity relative to total electricity generation. The following tables represent the results for renewable participation based on these IEA figures.







[2] See the “statistics data browser” of the IEA: https://www.iea.org/statistics/

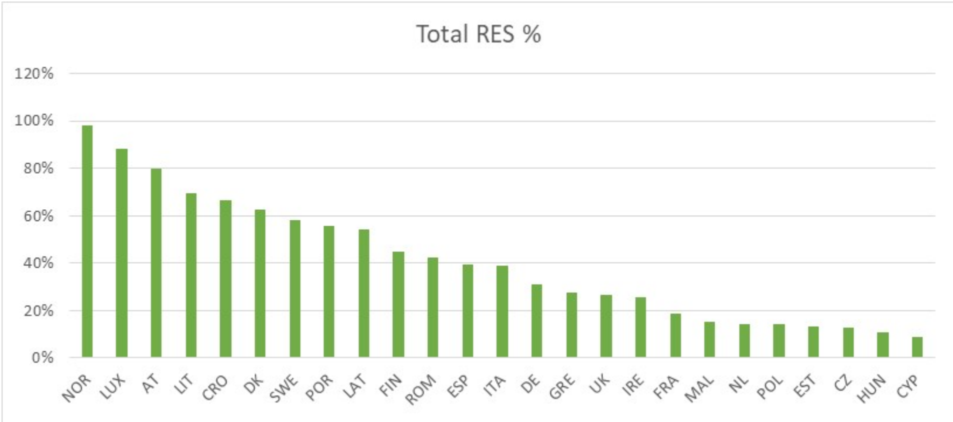


Figure 5 – Share of Hydro, Wind, Solar, and total RES generation of total electricity generation. Solar includes PV and concentrated solar-thermal. Total RES includes: Hydro, Wind, Solar, Biofuels, Waste, Geothermal, Tide. Source: IEA.

The data shows that the countries with highest shares of RES have high levels of hydro capacity. Denmark, for example, is a rare exception to this rule, as it has reached high percentages of total RES without any hydro capacity. Lithuania also reaches high % of total RES with equally much wind generation as hydro.

Differences between the ranking of renewable participation according to Eurostat or IEA data

The renewable participation percentage of Eurostat is based on energy consumption. This means that the share of RES is calculated as the renewable generation over total consumption (either primary energy consumption or electricity consumption). The IEA data on the other hand is calculated based on own production; e.g. the amount of renewable generation of total generation. For large countries the difference between the two approaches is negligible. Small countries, however, usually have higher shares of electricity imports or exports. In such cases, the two approaches of Eurostat and the IEA yield different results. The examples of Luxemburg and Lithuania, two relatively small countries, illustrate this.

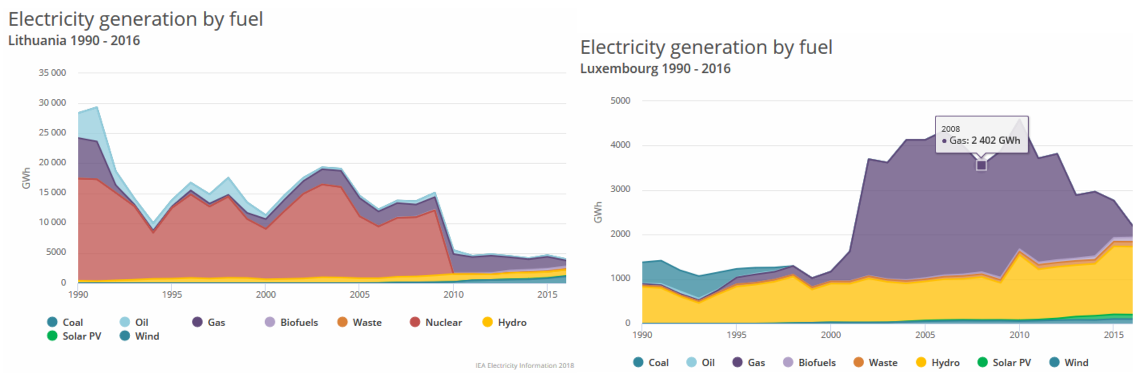


Figure 6 – Profile of electricity generation of Lithuania and Luxemburg according to IEA.

Lithuania ceased to operate their own nuclear power plants in 2004 and 2009, respectively. Since then, the total amount of own electricity generation has fallen significantly. For the remaining amount of electricity produced by own means, the renewable share is high. However, after 2010 electricity imports have covered for the nuclear capacity which disappeared. Imported energy is not necessarily renewable. This explains the discrepancy of results between IEA and Eurostat data. In Luxemburg we see a similar development regarding natural gas as a fuel to generate electricity.

It is thus not simple to fairly evaluate whether a country has successfully implemented renewables. First of all, we should distinguish between different types of renewables. High renewable shares of hydro were relatively easy to achieve for countries with the right topographic conditions like Norway, Sweden, or Austria. Other renewable resources, like wind and solar, have been more difficult to implement. Countries like Denmark, Italy, or Malta are thus to be highlighted for their successful implementation of wind and solar. Also, electricity exports and imports can bias the figures. For small countries with significant international grid interconnectors the renewable participation percentages have to be interpreted carefully.

4 Use of renewable support schemes in Europe

Each administration has a set of different support schemes at their disposal (see section 2 for a review). According to national preferences and conditions, countries have chosen to implement different support schemes. As for Europe, most European countries have opted for one of the renewable support schemes presented in section 2.

In Table 2 we present data from CEER (2018) on the type of renewable support schemes implemented in European countries. Note that this dataset represents the situation as of 2017-2016. Support schemes that have had an effect in the past, but which are no longer in force (as the Spanish Feed-in tariff, for example), are not represented in the table.

Country	Type of Support	Process determining the level of support or the quota	PV	On-shore Wind	Off-shore Wind	Bio-Energy	Hydro	Duration of support (years)
AT	Feed-in Tariff	Administrative procedure	√	√		√	√	13 to 15
	Investment grant	Administrative procedure	√				√	n/a
BE	Green Certificates	Administrative procedure	√	√		√	√	10 to 20
	Feed-in premium	Administrative procedure	√	√	√	√	√	
BUL	Feed-in premium	Administrative procedure	√	√		√	√	12 to 20
CRO	Feed-in tariff	Tendering procedures	√	√		√	√	14
	Feed-in premium	Tendering procedures	√	√		√	√	
CYP	Investment grant	Administrative procedure	√					n/a
CZ	Feed-in tariff	Administrative procedure	√	√		√	√	20 to 30
	Feed-in premium	Administrative procedure	√	√		√	√	
DK	Feed-in premium	Tendering procedures	√	√	√			-
	Feed-in Tariff	Administrative procedure					√	
	Feed-in premium	Administrative procedure				√		
EST	Feed-in Tariff	Administrative procedure	√	√		√	√	12
FIN	Feed-in Tariff	Administrative procedure		√	√	√		12
	Feed-in premium	Administrative procedure				√		
	Investment grant	Administrative procedure	√				√	
FRA	Feed-in tariff	Tendering procedures	√					10 to 20
	Feed-in premium	Tendering procedures	√	√	√	√	√	
	Feed-in Tariff	Administrative procedure	√			√	√	
	Feed-in premium	Administrative procedure		√		√	√	
DE	Feed-in premium	Tendering procedures	√	√	√	√		20
	Feed-in tariff	Administrative procedure	√	√		√	√	
	Feed-in premium	Administrative procedure	√	√		√	√	
GRE	Feed-in Tariff	Administrative procedure	√	√				20 to 25
	Feed-in premium	Administrative procedure	√	√				
	Feed-in Tariff	Administrative procedure	√	√	√	√	√	
	Feed-in premium	Administrative procedure	√	√	√	√	√	
HUN	Feed-in premium	Tendering procedures	√	√		√	√	5 to 25
	Feed-in premium	Administrative procedure	√	√		√	√	
	Feed-in premium	Administrative procedure	√			√	√	
IRE	Green Certificates	Administrative procedure		√	√	√	√	15
ITA	Feed-in premium	Tendering procedures		√	√	√	√	15 to 25
	Feed-in Tariff	Administrative procedure	√	√	√	√	√	
	Feed-in premium	Administrative procedure	√	√	√	√	√	
LAT	Feed-in Tariff	Administrative procedure	√	√	√	√	√	20
LIT	Feed-in Tariff	Tendering procedures	√	√		√	√	12
LUX	Feed-in premium	Tendering procedures	√					15
	Feed-in Tariff	Administrative procedure	√	√		√	√	
	Feed-in premium	Administrative procedure		√		√	√	
MAL	Feed-in premium	Tendering procedures	√	√				6 to 20
	Feed-in Tariff	Administrative procedure	√					
NL	Feed-in premium	Tendering procedures	√	√	√	√	√	8 to 15
NOR	Green Certificates	Administrative procedure	√	√	√	√	√	15
POL	Feed-in premium	Tendering procedures	√	√	√	√	√	15
POR	Feed-in Tariff	Administrative procedure	√	√	√	√	√	15 to 25
ROM	Green Certificates	Administrative procedure	√	√		√	√	15
ESP	Investment grant	Tendering procedures	√	√		√	√	20 to 30
SWE	Green Certificates	Administrative procedure	√	√	√	√	√	15
	Investment grant	Administrative procedure	√					
UK	Feed-in Tariff	Administrative procedure	√	√		√	√	10 to 20
	Feed-in premium	Tendering procedures	√	√	√	√	√	
	Green Certificates	Administrative procedure	√	√	√	√	√	

Table 1 – Overview of Renewable Support Schemes of European Countries. Source: CEER (2018, p. 12)

We use more data represented in CEER (2018) to also evaluate how ambitious the renewable support schemes of each country are. I.e. we attempt to estimate the force of impact of each renewable support scheme. This is done by two indicators:

1. The percentage of total electricity production which receives renewable support.
2. The monetary value of renewable support provided relative to total electricity production (€/MWh).

country	Electricity receiving support over gross electricity generation	country	Electricity receiving support over gross electricity generation
DK	63,3%	POL	12,1%
LIT	35,5%	CRO	11,6%
IRE	29,3%	NL	11,1%
POR	28,6%	EST	9,9%
GER	24,9%	CZ	9,3%
ITA	22,4%	HUN	7,4%
ESP	20,0%	CYP	7,3%
GRE	19,6%	FRA	7,0%
UK	19,3%	FIN	6,3%
AT	14,3%	NOR	3,3%
LAT	13,6%	BE	n.a.
SWE	13,5%	BUL	n.a.
MAL	13,4%	SLK	n.a.
ROM	13,4%	SLV	n.a.
LUX	12,7%		

Table 2 – Electricity receiving renewable support over gross electricity generation. Data for 2016. Source: CEER (2018)

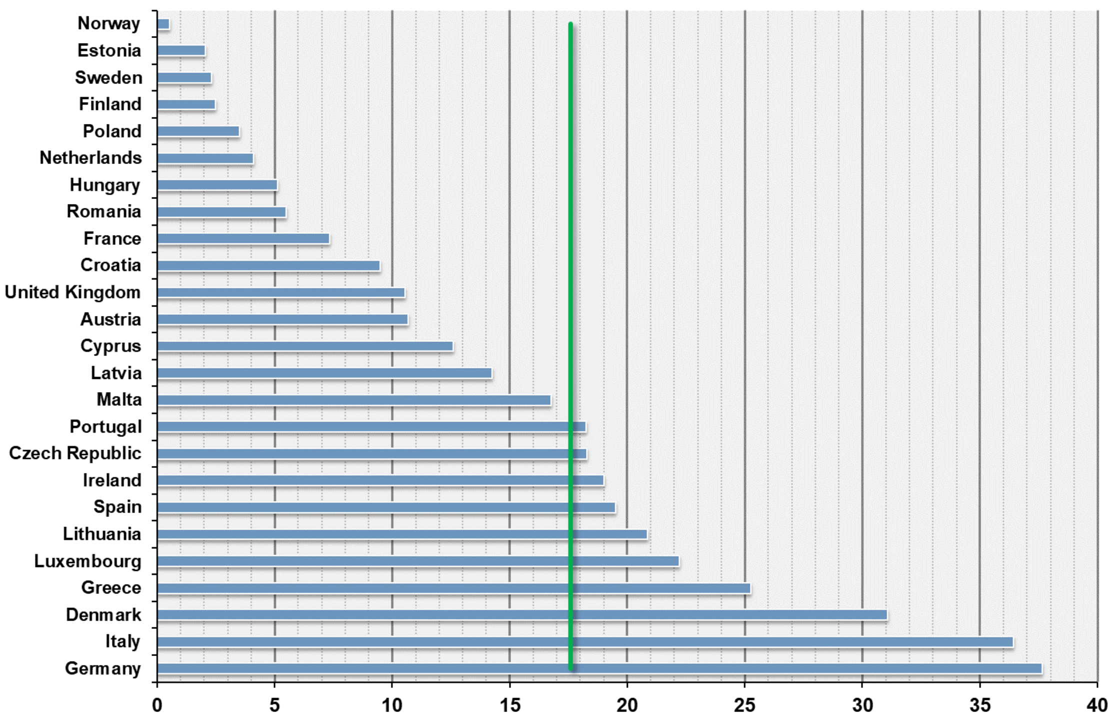


Figure 7 – Renewable electricity support per unit of gross electricity produced in 2016 (€/MWh). Source: CEER (2018). The green line represents the average of 17,60 €/MWh.

We then construct a ranking of country´s ambition of renewable support based on these two indicators. As indicated by the previous figures, Denmark has the highest share of supported renewable electricity production, while Germany has the highest value for the money spent on renewable support relative to the electricity market size. It is thus logical that these two countries are on the two top spots of our ranking for the ambition of renewable support schemes.

BOX 4 – Methodology for the ranking of renewable support schemes

For both indicators (The percentage of total electricity production which receives renewable support & The money value of renewable support provided relative to total electricity production in €/MWh), we set the value for the country with the highest value to 100. The value for all other countries is then set accordingly relative to this maximum value of 100. In this way the format of both indicators is converted into a comparable value, which can be added together for the ranking.

Country	Highest % of support scheme covered RES prod	Highest RES support per unit of gross elec. 2016 (€/MWh)	Ranking
DK	100,00	82,45	**182,45**
DE	39,34	100,00	**139,34**
ITA	35,39	96,71	**132,10**
LIT	56,08	55,40	**111,48**
GRE	30,96	67,03	**97,99**
IRE	46,29	50,49	**96,78**
POR	45,18	48,47	**93,66**
ESP	31,60	51,74	**83,33**
LUX	20,06	58,99	**79,05**
MAL	21,17	44,49	**65,66**
CZ	14,69	48,58	**63,27**
LAT	21,48	37,83	**59,31**
UK	30,49	27,98	**58,47**
AT	22,59	28,35	**50,94**
CYP	11,53	33,42	**44,95**
CRO	18,33	25,17	**43,49**
ROM	21,17	14,57	**35,74**
FRA	11,06	19,49	**30,54**
POL	19,12	9,34	**28,46**
NL	17,54	10,86	**28,39**
SWE	21,33	6,19	**27,51**
HUN	11,69	13,62	**25,31**
EST	15,64	5,42	**21,06**
FIN	9,95	6,64	**16,59**
NOR	5,21	1,46	**6,67**
BE	n.a	n.a	**n.a**
BUL	n.a	n.a	**n.a**

Table 3 – Ambition of the renewable support schemes of different countries. Source: Own calculus based on data by CEER (2018, p. 12).

It is then useful to analyze whether this ranking on the ambition of the renewable support scheme is somehow related to the type of renewable support. In particular, we are interested if the use of a FiT or FiP is related to the above ranking. Hence, we sort the countries by the type of renewable support scheme used:

	% of support scheme covered RES prod	RES support per unit of gross elec. 2016 (€/MWh)
Countries with both FIT & FIP		
CRO	11,60%	9,48
CZ	9,30%	18,30
DK	63,30%	31,06
FIN	6,30%	2,50
FRA	7,00%	7,34
DE	24,90%	36,43
GRE	19,60%	25,25
ITA	22,40%	36,43
LUX	12,70%	22,22
MAL	13,40%	16,76
UK	19,30%	10,54
AVERAGE	**19,07%**	**18,65**
Countries with FIT		
AT	14,30%	10,68
EST	9,90%	2,04
LAT	13,60%	14,25
LIT	35,50%	20,87
POR	28,60%	18,26
AVERAGE	**20,38%**	**13,22**
Countries with FIP		
BUL	n.a.	n.a.
NL	11,10%	4,09
POL	12,10%	3,52
AVERAGE	**11,60%**	**3,81**
Other (Neither FIT nor FIP)		
CYP	7,30%	12,59
IRE	29,30%	36,43
NOR	3,30%	0,55
ROM	13,40%	5,49
SWE	13,50%	2,33
AVERAGE	**13,36%**	**11,48**

Table 4 – Ambition of the renewable support system by type of support. Source: Own calculus based on CEER (2018)

The figures indicate a relationship between renewable support ambition and certain renewable support types used. Use of FiP and FiP tends to coincide with higher support scheme coverage and with money used relative to market size. But this tendency is probably smaller than expected (aprox. 20% coverage of FiT or FiP vs 13,5€ for other support schemes; and aprox. 18,5 €/MWh spent amount for FiT + FiP vs aprox 11,5 €/MWh for other support schemes).

5 Effect of renewable support on renewable deployment

In this section we study the correlation between the ambition of renewable electricity support and the deployment of these technologies. We do this by use of two methodologies:

1. Previous work by Mezosi et al. (2018)
2. An own evaluation based on the analysis of the previous chapters of this report

Effect of renewable support according to Mezosi et al. (2018)

Mezosi et al. (2018) develop an own methodology to evaluate the individual performance and effectiveness of country´s renewable support schemes. They include time effects and technological development in their analysis (by use of LCOE, Levelized cost of electricity generation), and they also distinguish between renewable support for wind and solar individually. This yields the evaluation index of Mexzosi et al. (2018) to rank European countries according to the effectiveness of their renewable support schemes ("Data Envelopment Analysis", DEA). According to the analysis of Mezosi et al. (2018) the countries with the most cost-effective renewable support schemes are:

- For wind: Norway, Sweden, Ireland, and Denmark.
- For solar: Romania, Malta, Cyprus, and Italy.

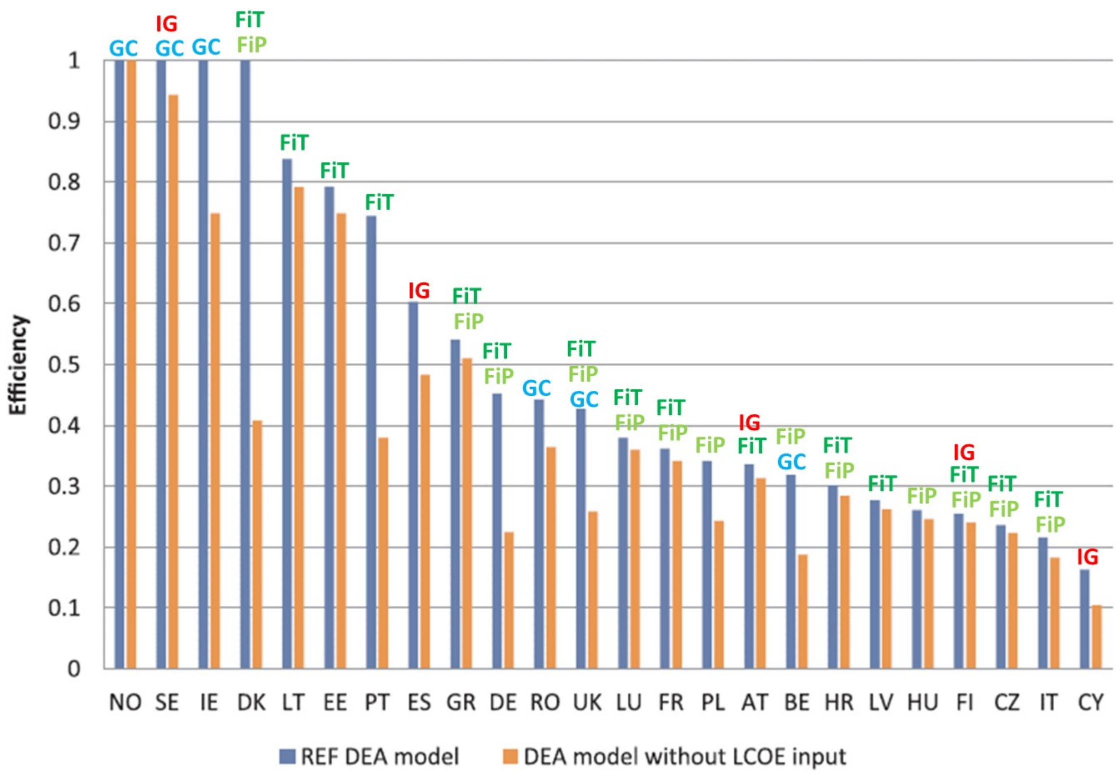


Figure 8 – Ranking of wind energy support schemes. Source: Mezosi et al. (2018). Type of renewable support scheme added in by the authors (FiT = Feed-in-Tariff; FiP = Feed-in-Premium; IG = Investment Grant; GC = Green Certificates). Notes: DEA (Data Envelopment Analysis)

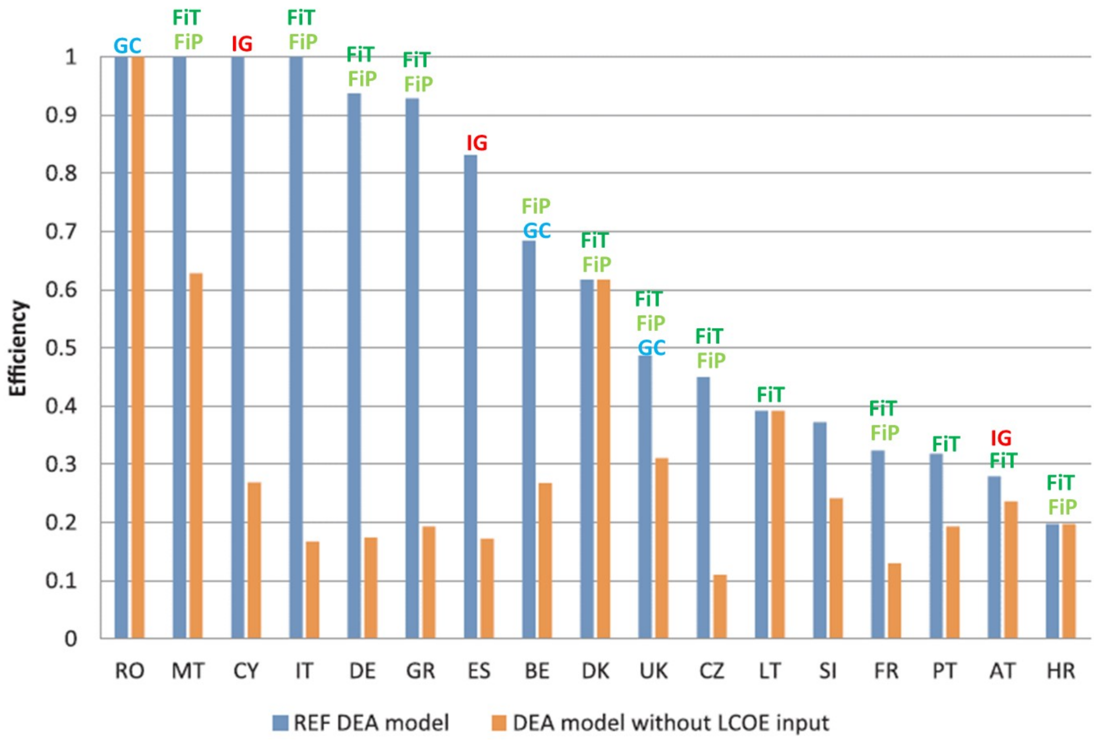


Figure 9 - Ranking of solar energy support schemes. Source: Mezosi et al. (2018). Type of renewable support scheme added in by the authors (FiT = Feed-in-Tariff; FiP = Feed-in-Premium; IG = Investment Grant; GC = Green Certificates). Notes: DEA (Data Envelopment Analysis)

Note also that we expanded table 10 and 11 from Mezosi et al. (2018). We added in symbols for the different types of renewable support schemes used in each country (see chapter 4).

The differences between the analysis DEA and DEA without LCOE indicate the

Effect of renewable support based on the analysis of this report

In chapters 2, 3, and 4 of this report, we already assembled and analyzed several data sets on renewable support schemes, renewable participation, and the ambition of renewable support. This allows us to execute an own analysis on the effect of renewable support scheme ambition on renewable deployment. Concretely, we use our indicator of the renewable support scheme ambition and put in relation with the renewable participation estimation from chapter 3 (method 2 – IEA data).

As we can see in the following graphs, there is a very strong correlation between the ambition of support and the penetration of wind and solar, but not so for hydro. This can be observed in the last panel. When all renewables are considered, the overall effect is mitigated by the lack of correlation between hydro and renewable support ambition.

Therefore, we can conclude that the ambition of the support level is a major determinant of the deployment of wind and solar in Europe.

Plot results for EU countries:

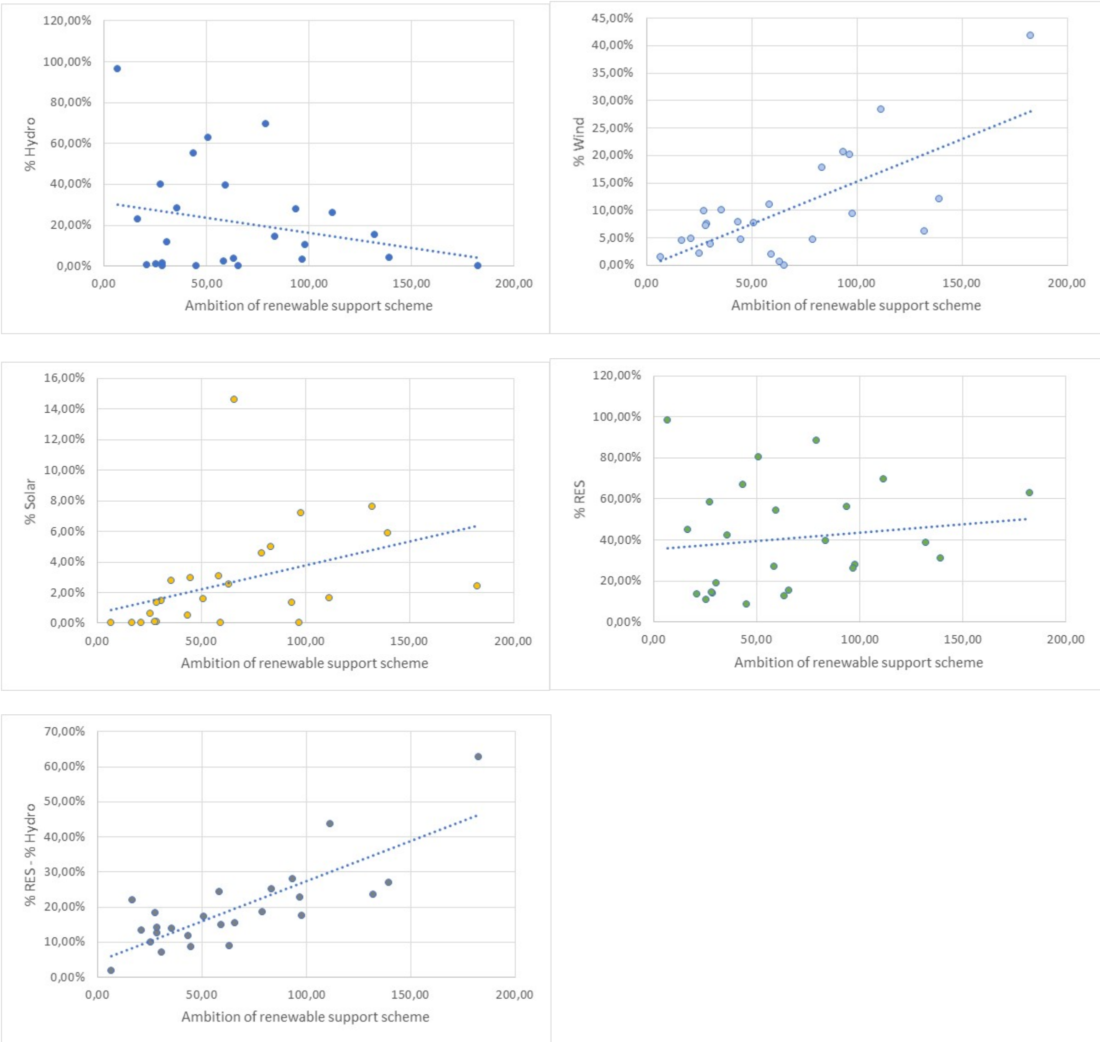


Figure 10 – Relation of RE participation and RE support scheme ambition. Source: own calculus based on EIA and CEER (2019).

However, we can also observe that some countries lie above the trendline for the average relationship of renewable support ambition and renewable deployment, while others lie below it. Interestingly, this dispersion (or standard deviation) is minimized when observing all renewables generation except hydro (the last graph in figure 7).

Analyzing this last relationship of renewable support scheme ambition and percentage renewable participation (exc hydro) for our dataset, we can also rank the countries according to their individual effectiveness; i.e. how much renewable participation (except hydro) did each country achieve given their own individual ambition of the support scheme? This is shown in the next graph, where high values indicate a country which was able to induce a high share of renewables (except hydro) given the ambition of their support scheme. As illustrated by the following table, Finland seems to be the leader here. Again, we also introduce symbols to indicate the support scheme used by each country in the figure.

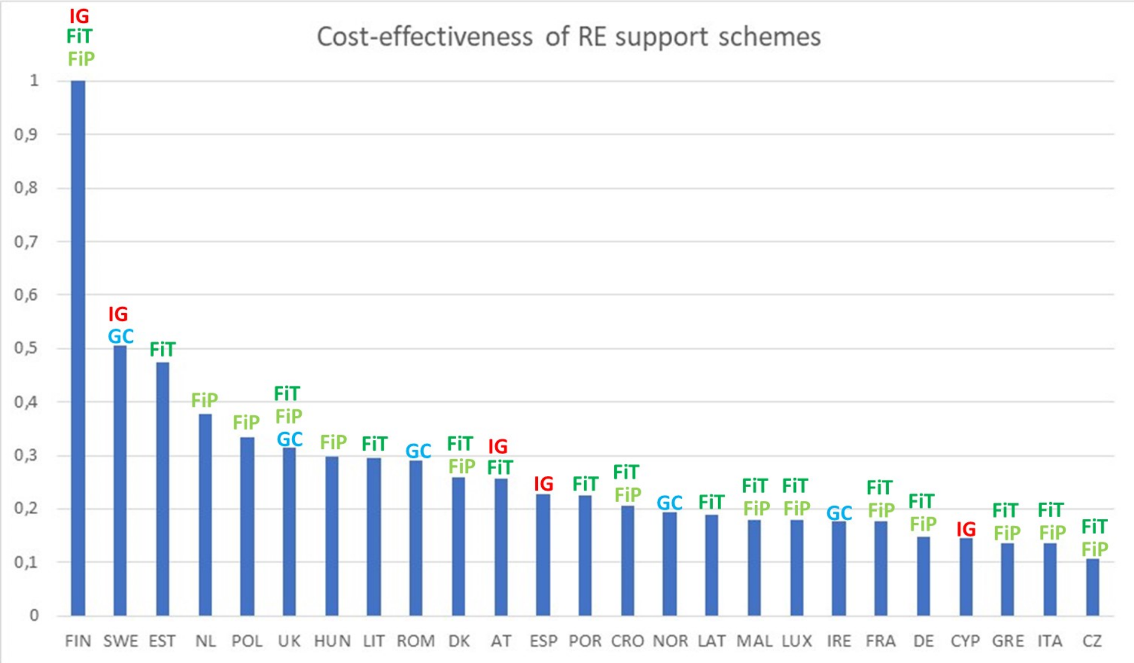


Figure 11 – Cost-effectiveness of renewable support schemes by country according to the data set used in this analysis. Type of renewable support scheme added in by the authors (FiT = Feed-in-Tariff; FiP = Feed-in-Premium; IG = Investment Grant; GC = Green Certificates).

Both rankings of countries should be interpreted carefully, however. Many factors that can influence the success of renewable support schemes are not reflected in the analysis. As pointed out by Mezosi et al. (2018) there is a "first-mover disadvantage" in renewable support. Countries that put renewable support schemes in place first had to create strong economic incentives in order to trigger renewable implementation. This is due to the lower level of technological development of the RE technology during these early days. As renewable support schemes usually support renewable installation over several decades, these early support costs are still locked in, inflating the overall support costs of the renewable support scheme. Therefore, the early movers of renewable support (Germany, the Czech Republic and Spain), score relatively poorly in this ranking. Moreover, different types of renewables generally require different support scheme strength. Solar, for example, might require higher support scheme ambition (as indicated by Mezosi et al., 2018). Countries trying to induce solar generation usually score lower on cost-effectiveness measures of their support schemes.

Therefore, the data set and the analytical approach used in this report are more suited to evaluate if renewable support schemes were generally successful in triggering renewable deployment – which they did. But an evaluation of which country was more successful in triggering renewable participation than others, should be done carefully.

Regarding the effectiveness of different support scheme types, there is mixed evidence. FiT support systems have been effective in promoting renewables, and not necessarily at a higher cost compared to other systems. Although other systems such as tradable green certificates introduce competition to lower the cost of support, their higher uncertainty may counteract this. However, it is not only the type of system, but the strength of it (the level of support provided) that probably determines its effectiveness in achieving large shares of renewables.

6 Other effects of renewable support schemes

In the previous sections we showed that renewable support policies do have an impact on the deployment of renewable generation capacity. In this context, it is worthwhile to analyze what other effects the renewable support schemes have had.

We evaluate two impacts which are of interest from a social and policy-maker point of view:

- The electricity price
- Electricity price volatility

Impacts on the electricity price

In general renewable generation is expected to decrease the price of electricity. This is because renewable generation enters the market at low marginal cost; as a matter of fact renewable sources as wind and solar are often referred to as “zero marginal cost” producers.

This has consequences on the electricity market, as the “zero marginal cost” generators enter the market first, and hence shift the merit order curve (the supply curve) to the right. The equilibrium price is reduced. This price reducing effect of renewable generation is generally known as the “merit order effect”.[3]

The following picture illustrates the merit order effect graphically.

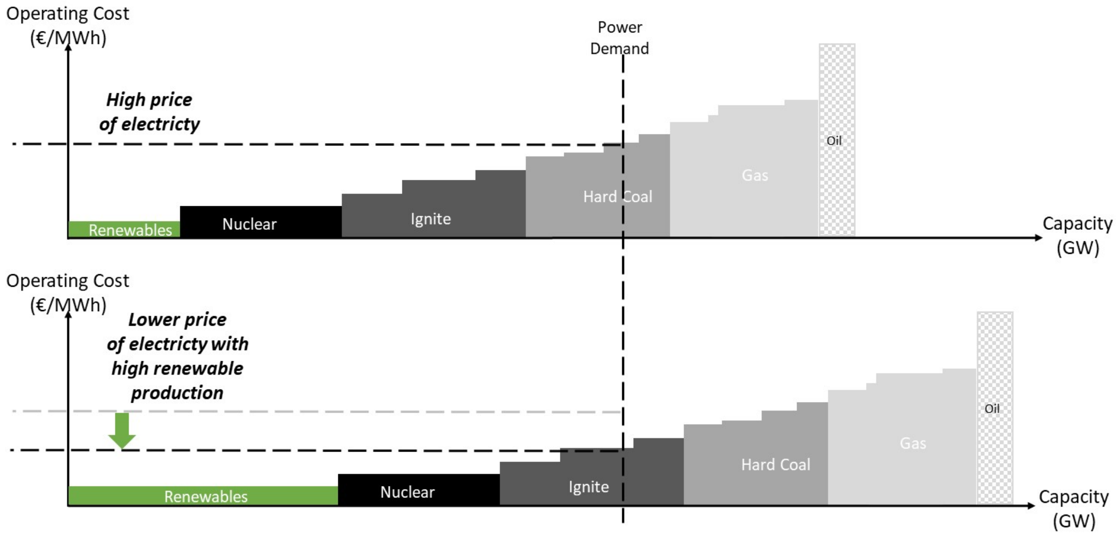


Figure 12 – Illustration of the merit order effect.

The merit order effect has also been proven empirically. Gelabert et al. (2011) found the merit order effect to be around 1€/MWh of additional renewable input for Spain. Würzburg et al.

[3] See also Johnson and Oliver (2019) for a description of the merit order effect.

(2013) and Paraschiv & Pietsch (2014) find similar results for Germany and Austria. Below we reproduce a figure from Würzburg et al. (2013) summarizing the size of the merit order effect of different analyses for several countries:

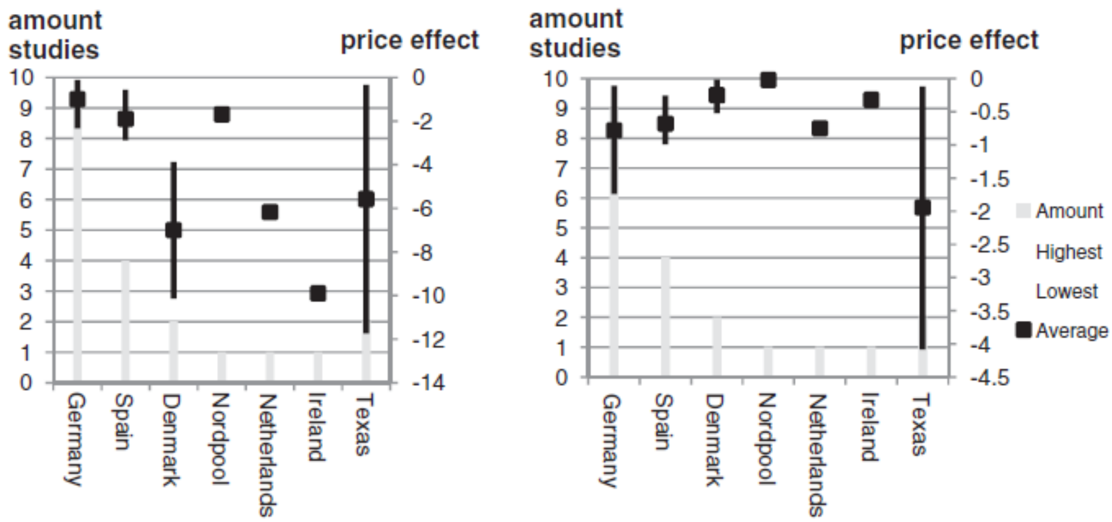


Figure 13 – Range of price effects of renewable production (merit order effect). Source: Würzburg et al. (2013). Notes: The black dot refers to the average price effect, and the black bar indicates the range of price effects as quantified by different investigations. The grey blocks indicate the number of studies performed for each country. The left graph quantifies the merit order effect in €/MWh per each additional GWh of renewable (or wind) energy produced, as reported by the specific literature. The right graph adjusts the merit order effect according to total market size. Interestingly, the right graph paints a more homogeneous merit order effect among different countries.

There is thus a general trend for renewable generation to reduce electricity prices. However, two comments have to be made regarding this conclusion:

1. **The merit order effect may be a short-term effect:**

In the long-run the price effect of more renewable generation is less clear. This long-run vs short-run distinction is important. In the short-run capacity is fixed and investment decisions (in generation capacity) cannot be altered. Adding-in more renewable generation hence reduces equilibrium prices on the electricity market (merit order effect). In the long-run, however, market participants can adapt their investment decisions, and the market mix (the generation technology mix) can change.

In this regard, long-run electricity prices also include the cost of new investments. Increasing the share of electricity production in an electricity market may result in higher long-term costs if the total cost of renewables is higher than the variable cost of the existing electricity generation it replaces. Therefore, the long-run effects of renewable generation on electricity prices are much less clear.

2. **The cost of the renewable support scheme must be considered:**

The potential social gains of lower electricity prices must be put in balance to the cost of the renewable support scheme that triggered the growth in renewable generation in the first place. This is a difficult analysis. Paraschiv and Pietsch (2014) find for example that the cost of the German FiT system was higher than the reduction in electricity costs for consumers which follows from the reduction in electricity prices (the merit order effect). This comparison of renewable support cost and supposedly social gains from price reductions for consumers is often made. However, when doing so, it is pivotal to point out that the price reduction of the merit order effect is not automatically equal to the social gain; it is just a transfer from conventional producers to consumers.

In this context, recall also the CEER figures on the quantities of support subsidies relative to total electricity generation, which we reproduce again below.

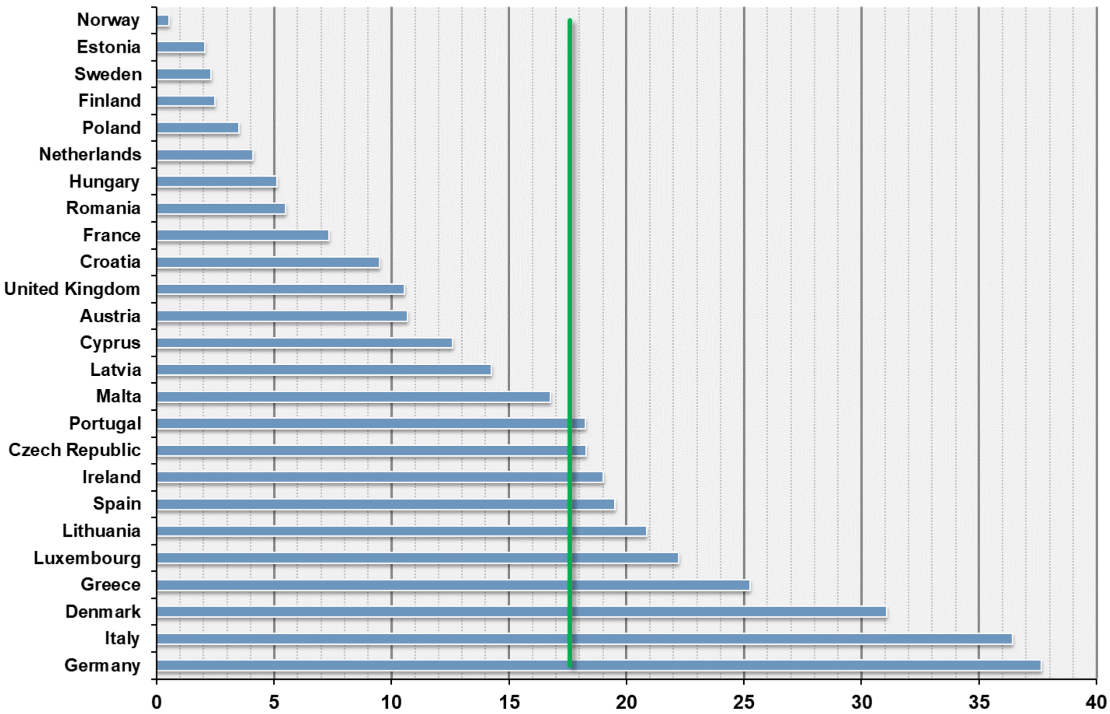


Figure 14 – Renewable electricity supported per unit of gross electricity produced in 2016 (€/MWh). Source: CEER (2018). The green line represents the average of 17,60 €/MWh.

Regarding the electricity prices in scenarios of high renewable participation, the IRENA analyses on the future of the European electricity systems can also provide additional insights. In these simulations IRENA predicts the electricity prices of the European markets for 2030, based on simulated deployment growth paths of renewables. As shown in the below figure on the simulated electricity market prices of the baseline scenario, electricity prices can be expected to rise in the future. This may be explained by the fact, already described above, that long-run costs must include investments, which may be high for renewables.

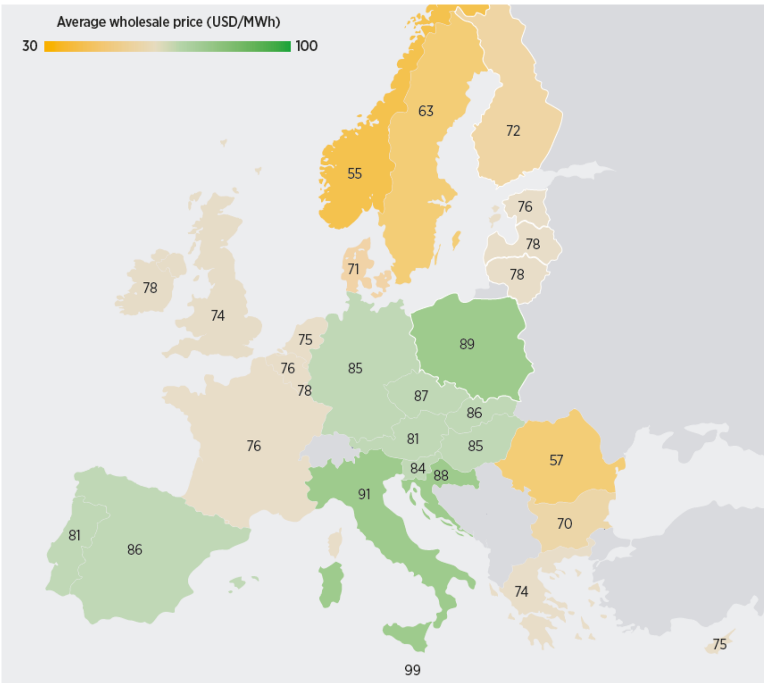


Figure 15 – Average electricity wholesale market price simulations (reference case) for 2030 for European countries (USD/MWh). Source: IRENA (2018, p. 64)

Impacts on electricity price volatility

Renewable generators, prominently so wind and solar, are intermittent (or variable). If and when they generate electricity depends on (partially) random factors as wind and solar irradiation. Therefore, the more generating capacity there is of these variable types, the less predictable market outcomes are. This causes the electricity price to be more volatile.

IRENA (2018) estimates the participation rates of volatile renewable generation for the European countries. These figures show how the electricity markets of the future will have to deal with higher shares of variable (or volatile) renewable generation.

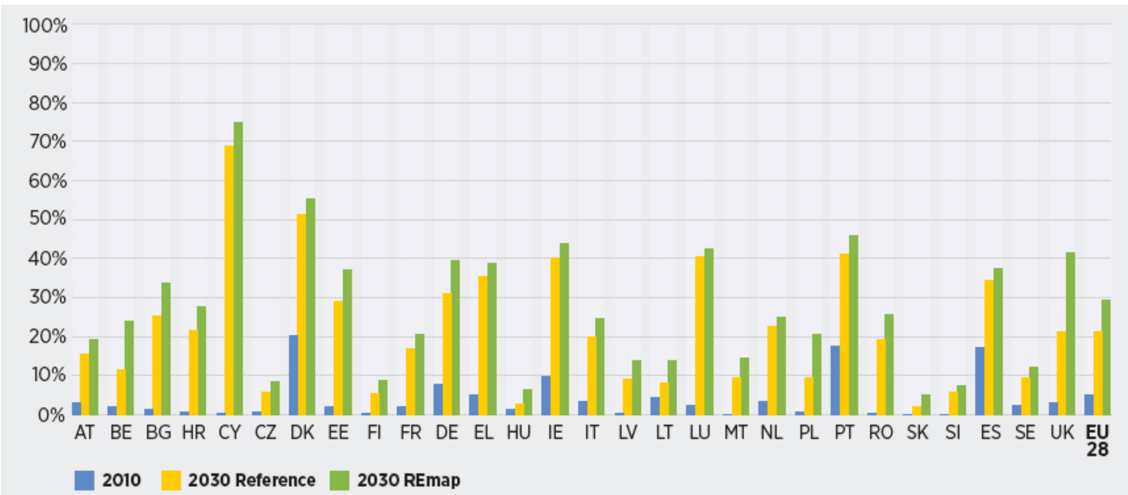


Figure 16 – Variable renewable energy share in total electricity generation by EU Member State in 2010 and 2030 under the IRENA reference scenario and the REmap scenario. Source: IRENA (2018, p. 57).

The effect of renewable energy on electricity price volatility has also been shown empirically. Ketterer (2014) showed that variable wind generation increases electricity price volatility in Germany. Rintamäkia et al. (2017) found that variable wind generation did not affect price volatility in Denmark, but did so in Germany. In general, solar generation is less problematic for electricity price volatility, as the production pattern is more predictable: it is connected to the solar cycle of night and day. Moreover, its production pattern coincides with the daily electricity demand profile, which can have a stabilizing effect on electricity prices. Hence, Rintamäkia et al. (2017) found that solar generation has reduced electricity price volatility in Germany.

In a recent analysis Johnson and Oliver (2019) use data from 2000 to 2011 from the Global Wind Energy Council and the European Photovoltaic Industry Association to investigate the effect of wind and PV generation on wholesale market prices in They find that short run price volatility in wholesale electricity markets increase significantly as penetration of renewables (wind and PV) increase. Johnson and Oliver (2019) conclude that this finding can expected to be robust for any kind of intermittent, zero-marginal cost generator. They also comment that improvements in prediction quality of such intermittent producers can enable electricity producers to adjust better to the intermittent quantities produced, thus helping to reduce the price volatility of renewables and enable a smoother integration of high penetrations of renewables.

7 Conclusions

Our analysis has shown that the ambition of the renewable energy support system is an important determinant of the penetration of wind and solar in European power systems. Although we have detected some differences among support types (FiT vs FiP vs quotas), with FiT showing more effectiveness than others, and not necessarily at a higher cost (because of its larger certainty for investors, which in turns reduces the financing cost, which is a large component of the total renewable cost), the level of support has shown a striking correlation with renewable deployment, across countries with different levels of renewable resource. This is a robust result that can of course be easily extrapolated to other regions.

Evaluating which country´s renewable support scheme is more efficient than others remains a difficult task because of many factors that are difficult to control for in such a benchmarking exercise (time effects, technological development, differences between renewable types, and availability of renewable resources). This is also highlighted by Mezosi et al. (2018).

Given that there is a strong drive to decarbonize the electricity sector, in order to achieve the large reductions required in carbon emissions, we should expect this support to continue in the following years.[4] Depending on its strength, this will result in variable levels of renewable energy penetration on global electricity markets, probably larger in Europe.

However, there will be a point, which is getting closer and closer, at which wind and solar will not need economic support any more: when their total cost is lower than the variable cost of the alternative generation technology (typically, natural gas), then renewables will penetrate to a large extent into global power systems, as long as other non-economic barriers are also eliminated. In fact, as we can already see by the results of renewable energy auctions

[4] Note however, that new EU State Aid guidelines require renewable support to be competitive, which may have an impact on the design and use of different support scheme types.

throughout the world, some solar and wind technologies already achieve costs competitive with natural gas. Although still strongly linked to the characteristics of the auctions, this clearly points out to a near future in which wind and solar can be competitive by themselves.

This in turn will produce a reduction in short term electricity prices. In electricity markets based on energy-only paradigms, this will then be translated into lower costs for consumers (financed by the loss of rents of conventional producers). However, many countries are already noticing this fact, and understanding that energy-only markets will not be able to provide (under the current conditions of most of them) the adequacy and reliability that customers need. This is driving an already very powerful conversation about the need to either reform energy-only markets, or to provide other markets for reliability (such as capacity markets). This will then change electricity prices: a (lower) variable, energy component, and a (higher) fixed, reliability one. Forecasts of consumer electricity prices must take this into account.

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