The cost of renewable energy:
A critical assessment of the Impact Assessments underlying the Clean Energy for All Europeans-Package

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Summary

The European Commission underpins its climate and energy policy proposals with extensive modelling. The modelling results play a substantial role in determining the outcome of Commission impact assessment, i.e. the analysis on costs and effects of specific proposals. Assumptions underlying Commission modelling thus determine to a large extent whether and to which degree certain policy choices will be regarded as beneficial.

Recent auctions in the real world resulted in significantly lower costs for renewable energy projects than suggested by Commission modelling (see Figure 1). Against this background, we analyse the modelling assumptions and results on the costs of renewable energy in impact assessments underpinning the Clean Energy for All Europeans-Package.[1] Our main findings are that the central target scenarios developed by the Commission[2] systematically overestimate the costs of renewable energy and downplay the role of policy.

Three aspects of the Commission modelling stand out that, in combination, result in a distorted picture of the renewables investment landscape in Europe:

1. The central target scenarios include simplified assumptions on cost of capital for renewable energy investments and unrealistic outcomes for the capacity factors accorded to renewables. Both result in significantly higher than plausible costs for further developing Europe's renewable energy potential.
2. The central target scenarios project prices for CO_2-allowances under the EU emissions trading system at higher levels than carbon analysts in the market and thereby exaggerate the role of markets in driving the development of renewables under both the existing and proposed market framework.
3. The assessments reflect only partially the importance of robust renewables policies and frameworks as a reliable and cost-effective way of reducing investor uncertainty and bringing down the cost of renewable energy.

Necessary downward adjustments to Commission modelling results, when combined, come to cost assumptions consistent with real world auction results (see Figure 2 for offshore wind).

Based on our analysis, we draw the following main conclusions:

→ Since the cost of renewables are in reality lower than assumed, a 27 percent share of renewables is not cost-effective. Only a significantly higher share would provide a cost-optimal contribution of renewable energy towards the EU 2030 target of at least 40 percent greenhouse gas reductions. Alternatively, a higher share of renewables would allow for a higher greenhouse gas reduction target in 2030.

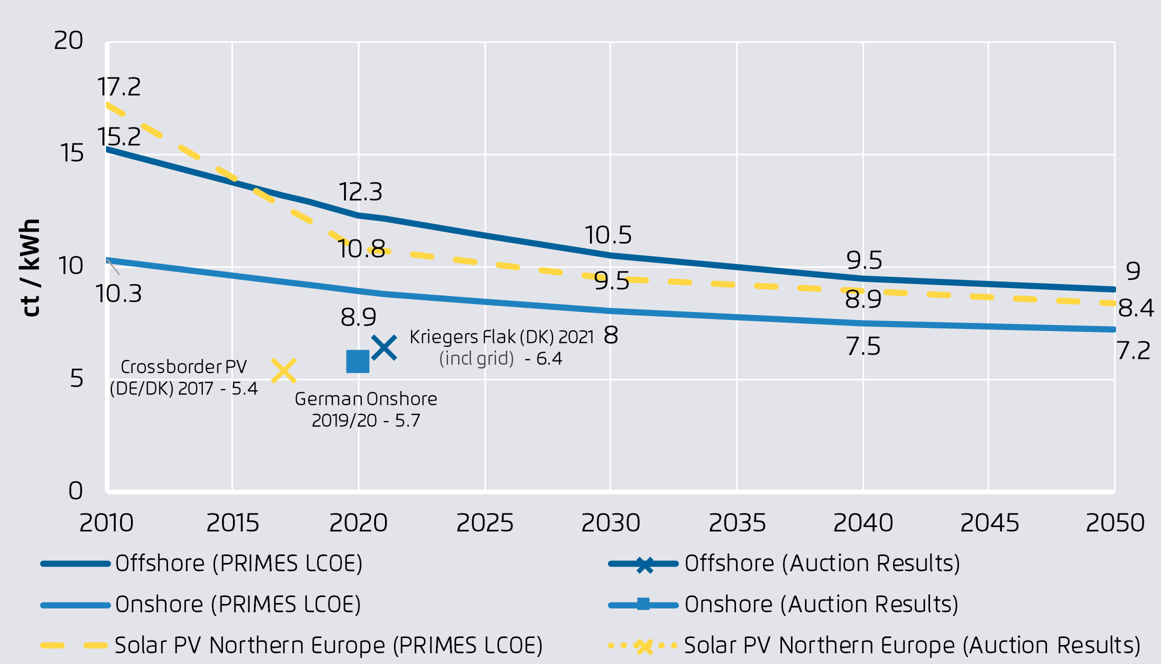
→ The EU legislator would be ill advised to believe the central target scenarios that the proposed power market and carbon market reforms will largely suffice for developing Europe's renewable energy potential throughout 2020-2030 at lowest possible cost. Discussions should rather draw on aspects in the Commission work showing that a cost-effective unlocking of Europe's renewable energy potential centrally rests on combining power market reforms with robust renewable energy frameworks that include clear targets and technology-specific pathways.

→ The setting of a higher level of ambition on renewable energy should take into account the significant cost reductions for renewable energy technologies, but also be informed by Europe's interest to remain home to a vibrant, highly competitive renewable energy industry that creates new economic and employment opportunities.

[1] Annex 1 includes an overview of the Impact Assessments and studies analysed for this paper, Annex 2 an overview of the main models used in Commission Impact Assessments for the Clean Energy for All Europeans-package, in particular PRIMES. Annex 3 provides a glossary of PRIMES scenarios that constitute the backbone of the modelling done for the Clean Energy for All Europeans-package.

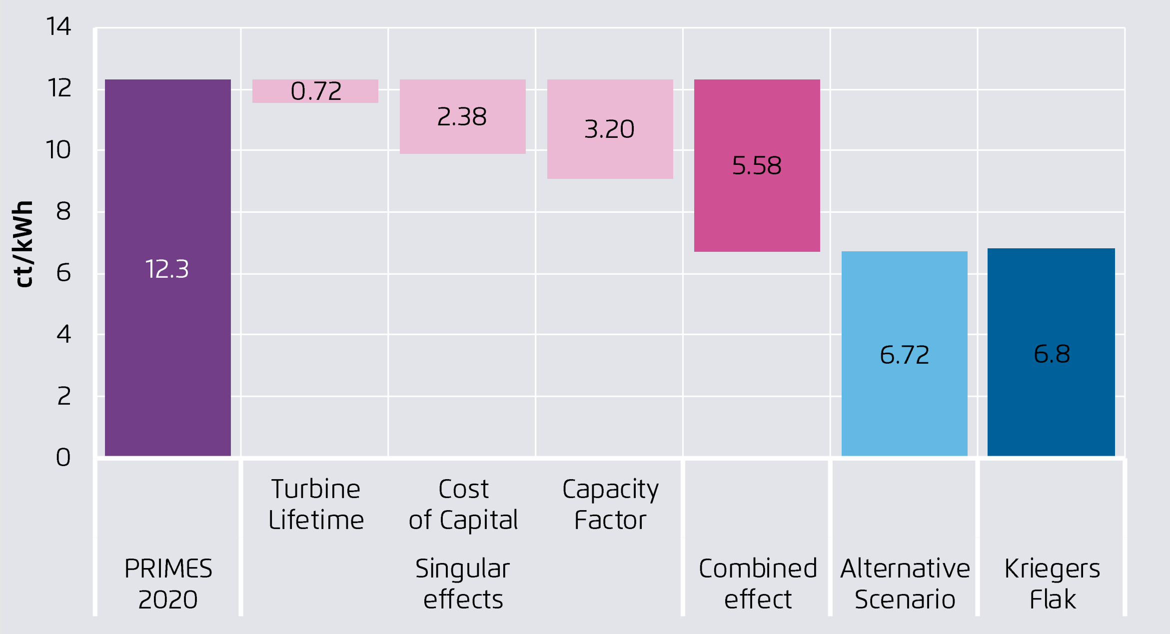
[2] EUCO27 and EUCO30. For details see the glossary in Annex 3.

Figure 1: Comparison of PRIMES LCOE cost assumptions with the results of recent auctions by year of expected realization (Offshore Wind, Onshore Wind and Solar PV)



Source: COM (2016) EU Reference Scenario 2016; BNetzA (2016, 2017); Danish Energy Agency (2016); ICIS (2017); Vattenfall (2016)

Figure 2: PRIMES 2020 Offshore Wind LCOE vs. Alternative Scenario and Real World Auction Results



Source: EU Reference Scenario 2016 and own calculations; Assumptions for singular effects (from left to right): Extension of operating lifetime from 20-25 years; Reduction of WACC from 7.5% to 3.5%; Increase of capacity factor to 4400 hrs; Kriegers Flak estimate includes grid costs.

Why energy modelling matters and how it was done for the CE4ALL-package[3]

Commission proposals are accompanied by an impact assessment. This involves at minimum a *qualitative* analysis of expected impacts, often also a *quantitative* analysis. Depending on the subject at hand, quantitative parts of impact assessments will involve some form of *modelling*.

When projecting the impact of various scenarios of policies and measures in the area of climate and energy in order to identify a "cost-optimal" approach, European Commission services mostly make use of the PRIMES-model; an energy market engineering-economic model owned and run by the Technical University of Athens. PRIMES has been used for Commission Reference Scenarios and Impact Assessment going back as far as 2003. Its results have been a critical reference point for the European energy and climate debate, in the 2050 Roadmap exercise as well as in the 2030 target-setting process.

For decision-makers, modelling has important advantages. Rather than guessing the impact of decisions at hand, modelling empowers decision-makers to anticipate the potential impact of specific choices and options as well as trade-offs that may exist. It seems important to stress, however, that modelling *does not provide a prediction of future developments*, as some of the input assumptions, including population growth, macroeconomic and fossil fuel price developments, technology improvements or policies that go into them remain uncertain. Rather, modelling *provides a sophisticated guess on how, judging from what we know today, specific measures and policies would contribute to shaping the future*.

The *practical relevance* of modelling results will depend on the framing of scenarios and the setting of key external parameters such as technology costs or by when specific laws and policies are assumed to be implemented. Typically, such choices are taken in close dialogue between Commission services and modellers involved.

The **Clean Energy for All Europeans-package** (CE4ALL-package) is supposed to deliver the EU climate and energy targets for 2030. In October 2014, the European Council set these targets as follows: a binding EU target of at least 40 percent domestic reduction in greenhouse gas emissions compared to 1990; a binding EU target of a share of at least 27 percent of renewable energy in final energy consumption; and an indicative EU target of at least 27 percent improvement in energy efficiency[4]. The latter target was combined with an instruction on the Commission to evaluate by 2020 the benefits of setting a higher target; which the Commission did, prior to proposing a binding EU-level energy efficiency target of 30 percent by 2030 as part of the CE4All-package[5].

The **initial target-setting in 2014 was supported by Commission analysis from 2012 and 2013** using PRIMES that aimed at identifying a cost-effective pathway from 2020 to 2030 on the way to meeting the EU's long-term decarbonisation target of 80-95% GHG reductions by 2050.

As part of its analysis the Commission looked at the cost of the total energy system under various target scenarios. Key findings from this analysis are summarised in Table 1. Overall, the analysis showed how higher renewables and efficiency scenarios would result in higher investment costs, but lower energy purchases. When comparing columns 2 and 3 of (GHG40/EE and GHG40/EE/RES30) an important finding is that **according to the Commission analysis in 2013, overall system costs for a scenario**

[3] This paper was written by Andreas Graf and Matthias Buck with contributions by Georg Thomaßen (Agora Energiewende).

[4] European Council (23 and 24 October 2014), *Conclusions on 2030 Climate and Energy Policy Framework, Doc SN 79/14.*

[5] By contrast, it should be noted in 2014 the European Parliament endorsed the following set of targets: a binding -40 percent target for greenhouse gas reduction and binding targets of 30 percent for renewables and 40 percent for energy efficiency.

Table 1: Overview of key modelling results for target scenarios from the 2014 Commission Impact Assessment accompanying the Communication on the2030 climate and energy policy framework

	Scenarios			
	REF	GHG40/EE	GHG40/EE/RES30	GHG45/EE/RES35
Total System Costs*	2,067	2,089	2,089	2,102
Investment Expenditure*	816	875	879	909
Fossil Fuel Net Imports*	461	441	439	434
GHG 2030	32.4%	40%	40%	45%
RES 2030**	24.4	26.4	30.3	35.4
EE 2030***	21.0%	29.3%	30.1%	33.7%

Source: 2014 COM on 2030 Framework
* In bn €'10 (average annual 2011-30)
** % final energy consumption
*** Evaluated against the 2007 PRIMES Baseline projections for 2030

of roughly 30 percent renewables was found to be almost the same as a scenario with roughly 27 percent renewables under the assumption that ambitious energy efficiency policies were pursued (30.1 percent energy efficiency).

Moreover, a **more ambitious 45 percent greenhouse gas emissions reduction scenario with roughly 35 percent renewables and slightly more ambitious energy efficiency policies** was found to cost 13 billion Euros (or 0,62 percent) per year more at total system costs level compared with a 40 percent greenhouse gas reduction target.
Notably, these findings are entirely based on the Commission's own analysis and do not include a critical analysis on the cost assumptions for renewable energy that is the focus of this paper.

Despite impact assessment results favouring a more ambitious 30 percent renewable energy target, both the European Commission[6] and the European Council[7] took a political decision in 2014 to support only a 27 percent renewable energy target, not 30 percent, and not 35 percent.

Much has changed for renewable energies since the Commission Communication on the 2030 framework from January 2014. Technology and supply chain improvements have translated into significant further cost reductions for wind (onshore and offshore) and solar photovoltaics that were not reflected in the 2014 impact assessment. Moreover, the use of competitive auctions has led to an intense period of downward price discovery for these technologies that has dramatically reduced the level of support needed to develop new renewables capacity. Since the beginning of 2016 alone, several auctions have resulted in support payment guarantees awarded to

[6] Commission Communication COM (2014) 15 final of 22 January 2014.

[7] European Council (23 and 24 October 2014), *Conclusions on 2030 Climate and Energy Policy Framework, Doc SN 79/14.*

Table 2: Overview of recent auction results for Offshore Wind, Onshore Wind and Solar PV

Technology	Auction	Quarter	Year of Construction	Latest Realisation	Capacity Auctioned	Result in € ct/kWh	PRIMES 2030 LCOE (€ ct/kWh)
Offshore	Borssele I & II (NL)	Q3 2016	2019	Q3 2021	760MW	7.27 (15 yrs) / 8.77* (incl. grid)	10.5 (incl. grid)
	Danish Near Shore (DK)	Q3 2016	2019	2020	350 MW	6.4 (17.5 TWh) / 7.5* (incl. grid)	
	Kriegers Flak (DK)	Q4 2016	2019-2020	2021	600 MW	4.99 (30 TWh) / 6.49* (incl. grid)	
	Borssele III & IV (NL)	Q4 2016	2020	Q4 2021	740 MW	5.45 (15 yrs) / 6.95* (incl. grid)	
	German Offshore I	Q2 2017	2024	Q4 2025	1390 MW	0.0 ct (20 yrs) / 1.50* (incl grid)	
Onshore	Spain 2016	Q1 2016	2018-2019	Q4 2019	2,979 MW	4.3 (20 yrs)**	8.0
	German Onshore I	Q2 2017	2018-2021	Q4 2019 - Q4 2021	807 MW	5.71 (20 yrs)***	
Solar PV	EEG Auction 4 (DE)	Q2 2016	2016-2017	Q2 2017	128 MW	7.41 (20 yrs)	6.5 (Southern Europe) 9.5 (Northern Europe)
	EEG Auction 5 (DE)	Q3 2016	2017	Q3 2017	118 MW	7.25 (20 yrs)	
	Cross-border Auction (DE/DK)	Q4 2016	2017	Q4 2017	50 MW	5.38 (20 yrs)	
	EEG Auction 6 (DE)	Q4 2016	2017-2018	Q2 2018	163 MW	6.90 (20 yrs)	
	Cross-border Auction (DK/DE)	Q4 2016	2017-2018	Q3 2018	21.6 MW	1.7 (20 yrs)****	
	EEG Auction 7 (DE)	Q1 2017	2017-2018	Q4 2018	200 MW	6.58 (20 yrs)	
	French Auction (FR)	Q1 2017	2017-2018	Q4 2018	534.5 MW	6.25 (20 yrs)	

Source: COM (2016) EU Reference Scenario 2016; Press releases by BNetzA, Danish Energy Agency, WindEurope, Vattenfall, DONG Energy, EnBW; ICIS (2017); www.4coffshore.com; * Based on NERA Consulting (2016) and IEA-RETD (2017) €0.15 added to tariff to account for development and grid connection costs. €0.09 applied to Danish Near Shore due to lesser distance from shore.
** This auction result represents a strike price of 0 ct /kWh, meaning that no market premium is provided on top of the average monthly wholesale market price. Instead, the projects would rely entirely on wholesale market revenues, even in months with low market prices. Unlike the Contract-for-Difference scheme in the UK, the German strike price does not represent a cap on potential market revenues.
*** In contrast to the other auctions, the Spanish auction was not for a market premium, but for a potential 25-year remuneration on investment based on government assumptions for a standard reference technology. The successful bids represented the maximum discount on this remuneration permitted under auction rules, roughly equivalent to a bid of 4.3 ct/kWh with market revenues. It should, however, be noted that based on the auction rules, these successful bidders will not receive remuneration unless the wholesale market price dropped below 3.45 ct/kWh, meaning that they will be wholly reliant on wholesale market revenues for the foreseeable future. The Spanish support system also allows the Spanish government to revise key parameters every 3 to 6 years leading to future revenue uncertainty.
**** This figure represents a weighted average. The successful bids ranged from 4.2-5.78 ct/kWh. A high-share of citizen wind projects (96%) increased the overall weighted average as they were awarded the highest/marginal strike price on the basis of a uniform-bidding procedure. The lowest strike price awarded on a pay-as-bid basis was 5.25 ct/kWh for the reference site used in the auction. Once a project is developed, this value is adjusted based on the wind conditions for the site relative to the reference site. As such, the final remuneration may vary (e.g. 4.46 ct/kWh – 130% high wind-resource location / 5.25 ct/kWh – 100% reference site / 6.78 ct/kWh – 70% low wind-resource location).
***** This value represents a market premium, not the full remuneration. In contrast to the German PV auctions, the Danish cross-border auction was for a fixed premium on top of the wholesale market price, not a floating premium with a strike price including the average wholesale market price. As such, the wholesale market price must be added to the auction result for comparability. For example, with the average Danish wholesale market price of €35/MWh in Q4 2016 revenues with the premium would be roughly 5.2 ct/kWh. This value will fluctuate over time.

successful bidders reflecting levelized costs of producing electricity that are below those assumed under PRIMES modelling for the year 2030 (seeTable 2). The differences are very substantial for offshore and onshore wind, but also significant for solar PV.
The **impact assessments done in 2016 for the CE4All-package** partially reflect this evolution, in particular as regards:

- updated technology cost curves (especially lower costs for solar PV),
- a downward revision on overall electricity production/consumption;
- a downward revision on fossil fuel prices; and
- adjusted discount rates for cost accounting.

The adjustments have resulted in noteworthy differences between the 2014 and 2016 assessments that are shown in Table 3[8]:

- Total system costs for the reference and target scenarios have dropped significantly, by more than 9 percent, revealing that both a 27 percent and a 30 percent renewables target can be delivered at considerably lower cost than projected in 2014.
- The difference between the 2014 and 2016 assessments is even more pronounced as regards the calculated average annual investment expenditure for *power generation*. The 2016 modelling resulted in 32.9 percent less projected investment expenditure for power generation than in 2014. The comparable target scenarios with 30 percent efficiency and 27 renewables is calculated to be 20 percent cheaper in 2016 than projected in 2014. This very significant drop in costs would occur despite a slight increase in the share of renewable electricity in the power sector between 2014 and 2016 (+2.6 percent).

Nevertheless, also the 2016 modelling exercise still has major shortcomings on cost assumptions for renewable energy investments during 2020-2030, and on effective measures for developing renewables at lowest possible cost. These are sketched out in the next chapter of the paper.

Table 3: Comparison of investment and total system costs for the 2030 climate and energy framework between the 2014 and 2016 European Commission Impact Assessments

	2014–2030 Framework IA			
	Ref2014		**GHG40/EE**	**GHG40/EE/RES30**
Avg. annual total system costs (2011-2030) in bn €'10	2067	N/A	2089	2089
Avg. annual investment expenditure for generation & boilers (2011–30) in bn €'10	50 bn €	N/A	53 bn €	55 bn €
Share of RES-E 2030	42.70%	N/A	46.10%	53.10%
	2016 – Winter Package IA			
	Ref2016	**EUCO27**	**EUCO30**	**EUCO3030***
Avg. annual total system costs (2010-2030) in bn €'10*	1880 (-9.1%)	1889	1896 (-9.2%)	1899 (-9.1%)
Avg. annual investment expenditure for power generation (2021–2030) in bn €'10	33.5 (-32.9%)	42.6	42.5 (-19.9%)	N/A
Share of RES-E 2030	42.5% (-0.2%)	47.30%	48.7% (+2.6%)	54.2% (+1.1%)

Source: 2030 Framework IA (2014), RES Re-cast IA (2016)

* Own calculation based on average 2010/2015/2020/2025/2030 values for 'Total energy-rel. and other mitigation costs' found in the COM (2017) Technical report on Member State results of the EUCO policy scenarios; Inflation adjustment based on the 2010-2012 inflation for the EU28 (Eurostat HICP) and RED Re-Cast IA (2016).

[8] It must also be noted that the Commission did not do an update of the GHG45/EE/RES35 scenario, despite the very significant drop in total system costs for the EUCO30 scenario

Shortcomings of the modelling for the CE4ALL-package

Our analysis on modelling assumptions and results on the costs of renewable energy in impact assessments underpinning the Clean Energy for All Europeans-Package identifies three main shortcomings.

The target scenarios of PRIMES in the 2016 modelling exercise:

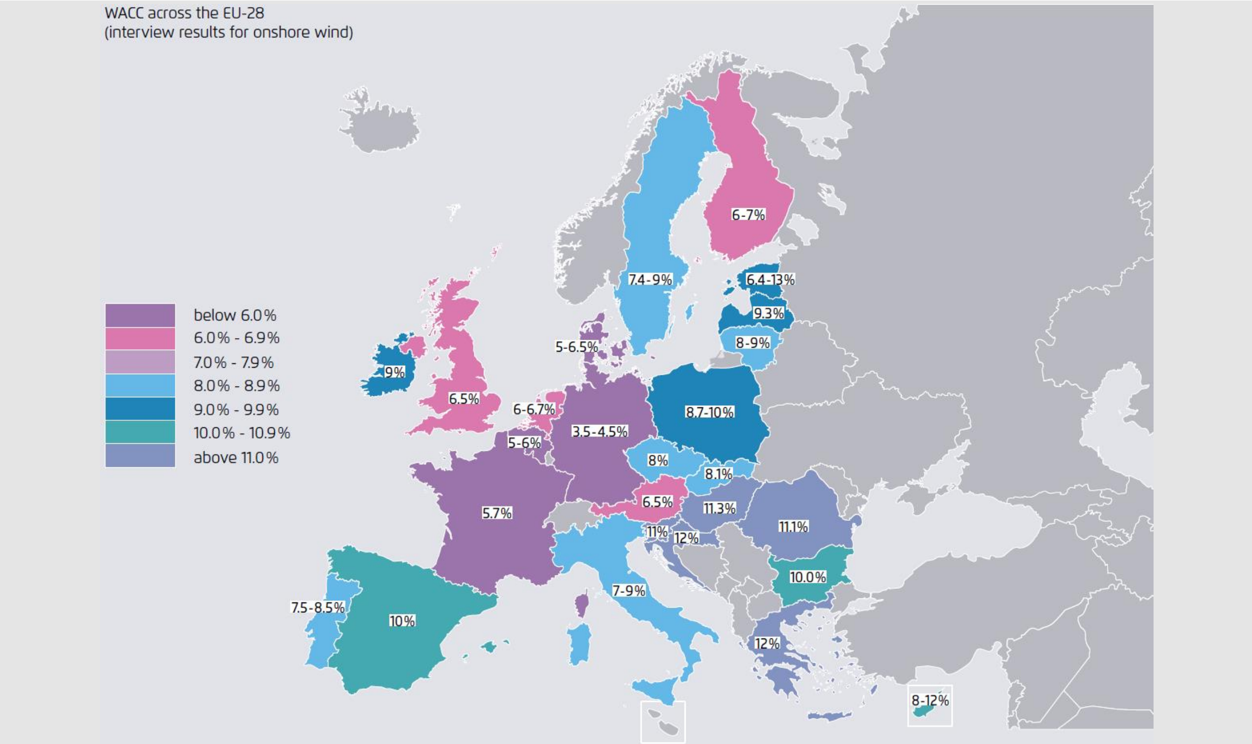
- overestimate the costs of renewable energy;
- overestimate the price of CO_2 and thereby exaggerate the role of markets in driving the development of renewable energies in Europe; and
- downplay the importance of robust sectoral policies and frameworks for developing Europe's renewable energy resources at lowest possible cost.

This is explained in more detail in the following sections.

Shortcoming 1: Overestimating the costs of renewables due to simplified assumptions concerning cost of capital for renewable investment and outdated assumptions on capacity factors

Research undertaken in 2014 revealed large differences in the **cost of capital for renewable energy investments** in different parts of Europe (Figure 3).[9] According to these studies, it cost about twice as much in 2014 to install an onshore wind power plant in Greece (capital costs at 12 percent) as it did in Germany (capital costs at 3.5 percent), all else being equal. This is due to the capital intensity of renewable energy projects and hence a large sensitivity of

Figure 3: Estimated weighted average cost of capital for onshore wind projects in Europe in 2014



Source: DiaCore (2016), *The impact of risks in renewable energy investments and the role of smart policies.*

[9] An update on cost of capital for renewable energy investments in South-Eastern Europe revealed continued large differences between countries while overall cost of capital levels have declined somewhat due to the zero interest rate policy of the European Investment Bank (see Ecofys and Eclareon (2017), *Mapping the cost of capital for wind and solar energy in South Eastern European Member States.*)

renewable energy investments to risk. Despite these very significant and well-documented differences, the Commission modelling for the central target scenarios EUCO27 and EUCO30 applies a flat-rate value for cost of capital of 7.5 percent across the whole of Europe.

The chosen 7.5 percent cost of capital flat-rate is significantly higher than capital costs for competitive technologies (e.g. wind onshore and solar PV) in mature markets (e.g., Germany, UK, Netherlands, France) where a majority of renewables investments in Europe is currently happening.[10] In consequence, the Commission central scenarios set costs of renewable electricity projects in these primary markets up to 20 percent higher in 2030 than plausible.[11] Furthermore, the Commission projections in the central scenarios do not reflect that it would be possible to bring down cost of capital for renewable energy investments all throughout Europe to "best in class"-levels currently found in Germany or France if additional policy measures are taken.[12]

A further significant upward-distortion of projected costs for developing renewables also results from some of the **capacity factors for renewable energy technologies projected in PRIMES** for the central target scenarios EUCO27 and EUCO30[13]. An analysis of PRIMES modelling results for offshore wind installations reveals that PRIMES modelling results in significantly lower than plausible yearly full load hours (3.000-3.350)[14], corresponding to a capacity factor of 34-38 percent. To put this in perspective, the Danish Regulatory Agency has estimated a capacity factor for Danish offshore wind farms of 50 percent (or 4.400 full load hours on average) in the year 2015.[15]

Applying such a higher capacity factor in the European Commission's 2016 Reference Scenario would increase the yearly electricity production by offshore wind farms from 128 TWh to roughly 197 TWh in 2030. Put differently, the same capacity of offshore wind resources would generate approximately 54 percent more electricity than projected in the Commission Reference Scenario (see Figure 4).[16] Taken together, our findings (lower WACC, higher capacity factors) imply that the central target scenarios in PRIMES are significantly overestimating the costs of investments in renewables and particularly the costs for developing Europe's offshore wind resources and hence also the support needed to make them viable.

Given these assumptions, the 27 percent share of renewable energies cannot be the cost-optimal contribution of renewable energy towards the 40 percent greenhouse gas target. The contribution of renewables should be higher as renewable energies are relatively more competitive than other alternatives deployed by PRIMES (e.g., nuclear or carbon capture and storage).

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[10] For example, more than 70 percent of new capacity installations for wind energy in 2016 occurred in Germany, UK, Netherlands and France, 44 percent in Germany alone, the Member State with the lowest cost of capital in Europe for renewable energy investments (Wind Energy Europe 2017).

[11] To demonstrate the difference this change in weighted average cost of capital (WACC) makes, we calculated the levelized cost of onshore wind using the PRIMES assumptions and output data. Applying the WACCs of 7.5% used by PRIMES and the DiaCore value of 3.5% for Germany results in significant cost differences (9,6 cents vs 7.5 cents / KWh in 2015; 8 cents vs 6.3 cents / KWh in 2030).

[12] I. Temperton (2016), *Reducing the cost of financing renewables in Europe, Study prepared for Agora Energiewende.*

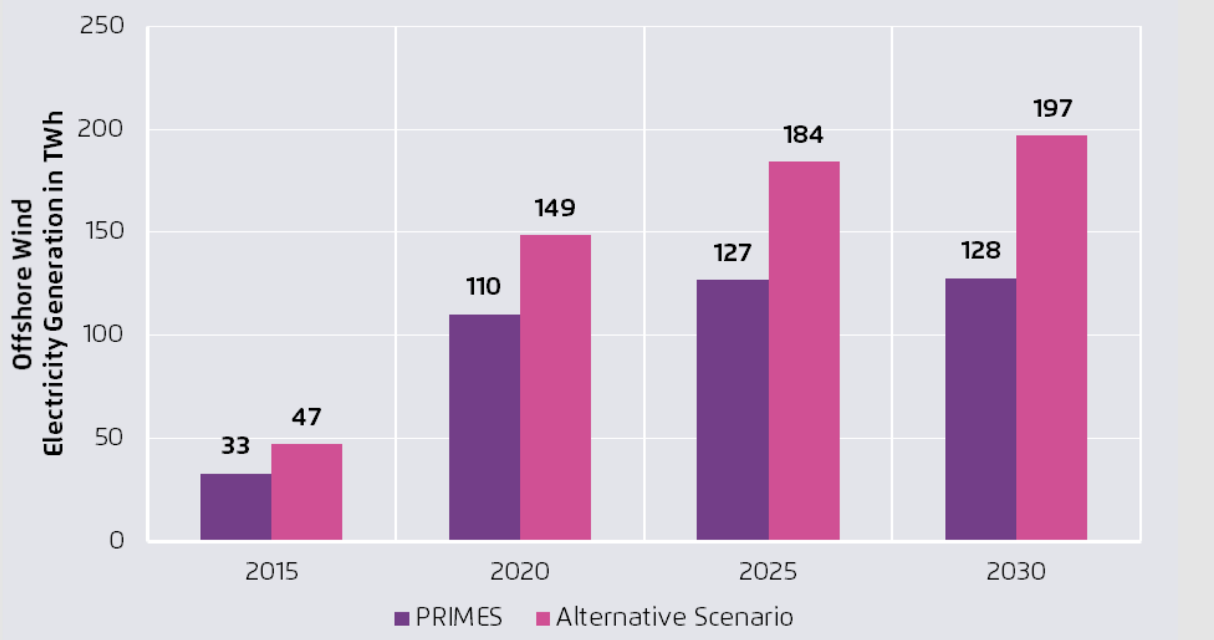
[13] Capacity factors are an outcome of the PRIMES, not an assumption. However, based on the modelling results and the model's assumptions it is possible to calculate an average capacity factor value for each generating technology based on this outcome.

[14] Own analysis based on PRIMES modelling results.

[15] See Danish Energy Agency and Energinet.dk (2016), *Technology Data for Energy Plants Updated Chapters*, August 2016.

[16] The lower costs in reality are also acknowledged by the Commission. On page 89 of the RED Re-Cast IA, the Commission writes " as regards offshore wind in particular, recent tenders have cleared with a cost of support of around 80€/MWh, which is below the cost assumptions made under REF2016 and other policy scenarios conducted for this and other related Impact Assessments.

Figure 4: Comparison of Offshore Gross Electricity Generation between 2015-2030 (in TWh) for PRIMES Modelling Results and Alternative Scenario with Higher Capacity Factors



Source: COM (2016), *EU Reference Scenario 2016* and own calculations based on PRIMES assumptions
Note: Assumptions for alternative Offshore Wind Full Loud Hours (2015-2030) based on Danish Energy Agency and Energinet.dk (2016)

Shortcoming 2: Prices for CO_2 allowances are projected at significantly higher levels than by carbon analysts in the real market, thus overestimating market-driven deployment of renewables

The EU emissions trading system (ETS) provides a stable upper boundary for carbon emissions from facilities covered under the system. However, the system has consistently been oversupplied. In 2016, the system passed the landmark of more than 3 billion surplus allowances[17], i.e. not far from the emission budget of two calendar years. The only reason for certificate prices not to be zero despite this enormous oversupply is that allowances are “bankable”, i.e. they only expire through use. The ETS allowance price of 4–5 Euros per tonne of CO_2 thus reflects the expectation of market participants that allowances may be needed in the *future*.

According to the most recent projections that reflect reform proposals currently discussed between European Parliament and Council, it seems certain that ETS allowance prices will remain far from incentivising investments into renewables or into energy efficiency throughout the 2020–2030 decade and are

Table 4: ETS carbon price assumptions (€/tonne of CO2) in the RED Re-Cast IA

Ref2016	EUCO27	EUCO30	EUCO3030
34	42	27	27

Source: RED Re-Cast IA (2016)

[17] Agora Energiewende and Sandbag (2017), *Energy Transition in the Power Sector in Europe: State of Affairs in 2016. Review on the Developments in 2016 and Outlook on 2017.*

unlikely to reliably push for a switch from coal-fired to less carbon-intense gas-fired generation before the end of the 2020-2030 decade.[18]

These real-world projections contrast with the prices of ETS allowances projected by PRIMES in the CE4ALL package impact assessment. The Commission modelling does indeed project significant increases in the carbon price, in particular under the EUCO Scenarios (see Table 4). For the EUCO30 scenario, that reflects the targets now proposed by the Commission, CO_2 prices are expected to reach 27 Euros per tonne in 2030.

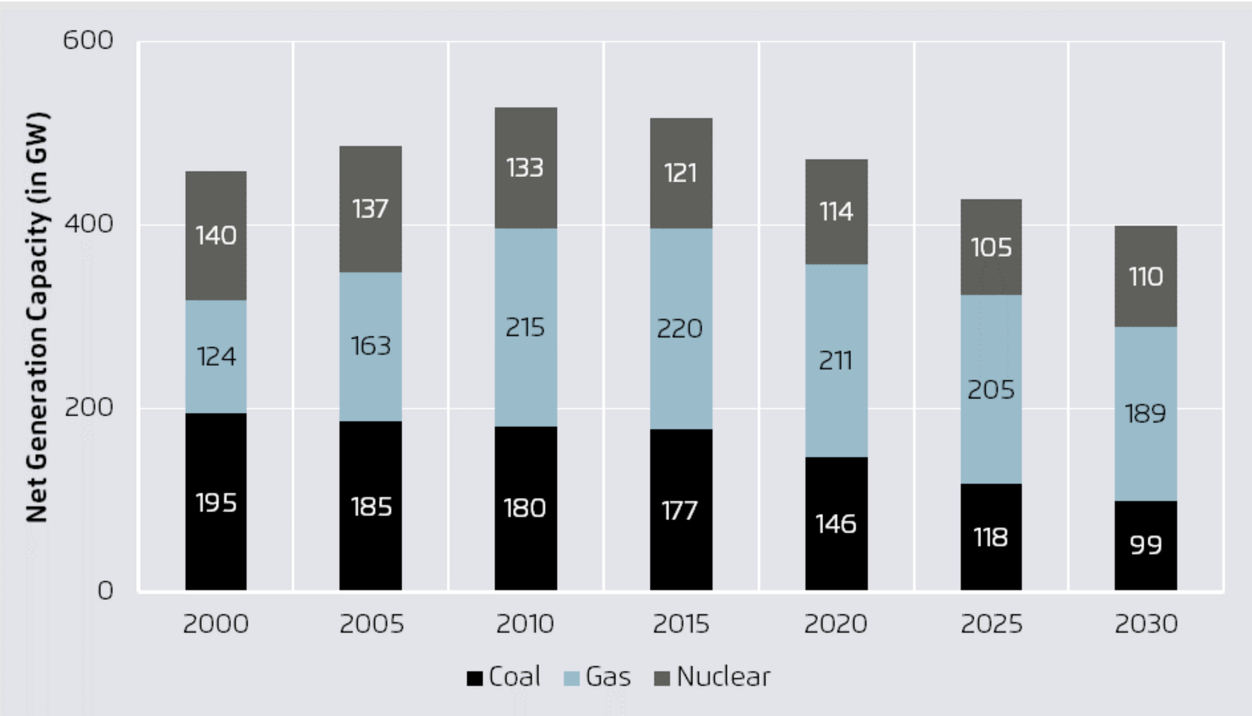
Since PRIMES applies the assumption of perfect foresight for investors, the model also assumes that the ETS is already driving behavioural change today in line with these higher price projections.

This has two important consequences:

First, PRIMES modelling for the CE4All-package assumes that significant levels of renewable generation capacity will be built autonomously in the reference scenario.

Second, PRIMES modelling for the CE4All-package assumes that significant levels of coal generation ca-

Figure 5: Evolution of Conventional Net Generation Capacity (in GW) in EUCO30



Source: E3M Lab & IISA (2016) *Technical Report on Member State results of the EUCO policy scenarios.*

[18] See Sandbag (2017), *Pricing ETS Reforms, 27 March 2017* providing an overview of price projections by carbon analysists in the market and Perino and Willner (2017), *Allowance Prices and Design Choices in Phase IV of the EU ETS* for a more academic analysis coming to the same conclusion. A price of around 30 Euro/t CO_2 would achieve a reliable switch from coal to gas. However, a carbon price of at least 60 Euros/t CO_2 is needed for driving the adoption of zero-carbon assets like renewables (Agora Energiewende (2016), *The Power Market Pentagon. A Pragmatic Power Market Design for Europe's energy Transition*). To fully internalise the true social costs of greenhouse gas emissions would require an even higher carbon price.

pacity will be retired early or cancelled as investments from 2021-2030, in significant part due to rising ETS prices (see Figure 5).[19]
The described difference between ETS allowance price projections in the real world and in the Commission central scenarios has important consequences for the cost of renewable energies and for measures needed to develop renewables at lowest possible cost:

First, the contribution of the ETS to increasing electricity market revenues for renewable energy producers will be smaller than projected by the Commission. This underscores the need for keeping investment costs into renewables as low as possible through robust frameworks that provide investors with certainty.

Second, prices for CO_2 allowances are unlikely to make a significant contribution to reliably switching from coal- to gas-fired generators before the end of the 2020-2030 decade. In consequence, inflexible, cheap coal baseload capacity will stay in the market for longer than projected by the Commission, unless other measures are taken[20]. By extension, this also implies the power market design reforms proposed by the Commission will have less impact in making markets faster and more flexible.[21]

Or, put differently: power markets in Europe will become "RES ready" later than projected by the Commission modelling. – To avoid higher costs from this uncertainty requires robust and stable renewable energy policies.

Overall, we conclude that the overly optimistic assumptions on prices for CO_2 combined with perfect foresight assumed for investors exaggerate the projected relevance of carbon markets as a driver of cost-effective renewable energy development and significantly underestimate the importance of robust and reliable dedicated renewable energy frameworks with clear targets and pathways at European and national levels.

Shortcoming 3: The Commission's scenarios downplay the importance of robust renewables frameworks to reduce uncertainty and to bring down cost

One of the core ambitions of the Commission for the CE4All-package is for renewables in the power sector to earn an increasing fraction of their revenues from electricity markets by improving and integrating short term markets, enhancing the role of flexibility and strengthening the ETS.

Table 5: Average RES-Value for power generation in IA Scenarios (€/ MWh)

Sector	Ref2016	EUCO27	EUCO30	EUCO3030
Total	**11**	**7**	**16**	**58**
Power	0	6	23	51
H&C	20	6	6	62
Transport	12	12	12	16

Source: RED Re-cast IA (2016), p. 254

The Commission used PRIMES modelling to assess the ability of renewables to finance themselves in the energy-only market over the period 2021-2030,

[19] This message seems to contradict the findings of a study by the European Environment Agency from September 2016 that cautioned in unusually clear terms against the risk of a carbon lock-in in Europe, inter alia because of persistently low prices of ETS allowances. EEA (2016), *Transforming the EU power sector. Avoiding carbon lock-in.*
[20] It should be noted that a key factor highlighted in the model documentation as influencing the development of conventional power generation in the PRIMES model is the assumed implementation of new emission performance standards for large combustion plants under the Industrial Emissions Directive (IED). However, the model's assumptions concerning the effect of the IED are not made explicit. It is also still too early to tell what impact exceptions and derogations from the IED will have on the decision of operators to retire older coal power plants due to IED compliance costs.
[21] See M. Buck, M. Hogan, C. Redl (2015), *The Market Design Initiative and Path Dependency. Smart retirement of old, high-carbon, inflexible capacity as a prerequisite for a successful market design.*

taking into account a revision of the ETS framework and proposed market design reforms.

The Commission concludes for the central target scenarios that under the right framework conditions only little support for renewable energy will be needed for certain renewable technologies (particularly onshore wind, solar PV). Key assumptions affecting this projection are improved market functioning due to removing priority dispatch and increased investor confidence in a rising ETS price.[22]

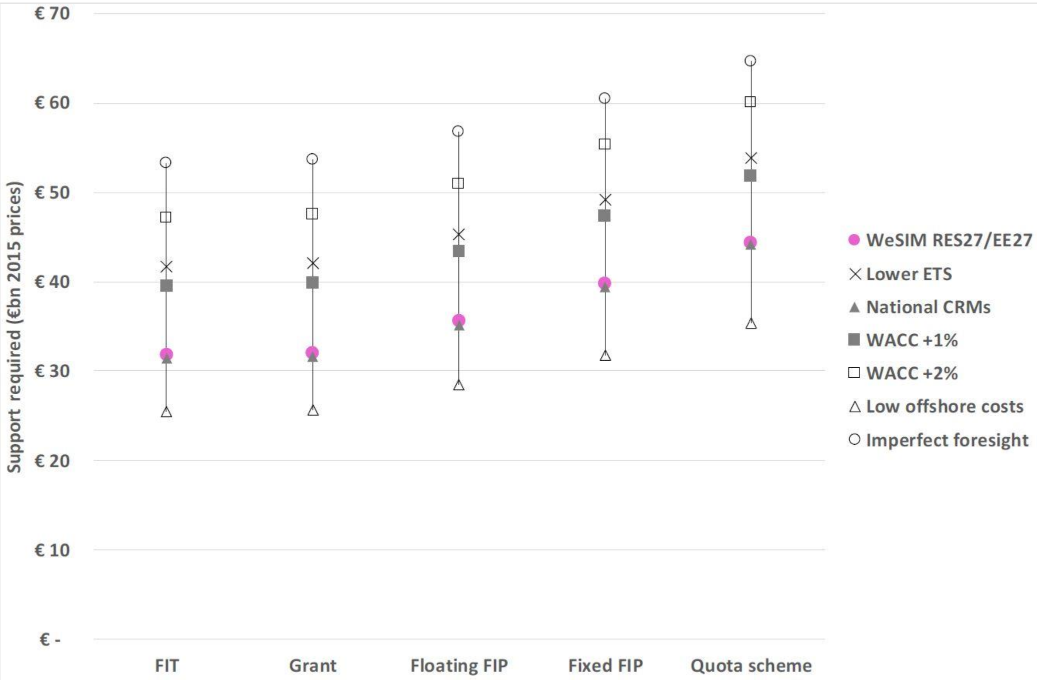
These headline messages on the potential of reformed power markets and a strengthened ETS to enable mature renewables to “stand on their own feet” somewhat hide that PRIMES uses input parameters for the electricity, heating and cooling and transport sectors that *implicitly* include renewable energy-specific policies and measures.

In the central target scenarios, these implicit RES policies and measures are referred to as ‘RES values’. RES values are applied when assessing the cost-effective development of renewable energy.[23] These inputs represent a shadow price which is internalized in the cost-optimizing behaviour of actors in the model, thus leading to higher renewables uptake.

RES values contain implicit policies and measures that are applied equally across all Member States and help to close revenue gaps for investments that cannot be wholly financed under pure market conditions. The average renewables value was set at 7 €/MWh for EUCO27, 16 €/MWh for EUCO30, and at 58 €/MWh to reach a share of 30 percent renewables in the case of EUCO3030 (Table 5).

Different than the quantitative modelling done for the central target scenarios, some of the more qualitative assessment of impacts done for the recast of

Figure 6: Funding gap between 2020-2030 for RES investments in € bn (2015 prices) by sensitivity



Source: CEPA (2017) *Supporting investments into renewable electricity in the context of deep market integration of RES-e after 2020.*

[22] See Impact Assessment for the Renewable Energy Directive Recast, p. 75.

[23] E3MLab (2016), *PRIMES Model Version 6, 2016-2017: Detailed model description*

the Renewable Energy Directive is more explicit on the preconditions for a market-based financing of renewable energy investments. It acknowledges that there is considerable uncertainty as to when the necessary conditions for RES parity will take hold. According to this assessment, achieving "RES parity" depends on a variety of factors, including[24]:

1) a continued decrease in technology costs;
2) the availability of (reasonably cheap) capital;
3) social acceptance;
4) sufficiently high and stable fossil fuel prices;
5) addressing the current surplus of carbon allowances;
6) reducing the occurrence of low or negative market prices;
7) reducing balancing costs for renewables producers;
8) bringing additional revenues to RES producers in balancing and ancillary services markets;
9) ensuring a timely and sufficient deployment of all sources of flexibility in order to limit the renewables "cannibalization effect"; and
10) electricity overcapacity effectively exiting the market.

This is indeed a long list. A background study done for the Renewable Energy Impact Assessment provides more detail on the relative weight accorded to these different factors.[25]

A sensitivity analysis of the modelling used (see Figure 6) reveals that ETS prices are the main drivers of viability gaps of renewable power producers in the medium to long-term. Both the assumption of lower than expected ETS prices and of "imperfect foresight", which simulates the more realistic myopic investment behaviour among investors under uncertain increases in carbon prices, generate significantly higher funding gaps for the investments

Box 1: Putting the 0-Cent tender results for offshore projects in Germany in perspective

On 13 April 2017 the German Federal Network Agency (BNetzA), announced the results of Germany's first competitive offshore wind tenders, in which a total of 1,490 MW of offshore wind capacity were auctioned. For 1,380 MW the successful bid was 0.0 ct/kWh, i.e. projects requesting just the grid access, but no market premium. If successfully realized, these projects would be wholly financed by energy market revenues. The projects are to be built by 2025.

These impressive results highlight the growing competitiveness of offshore wind technologies. With costs for wind offshore apparently being at 5 to 6 ct/kWh in 2025 they strongly make the case for recalculating the optimal renewables share in European power production.

However, these successful 0-cent-bids not only include the expected further cost reductions for wind turbines built in 2023-2024, but also reflect assumptions by the project developers on electricity price developments by 2025 – rising from the current 3.5 ct/kWh to some 5.5 ct/kWh or more. These price expectations are strongly contingent on the removal of surplus fossil generation capacity, enhancing carbon price signals and successfully implementing power market reforms. If some or all of these assumptions fail to materialize the project developers may still decide in 2021 not to actually build the projects. The penalty for not realizing successful tender bids is 100 EUR/kW (i.e. 138 million Euros for the 1,380 MW zero-bid-projects), which is significant, but does not exclude taking a final investment decision only in 2021, as evidenced by the press release of DONG Energy, that won 480 MW of the 0-cent-bids.

[24] See Impact Assessment for the Renewable Energy Directive Recast p. 29-30.

[25] CEPA (2016), *Supporting investments into renewable electricity in context of deep market integration of RES-e after 2020: Study on EU-, regional- and national-level options*

needed between 2020 and 2030 to reach the EU's 2030 renewable energy target.

Moreover, technology and capital cost are also found to have a significant impact on the viability of RES investments. In particular, adding two percent to the assumed WACCs of renewables investments, pushes up the viability gaps of all technologies by 2030, resulting in a higher funding gap for all technologies across every policy option.

Due to these significant uncertainties, the Commission acknowledges in the Renewable Energy Impact Assessment that support schemes will be needed for at least a transitional period. It proposes the use of competitive tenders to enable the market to confirm over time the necessity and level of support that continues to be needed and provide a natural phase-out mechanism for support.

A deeper look into the Commission Impact Assessments thus shows that the headline political message "mature renewables will be able to stand on their own feet after 2020" needs significant nuancing as to the preconditions attached to this statement. Rather than confirming the political headline message, the Commission modelling shows that it is indeed a combination of power market design reforms with robust EU-level and national renewable energy policies and frameworks that will deliver least cost renewable energy investments in Europe.

Robust renewable energy frameworks, favourable financing conditions, well-functioning power markets, the early retirement of generating overcapacity in particular of inflexible baseload coal-fired generator, and a meaningful ETS allowance price could combine to fully phasing-out the need for specific support to renewable energy projects. Competitive tendering will automatically show where and when investors consider the appropriate conditions to be in place (Box 1).

Conclusions

From our analysis we draw the following conclusions:

1. **Renewables are cheaper than modelled by the Commission.** In reality, capacity factors are higher than modelled and capital costs are in several countries in the EU a lot lower than expected. Renewables are thus relatively more competitive than other alternatives deployed in the Commission modelling (e.g., nuclear or carbon capture and storage).

2. **A significantly higher share of renewables is cost efficient to reach Europe's 2030 climate target.** The necessary downward correction in cost assumptions for renewables imply that the 27 percent share of renewable energies cannot be the cost-optimal contribution of renewable energy towards the 40 percent greenhouse gas reduction target. The cost-effective share needs to be significantly higher.

3. **New modelling with updated cost assumptions and higher RES shares is needed.** It would seem highly relevant for the political discussion on the CE4All-package in the European Parliament and in the Council to see an updated calculation on higher ambition levels on renewables with real world cost assumptions. An important starting point should be an update of the GHG45/EE/RES35-scenario modelled in 2014 (45 percent greenhouse gas emission reductions, 35 percent share of renewables, 34 percent improvement in energy efficiency) that came out only slightly more expensive at total system costs level compared to the 40 percent greenhouse gas reduction scenarios.
   This holds especially since the Paris Agreement on Climate Change aims at limiting global warming to at most 2 degrees above preindustrial levels. However, the contributions by the Parties to the Paris Agreement do not reach that goal. To fill the gap, a review and pledge-process was agreed, where the rest of the world will surely expect Europe to increase its 2030 climate target above the current -40% objective.

4. **Robust renewable energy frameworks are fundamental for unlocking Europe's renewable energy potential at lowest possible cost.** The Commission modelling overplays the role of markets and emissions trading in driving the development of renewables. It also somewhat hides the implicit assumption of robust renewables policies and frameworks in the Commission central target scenarios.

5. **Robust renewable energy frameworks combined** with **improved power market functioning can bring the need for premium payments above market price down to almost zero.** This is the main message from background studies done for the Commission impact assessment for the Renewable Energy Directive and recent real world auction results (see Box 1). Key ingredients include: Removal of surplus fossil generation capacity, in particular inflexible baseload coal-fired generators; robust renewable energy frameworks; favourable financing conditions; well-functioning power markets, in particular no capacity markets; enhanced inter-connectivity; and a meaningful ETS allowance price of around 30 Euros per tonne of CO_2-emissions.

6. **Higher ambition on renewables benefits Europe's industrial base** and **public health** (due to reduced air pollution), it enhances **energy security** (by reducing dependence on fuel imports) and **reduces the vulnerability of Europe's economy** to more volatile fuel prices on world markets.

Annex 1: Main documents reviewed for this analysis

For this assessment Agora Energiewende analysed the Impact Assessment for the 2014 Commission Communication on a 2030 climate and energy policy framework, the key Impact Assessments relating to renewable energy and market design in the context of the 2016 'Clean Energy for All Europeans' Package, as well as studies related to these impact assessments. The core focus of the assessment is on the following Staff Working Documents, modelling results and studies:

- The Impact Assessment for the Communication 'A policy framework for climate and energy in the period form 2020 up to 2030' (**2030 IA**)[26]
- The Impact Assessment for the Renewable Energy Directive Re-Cast ((**RED Recast IA**)[27]
- The Impact Assessment for the Market Design Initiative[28] (**MDI IA**)[29]
- Technical report on Member State results of the EUCO policy scenarios[30]
- EU Reference Scenario 2016 (**REF2016**)[31]
- EU Reference Scenario 2013 (**REF2013**)[32]
- CEPA Study on RES Support after 2020[33]

Annex 2: Overview of models used in the COM IA

- **PRIMES:** PRIMES is a private energy market engineering-economic model that is developed and maintained by the E3MLab/ICCS of National Technical University of Athens in the context of research programmes co-financed by the European Commission. It is a partial equilibrium modelling system that simulates an energy market equilibrium in the European Union and each of its Member States, including consistent EU carbon price trajectories. PRIMES has been used for Commission Reference Scenarios and Impact Assessments going back as far as 2003. Its modelling results have been a critical reference point for the European energy and climate debate, including in the 2030 target setting process, the 2050 Roadmap exercise and most recently the CE4All Package. The model is, in particular, used to project the impact of various scenarios of policies and measures in the area of climate and energy in order to identify a cost-optimal approach.
- **PRIMES/OM:** Part of the modelling for the Commission's assessment of the need for RES support in the period 2021-2030 in the MDI IA was performed using PRIMES/OM, a specific version of the PRIMES model that can assume different types of competition in the electricity market, as well as model how Capacity Mechanisms affect the investment decisions of the market participants.
- **PRIMES/IEM:** Part of the modelling for the Commission's assessment of the need for RES support in the period 2021-2030 in the MDI IA was performed using PRIMES/IEM, a day-ahead and unit commitment simulator developed by NTUA. The model places more emphasis on accurately simulating the market behaviour of generators by assuming specific bidding strategies followed by the market participants and departing from the usual marginal cost assumption. The model was used to assess the benefits of the energy-only market in greater detail.

[26] COM (2016) SWD(2016) 15 final
[27] COM (2016) SWD(2016) 418 final
[28] The Impact Assessment for the Market Design Initiative covers all market design related legislative proposals in the CE4ALL Package, including both the Electricity Market Regulation and Directive.
[29] COM (2016) SWD(2016) 410 final
[30] E3MLab & IIASA (2017) *Technical Report on Member State results of the EUCO policy scenarios – Corrected version dated 25 January 2017.*
[31] COM (2016), *EU Reference Scenario 2016: Energy, transport and GHG emissions – Trends to 2050.*
[32] COM (2013), *EU Energy, Transport and GHG Emissions – Trends to 2050: Reference Scenario 2013.*
[33] CEPA (2017) *Supporting investments into renewable electricity in the context of deep market integration of RES-e after 2020: Study on EU-, regional- and national-level options. Report for the European Commission Directorate General for Energy under Contract ENER/C1/2015-394.*

- **WESIM**[34]**:** The Whole-electricity System Investment Model (WESIM) is a comprehensive electricity system analysis model operated by Imperial College London, which aims at simultaneously balancing long-term investment-related decisions against short-term operation-related decisions, across generation, transmission and distribution systems, in an integrated fashion. The objective function of WESIM is to minimise the overall system cost, which consists of cost of investment in generation, network, interconnection and emerging flexible network, storage and DSR technologies and cost of operating the system, which includes generation operating cost and cost of supply interruptions. This model is used in the CEPA Study on RES Support after 2020[35] and provides the modelling basis for the Commission's assessment of the need for RES support in the period 2021-2030 in RED Recast IA. While the study uses some inputs from the EUCO Scenarios (for example, the electricity generation capacity mix), it operates differently from PRIMES and uses different technology cost and cost of capital assumptions.

Annex 3: Glossary of PRIMES Scenarios

- **REF2013:** This is the EU 2013 Reference Scenario, finalized in July 2013, which was used as the reference scenario for the 2014 Communication 'A policy framework for climate and energy in the period form 2020 up to 2030' (**2030 IA**). It focuses on current policy trend projections – not forecasting future policies. It includes 2010 statistics on population and economic development, and national and EU policies and measures adopted until spring 2012. The scenario achieves -32.4% GHG, 24.4% RES and 21.0% EE.
- **GHG40/EE:** This is a scenario from the 2030 IA with a pre-set target for GHG emission reductions (-40%) and enabling conditions for energy efficiency. The scenario achieves -40% GHG, 26.4% RES and 29.3% EE. The scenario assumes no dedicated policy in support of RES in addition to the Reference Scenario.
- **GHG40/EE/RES30:** This is a scenario from the 2030 IA with a pre-set target for GHG emission reductions (-40%) and renewable energy (30%), RES values of €56/MWh in 2030 and enabling conditions for energy efficiency that are identical to those found in GHG40/EE. The scenario achieves -40% GHG, 30% RES and 30.1% EE.
- **GHG45/EE/RES35:** This is a scenario from the 2030 IA with a pre-set target for GHG emission reductions (-45%) and renewable energy (35%), RES values of €142/MWh in 2030 and EE policies that go beyond the enabling conditions in GHG40/EE and GHG40/EE/RES30. The scenario achieves -45% GHG, 35% RES and 33.7% EE.
- **REF2016:** This is the EU 2016 Reference Scenario, which was used as the reference scenario for the CE4All Package. It projects greenhouse gas emissions, transport and energy trends up to 2050 on the basis of policies adopted at national and EU level until December 2014, as well as updated fuel price and technology cost assumptions relative to the EU 2013 Reference Scenario. As such, it serves as a baseline scenario to approximate a case in which no further policies to reach the 2030 targets would be adopted. The scenario achieves -32.4% GHG, 24.4% RES and 23.9% EE (this is the equivalent of -16% primary energy consumption compared to 2005).
- **EUCO27:** This scenario is the central target scenario used by the Commission when assessing policy options for the delivery of the 2030 climate and energy targets to provide a common "context" for all of the CE4All Package Impact Assessments. It was used as the starting point for the baseline scenarios for the RED Re-cast (the 'CRA: Current Renewables Arrangement' Scenarios) and the Market Design Initiative (the 'CMA: Current Market Arrangements' Scenario), and as a baseline scenario for the assessment of

[34] http://www.wholesem.ac.uk/documents/icl-model-summary

[35] CEPA (2017)

the cost of increased ambition on energy efficiency in the Impact Assessment done for the Energy Efficiency Directive. The scenario is set to meet all 2030 targets set by the European Council, including for greenhouse gas reductions, for the distribution between ETS and non-ETS, and for renewables and efficiency. The scenario includes an increase in the ETS linear reduction factor to 2.2% from 2021-2030, average renewables values of €6/MWh in 2030 and a variety of enabling conditions for energy efficiency. The scenario achieves -40.7% GHG, 27.0% RES and 27.4% EE (this is the equivalent of -20% primary energy consumption compared to 2005)

- **EUCO30:** This scenario builds on the EUCO27 scenario, but increases enabling conditions for renewable energy and energy efficiency to meet both a 30% EE and 27% RES target, including average RES values of €23/MWh in 2030. The scenario achieves -40.8% GHG, 27.1% RES and 30.0% EE (this is the equivalent of -23% primary energy consumption compared to 2005)
- **EUCO3030:** The scenario builds on the EUCO30 scenario, but increases enabling conditions for RES to meet both a 30% RES and a 30% EE target, including average RES values of €58/MWh in 2030. The scenario achieves -43.2% GHG, 30.2% RES and 30.0% EE.