Power Perspectives 2030

On the road to a decarbonised power sector

Executive Summary

A contributing study to Roadmap 2050: a practical guide to a prosperous, low-carbon europe

EXECUTIVE SUMMARY

A. CONTEXT

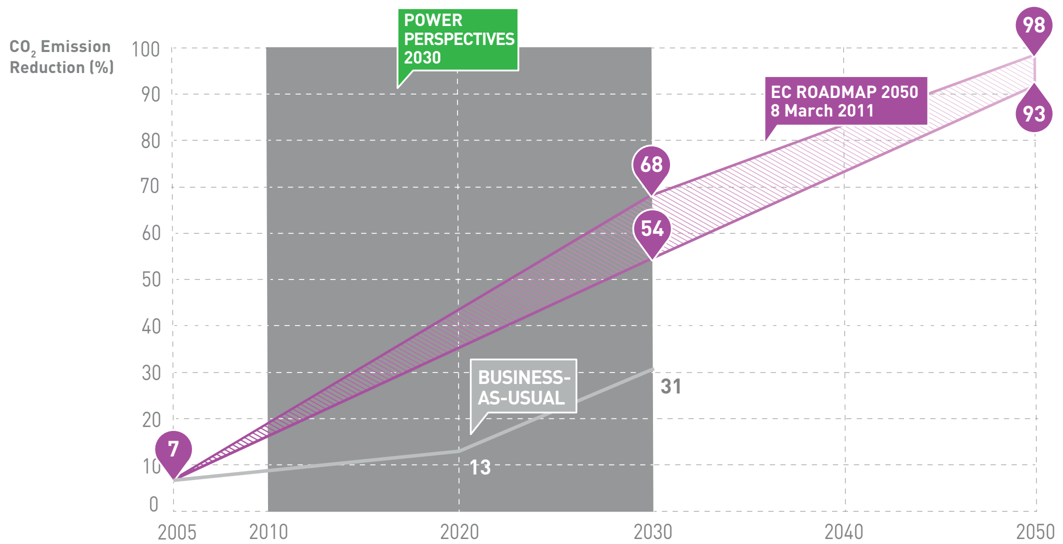
In October 2009, the European Council set an economy-wide greenhouse gas (GHG) abatement objective of 80–95% below 1990 levels by 2050. In support of this objective, the European Climate Foundation (ECF) initiated a study to establish a fact base for achieving this goal and to derive the implications for European industry and in particular for the power sector. The result was *Roadmap 2050: a practical guide to a prosperous, low carbon Europe*, published in April 2010. It showed that the transition to a fully reliable, fully decarbonised power sector by 2050 is a pre-condition for achieving the 80% economy-wide emissions reduction target. The study also established that full power sector decarbonisation is technically feasible and economically affordable.

On March 8, 2011, the European Commission confirmed this conclusion when it published *"A roadmap for moving to a competitive low carbon economy in 2050"*. In that document, the Commission set out sectoral carbon dioxide (CO_2) reduction trajectories with a mid-term view on 2030 to steer the decarbonisation of the economy on a manageable and cost-effective course. For the power sector, the Commission proposed a CO_2 reduction range of between 54% and 68% by 2030 compared to 1990 levels. Later this year, the Commission will follow up with a specific energy roadmap that analyses pathways based on this trajectory towards 2030 and the 80-95% reduction by 2050, while improving energy security and competitiveness.

It is in the context of these new policy developments that the ECF decided to embark on a new study: *Power Perspectives 2030: on the road to a decarbonised power sector.*

This study provides a view on the progress that is necessary by 2030, creating a way-point by which to navigate the path to a fully decarbonised power sector by 2050.

Power Perspective 2030 finds that existing plans for renewables and transmission grids up to 2020, if fully implemented, constitute an adequate first step to decarbonisation but that the transition needs to accelerate towards 2030 in order to remain on track to the 2050 CO_2 abatement goal for the power sector. This acceleration implies a near doubling of investments in low-carbon generation and a near doubling of electricity grid capacity in the decade after 2020. Hence, in the current decade, the European Union, its Member States and the relevant commercial undertakings need both to ensure the implementation of current commitments and to establish an adequate policy and legal framework to steer the decarbonisation of the power sector beyond 2020.



PERSPECTIVES 2030 ▶What are the complications?
▶What are the solutions at hand?

B. OBJECTIVE

The ambition of *Power Perspectives 2030* is to analyse what is required between today and 2030 to remain on a secure pathway to a decarbonised power sector by 2050. It attempts to identify the challenges and solutions based on today's knowledge of the options.
Last year's *Roadmap 2050* report showed that the transformation to a decarbonised and secure power sector is technically feasible at similar overall cost to a non-decarbonised power mix, due to a major shift from operational costs ("opex") to capital investments ("capex"). An increase in upfront investments is recouped over time by substantial reductions in operating costs. While last year's report significantly increased confidence in the feasibility of the 2050 end-goal, it also hinted at the challenges Europe will face in implementation. *Power Perspectives 2030* now brings more detailed insight into these challenges and the solutions at hand to remain on track towards full decarbonisation by 2050.

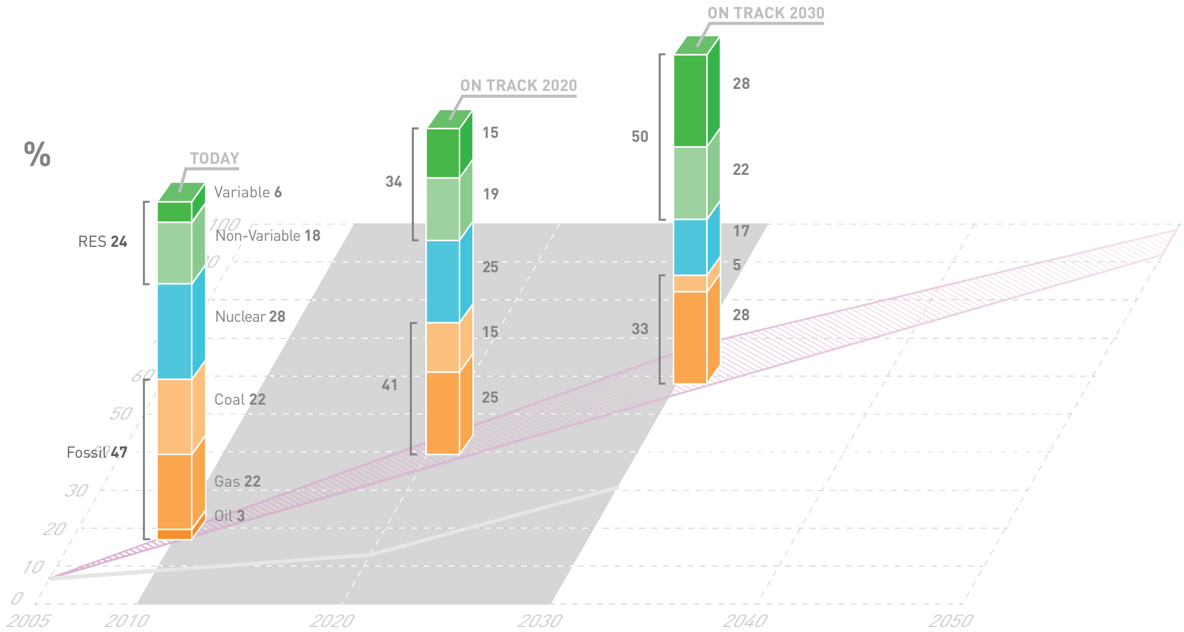
C. APPROACH

Power Perspectives 2030 focuses on the transition between today and 2030 and closely follows the sectoral emissions trajectory set out by the European Commission's March 8, 2011 communication, which indicates a CO_2 emissions reduction range of around 60% for the power sector in 2030.

From a methodological point of view, the analysis first defines the demand and production mix as an input to determine the hourly demand and production curves, and then defines transmission and back-up capacity required to meet demand at optimal cost and at current levels of system reliability. The modelling applies the following conditions: achieving the EC's 2030 CO_2 emission reduction range, maintaining power supply reliability at current levels and, where possible, avoiding early retirement of existing assets. Import/export of power for each country is limited in 2020, as each country is expected to be more or less self-sufficient (with a few exceptions). In 2030 more import/export is allowed but self-sufficiency is preserved despite the increase in RES capacity for almost all countries.

The report compares the results from various sensitivity scenarios against the central scenario to bring qualitative and quantitative insight into the effects of changing specifc elements of the power system (supply – transmission – demand). This central scenario is called the *On Track case.* Up to 2020, it is based on the full implementation of the existing plans for the power sector[1]. Towards 2030, it models a power system in line with the EC's emission reduction goals with a production mix with 50% renewable energy sources[2] (12% wind on-shore, 10% wind off-shore, 6% solar PV, 10% biomass, 11% hydropower and 1% geothermal), 34% fossil fuels (28% gas, 6% coal) and 16% nuclear across Europe. This differs from a *Business-as-Usual case* where the current plans and targets up to 2020 are not implemented and the CO_2 reduction range for the power sector in 2030 is missed by half[3].

1 These plans are: the National Renewable Action plans (NREAPs) and the Ten-Year National Development Plans from ENTSO-E (TYNDP).
2 Renewable energy sources cover a diverse portfolio of commercial technologies with very different charachteristics. This diversification of resources is important for the security and reliability of electricity supply
3 This scenario is well described in the European Commission's PRIMES report "EU trends to 2030 - baseline", (update 2009). This leads to an emissions reduction of 13% in 2020 and 31% in 2030.



	ON TRACK	
	2020	**2030**
Supply	NREAPs	Built by model
Transmission	ENTSO-e	Built by model
Demand	Primes + fuel shift	Primes + fuel shift

D. STAYING ON TRACK TO DECARBONISATION

1. THE COST OF DECARBONISATION REMAINS WITHIN SIMILAR RANGES OVER THE DECADES, BUT A SHIFT FROM COST (OPEX) TO INVESTMENTS (CAPEX) NEEDS TO BE PURSUED

The analysis shows that it is possible to remain on track to decarbonisation towards 2030 at a levelised cost of electricity (LCOE)[4] for new builds similar to the LCOE in this decade. The analysis shows LCOE numbers of €89/MWh in 2020 and €85/MWh in 2030 for new builds, including CO_2 prices, which is only a small increase compared to the estimated value of €82/MWh for new generation added in the previous decade[5]. These estimates are comparable to the numbers in last year's *Roadmap 2050* report which showed a backcasted LCOE of €84/MWh in 2020 and €86/MWh in 2030[6]. The analysis thus shows it is feasible to keep LCOE under control through the decades of transition to a fully decarbonised power sector. The increase in upfront investments will have to be incentivised appropriately but will pay–off through decreasing operating costs.

4 "Levelized cost of electricity" is an expression of the total cost of a product including both current outlays for operations and a charge each period to repay the initial capital investment.
5 This is an estimation of the average LCOE in the decade 2000 – 2010, based on costs estimated in IEA WEO 2009 and in Nuclear Energy Agency reports published in June 2010. The LCOE per technology is based on latest information from Eurelectric
6 There are a few differences in approach between *Roadmap 2050* and *Power Perspective 2030* in this regard, such as more conservative assumptions on load factors and higher granularity in grid modelling then in "Power Perspectives 2030"

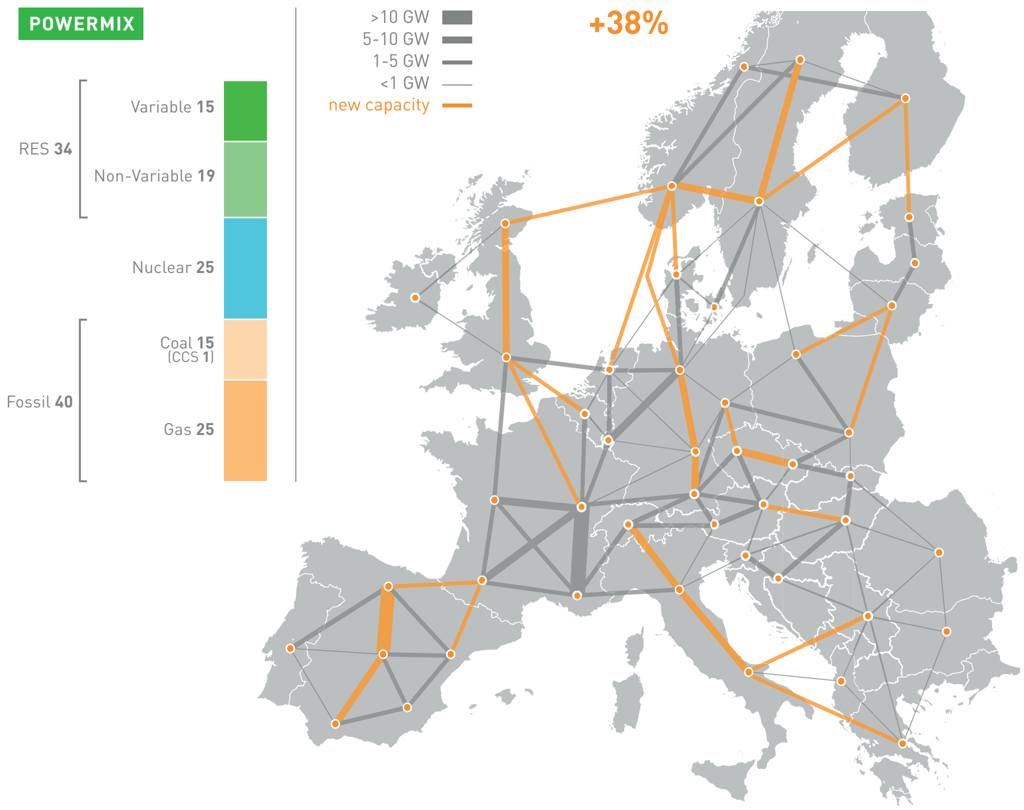
2. EXISTING POWER SECTOR PLANS AND TARGETS ARE ADEQUATE TO BALANCE THE POWER SYSTEM UP TO 2020, BUT SIGNIFICANT IMPLEMENTATION CHALLENGES REMAIN

The analysis shows that current power generation and grid plans are adequate to balance the planned power mix in 2020[7]. Still, it is clear that full implementation of these plans requires substantial effort, particularly by Member States. For example, Europe's transmission system operators (ENTSO-E) have a ten-year network development plan requiring an increase in transmission lines of 64 GW from 2010 to 2020 - a 38% capacity increase over the existing network. Similarly challenging are the implementation of the National Renewable Energy Action Plans (NREAPs) through which Member States expect to comply with the 20% target in the binding Renewables Directive. Challenges also remain in achieving the 2020 energy savings target, where European leaders have indicated that so far only about half of the desired energy productivity gains are set to being realised[8].

As recognised by European Energy Ministers earlier this year[9], major investments will be needed for new low-carbon generation up to 2020. The analysis for the *On Track case* confirms the EC investment estimates and shows that around €628 billion (of which €567 billion for generation, €15 billion for back-up capacity and €46 billion for transmission expansion) needs to be mobilized in the period from 2010 to 2020. The numbers indicate that the challenge of attracting investments lies primarily with low-carbon generation technologies, and less with back-up or transmission expansion.

2020 Current plans are an adequate first step

ENTSO-E + NREAPs = Balanced power system with low RES curtailment (0.6%)



7 RES curtailment on average remains very low, around 0,6% in 2020. For more details see exhibit 10 in the full report.
8 Special European Heads of State Summit on Energy and Innovation on 4th February 2011.
9 European TTE Council, February 28th 2011 – http://www.consilium.europa.eu/uedocs/cms_data/docs/pressdata/en/trans/119518.pdf

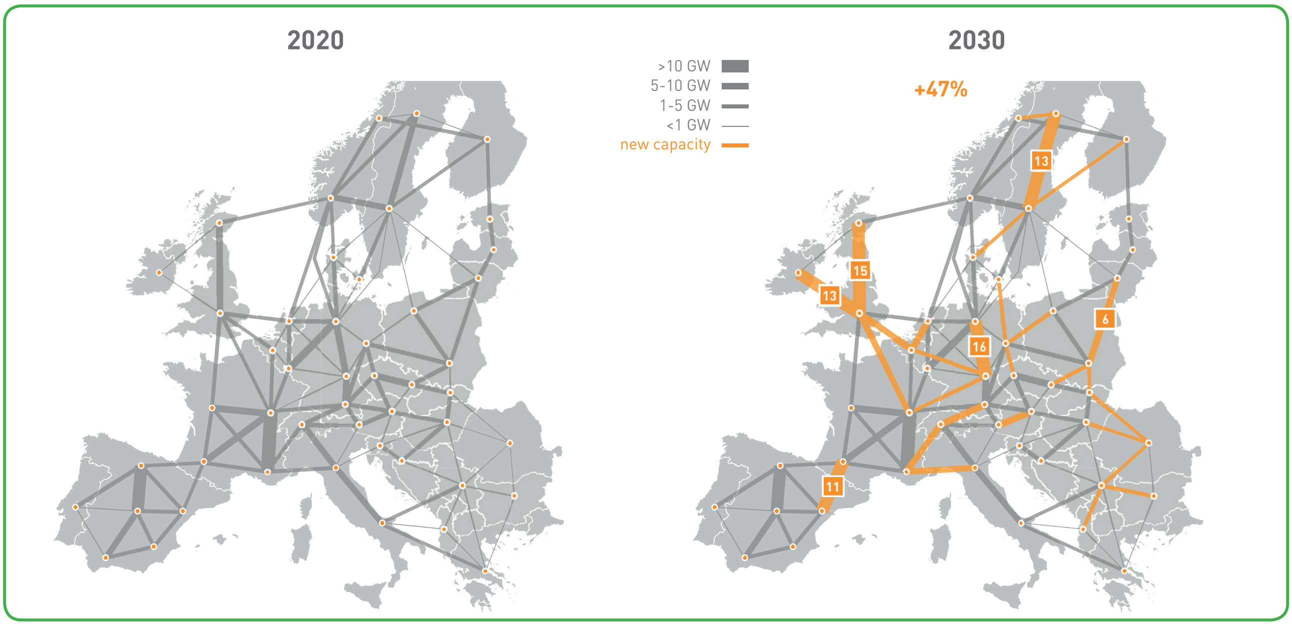
3. KEY CHALLENGES ON THE ROAD TO DECARBONISATION

3.1. TRANSMISSION GRIDS

Significant new grid capacity is required beyond 2020. Additional investments in transmission grids, including off-shore wind connections, of €68 billion for the *On Track case* are projected from 2020 to 2030 to enable the construction of around 109 GW of additional transmission capacity – a 50% increase from the planned network in 2020 and a near doubling of today's existing capacity. Most of the additional interconnections are projected across borders (between southern UK and Ireland (13 GW), between southwestern France and northeastern Spain (9 GW)), but large transmission upgrades are also required within countries (northwestern to western Germany (10 GW), northern to southern UK (8 GW))[10].

Grid build-out risks being slowed down by several factors, e.g. delayed planning or consenting procedures and a lack of clarity regarding the cost allocation of interconnectors among participating countries and transmission operators. The current system relies on investors building interconnectors on a merchant basis or on ad hoc bilateral arrangements between member states driven by the economic rents that underpin merchant transmission[11]. However, the basic economics of merchant interconnectors make it very unlikely that this will lead to the level of required investment identified in our analysis.

Upgrading the grid infrastructure is, however, the most cost–effective way to keep a power system in transition secure and reliable. Less transmission build-out will lead to less optimal use of RES and additional need for back-up capacity[12]. Sensitivity scenarios with a 50% reduction in transmission capacity when compared to the *On Track case* show more volatile prices, higher curtailment levels, and an increase in back-up capacity required in 2030 leading to slightly higher emissions in 2030. When applying an even higher share of diverse RES (60% in 2030), the effects of insufficient transmission build-out increase exponentially. Hence, transmission expansion throughout Europe is a fundamental enabler for integrating power markets and is the most cost effective means to accommodate higher levels of diverse RES in a secure and robust power system.



10 Sensitivity analyses demonstrate that the 2030 emission reduction range is also achievable with lower levels of investment in new transmission. However in all cases this leads to increases in cost and price volatility. We did not test specifically the impact of a larger role for distributed generation but the analysis provides strong indication that a more distributed solution has minimal impact on the scale of the optimal transmission expansion, though the architecture of the expansion could be expected to be somewhat different.

11 It is acknowledged that the European Commission has in October 2011 tabled legislative proposals that address these issues.

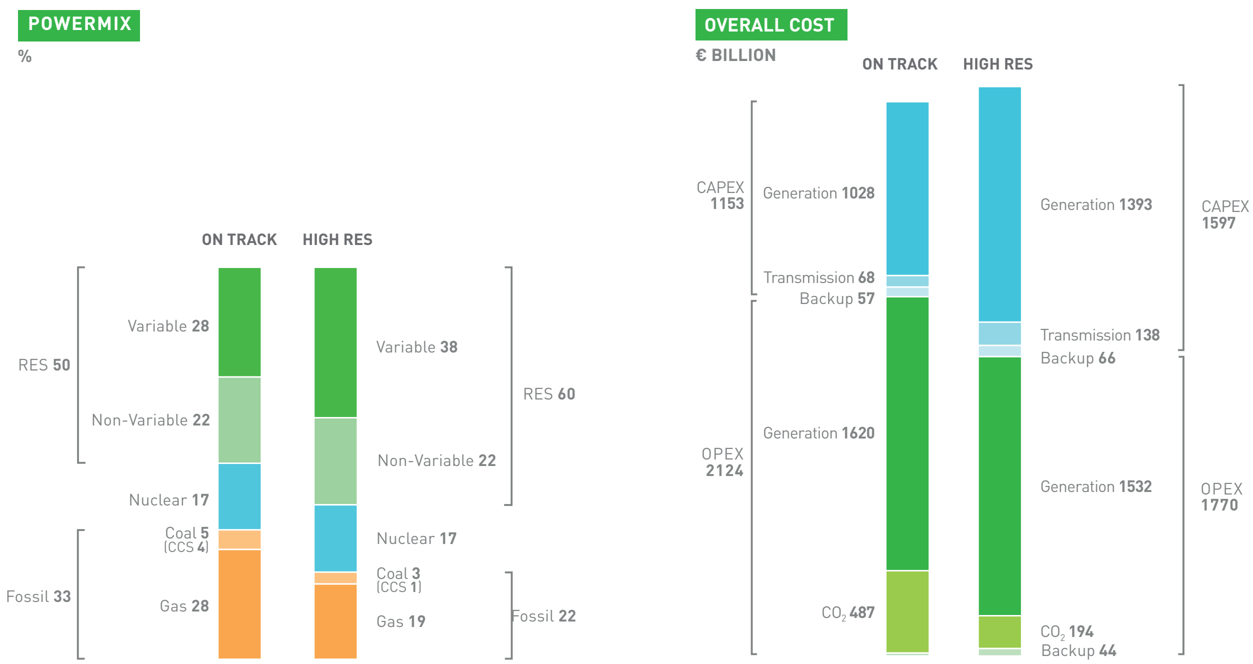
12 If further developments in battery storage technologies materialise and solutions become cost-effective alternatives, they can play an important role in optimising system balancing in combination with transmission and back-up.

3.2. LOW-CARBON GENERATION TECHNOLOGIES

Power Perspectives 2030 shows that diversification and decarbonisation can go hand in hand both up to 2020 and beyond, and is driven by a continuation of the deployment of a portfolio of promising RES technologies. This is essential to a well-diversified, no-regrets decarbonisation trajectory for the power sector. To support the deployment of these low-carbon technologies, more upfront investment (capex) in generation capacity is required. In the *On Track case*, €1,153 billion capital expenditure (of which €1,028 billion for generation, €57 billion for back-up and €68 billion for transmission expansion) is needed in the period from 2020 to 2030[13]. That is a near doubling of the estimated investments required in the period from 2010 to 2020, bringing the total capex for the next two decades together to €1,781 billion, representing 0.5% of EU-27 GDP (based on 2010 GDP) per year for the 2010-2020 period. This is a significant challenge and may require adaptations to the power markets or other measures to stimulate investments. There is a growing consensus within the financial community that, alongside existing approaches, new models will need to be found to finance this transition[14]. Interestingly, a 2030 power mix with even higher shares of diverse RES (60%) pushes up the required investments but benefits overall from a significant decrease in operating costs inclusing fossil fuels and carbon prices.

Higher shares of RES is technically possible at similar cost

Increased in investments is off-set by decreased fuel costs.



With current levels of variable RES penetration incremental operational requirements, such as hourly balancing and provision of operating reserves, have been absorbed by the system. As penetration continues to expand, however, the operational requirements will expand as well. There is a growing need to make these impacts more transparent, address them in a cost-efficient manner and allocate the associated costs across all relevant stakeholders.

13 The report assumes that learning rates and cost reductions for RES will increasingly be driven by Rest of World deployment; though demand in the EU remains important. For details, please see exhibit 12 in the report.
14 ECF (2011), Roadmap 2050: Financing for a zero-carbon power sector in Europe - http://www.roadmap2050.eu/attachments/files/R2050-Financing.pdf

Beyond 2020, when shares of diverse, variable renewables become more significant, enhacing European-wide cross-border cooperation can reduce required investments. In a sensitivity scenario with less coordinated diverse RES deployment, whilst still reaching 50% renewables in 2030, around 20% more investments will be needed for generation in the period 2020-2030.

3.3. ROLE OF GAS

In all scenarios, the analysis shows that gas-fired generation will play an important role going forward. Gas-fired plant provides 22% of the annual power demand in 2010, 25% in 2020 and 28% (25% unabated, 3% gas-with-CCS) in the 2030 *On Track case.* Gas-fired plants act both as flexible baseload (replacing coal-fired generation) and as back-up resource in support of increased shares of diverse, variable RES generation, while conforming to the EC's 2020 and 2030 power sector CO_2 emission reduction goals. Beyond 2030, CO_2 abatement goals are such that gas can only remain a significant fuel source in the power mix if commercially deployable solutions are developed to substantially eliminate carbon emissions from gas-fired generators.

As overall gas consumption is expected to remain stable in the next decades, due to the projected shift in gas usage from the heating sector to the electricity sector, the analysis finds that planned gas network infrastructure by 2020 will be adequate in most areas in Europe. As with the electricity grid, the investments required in the gas network to implement the 2020 plans may require specific incentives[15].

3.4. DEMAND SIDE RESOURCES REDUCE THE BALANCING CHALLENGES IN A DECARBONISED POWER SYSTEM

Power Perspectives 2030 shows that substantial new transmission capacity and large investments in the deployment of low-carbon technologies are vital if we are to keep decarbonisation on track. In search of tools to help deliver these fundamentals, the analysis clearly shows the benefits of stimulating implementation of demand response and energy efficiency measures.

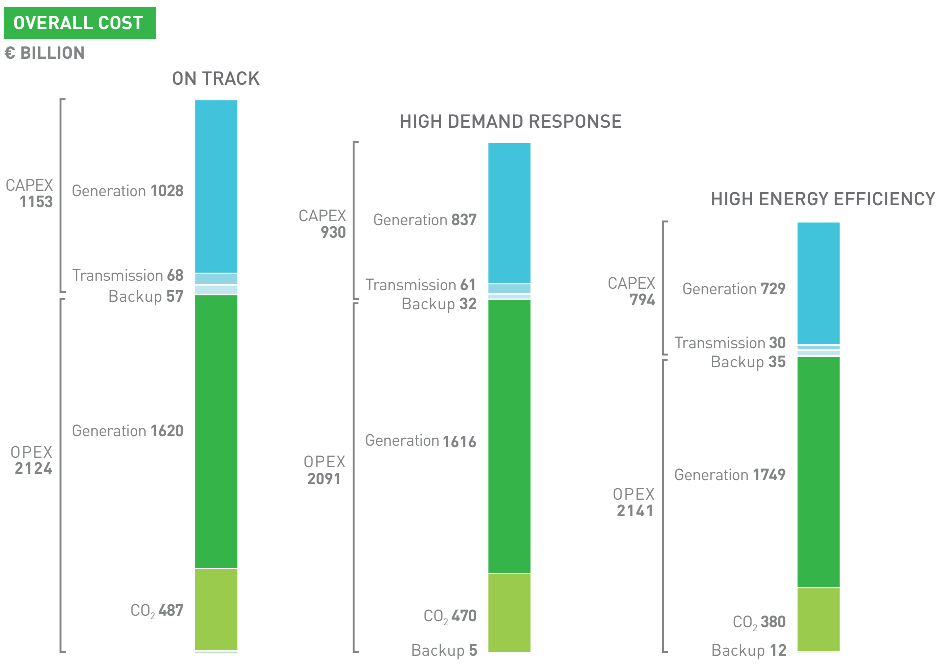
Demand response is a dynamic demand mechanism to manage consumption of electricity in response to supply conditions. A realistic demand response potential in 2030, shifting up to 10% of daily load in response to availability of supply, decreases the need for grid capacity by 10% and back-up capacity by 35% and thus helps in managing the risk of insufficient grid transmission[16]. Demand response also reduces the volatility of power prices by better matching demand to available supply, reducing volatility by 10–30% compared to the *On Track case* and by more than 50% compared to a scenario with less transmission capacity. This implies Demand Response is a critical tool in case transmission capacity does not get built as needed, and in all cases reduces costs and mitigates implementation challenges.

Energy efficiency measures also yield substantial benefits in mitigating the investment and grid challenges in the power system. It is also important to compensate for the upward pressure on electricity demand due to electrification of the transport and heating sectors. If similar annual demand reductions as those necessary to achieving the EU's 20% energy savings target by 2020 are applied towards 2030, electricity demand stabilises at a rate of +0.3% per year. This differs from the annual +1.8% demand growth in the *On Track* case and results in a 50% decrease in transmission investment and a 31% decrease in back-up investment, saving €299 billion in investments (i.e 30% lower capex).

15 ENTSO-G estimated investments to be around €89,3 bn
16 The EU has regulated and incentivised smart metering rollout across Europe, which is one of the key enablers for demand response, following Directive 2009/72/EC (internal market in electricity).

Demand response and energy efficiency make a real difference

Required investments in generation and transmission reduce substantially.



4. IMPLICATIONS FOR THE POWER MARKETS

Power Perspective 2030 employs the analysis to look at two fundamental questions directly relevant to power markets: What role will electricity markets play in achieving decarbonisation, and how will decarbonisation affect the evolution of the electricity markets?

Conventional thermal resources will continue to play a role as the system decarbonises but the growing share of low marginal cost variable resources in the supply mix, like wind and solar, will transform the operating environment in the energy markets across Europe. Our analysis of market prices finds that a large share of variable RES in the supply portfolio does not necessarily lead to a fall in wholesale energy prices to problematic levels. Such a development can be avoided if power systems are well integrated, with transmission capacity expanded as needed in a timely manner, and if an effective balance is maintained between demand for resources of various types and the supply of those resources. The analysis does provide support for the proposition that wholesale market prices are likely to become more volatile.

This relates to the question of the mix of conventional resources that will be required as decarbonisation progresses in support of continued growth of a diverse portfolio of RES technologies. As the share of variable RES grows, the space in the market for inflexible resources, like some traditional 'base load' plants that are technically and/or commercially incapable of frequent and significant changes in production, will gradually shrink. Conversely, the need for resources capable of operating efficiently and reliably with more frequent upward and downward changes in production will grow. There will also be an increasing need for resources that can survive commercially despite long periods of inactivity interrupted by short periods of steady-state operation.

Steering investments toward the required flexibility of generation resources warrants careful consideration. The concept of separate "capacity mechanisms" has gained traction in some Member States, yet our analysis demonstrates that capacity alone (i.e the undifferentiated ability to produce energy) is not an adequate description of what is needed, and in fact surplus unresponsive capacity can be part of the problem. Market adaptations, if adopted, need to value resources differently depending on their ability to provide the differentiated services a decarbonized power sector will increasingly require. One possible approach to ensuring investment in such resources is to develop "capability-based" market instruments[17] (as opposed to capacity only). An additional concern is that the uncoordinated implementation of national capacity mechanisms poses a signficant risk of frustrating market integration.

Hence, the effectiveness and efficiency of markets for flexible services will be a critical factor in addressing the operational challenges of decarbonisation. Various tools exist to address these operational challenges, including storage, demand response, flexible supply options and back-up plants. The sensitivity scenarios in *Power Perspectives 2030* with higher demand response and energy efficiency have affirmed the significant value of these resources to meeting supply security, competitiveness and decarbonisation objectives. As demand response is largely a flexibility resource, markets and regulators should ensure these have full and equal access in order to determine their true value and incentivise investment.

E. CONCLUSIONS

There are no simple choices. Transparency and information will be of decisive importance in driving broad public, political and commercial support for the transformation. The debate on the EU's energy future has for a long time been blurred by over-simplified analysis, partly based on presenting future options as current realities. The ambition of *Power Perspectives 2030* has been to analyse what needs to happen in the coming twenty years based on today's knowledge of the options and the choices still before us.

To a large extent, the transition to a decarbonised power system is about investments. Whether or not the required level of investment will be forthcoming is in essence a matter of striking a balance between investor risk, the cost of capital, social interests and the economic efficiency of the expected outcomes. Where possible this should be accomplished through coordinated and incremental improvements to existing market arrangements but it is unlikely to happen without governments exerting significant influence on the framework for investments made by market players over a longer time period. The overall challenge is to run a step-wise transformation and gradually build a stronger platform to reach the 2050 end-goal.

Power Perspectives 2030 shows that to remain on track to achieve the 2020 and 2050 energy and climate objectives, existing National Renewable Energy Action Plans, ENTSO-E grid plans and carbon pricing taken together represent a sound and adequate first step and the EU and its Member States must first fully implement them, with sufficient emphasis on public acceptance and financing. This is clearly a challenging task and appropriate measures must be taken to ensure that all stakeholders involved can and will realise these plans. Meanwhile, policy-makers, regulators and market actors must work together to create the right pre-conditions to accelerate decarbonisation towards 2030. Important prerequisites are to ensure regulatory certainty and clarity for investors; build public acceptance; incentives for TSOs; finance, and relevant

17 Capability-based market instruments are different from capacity-based market instruments in that they establish system-wide values for capacity services rather than for capacity as such. This is further explained in exhibit 46 of the report.

planning instruments. Already in the current decade, a stronger sense of direction towards 2030 is needed to support investments and enable markets to support the transition to a decarbonised power sector.

Hence, a stable policy & legal framework for 2030 is required, adapted to the scale and nature of the challenges:

1. **Building new and improved transmission grid infrastructure is essential to balance a decarbonised power system cost-effectively** and to integrate energy markets. Beyond 2020, the lowest cost solution calls for twice as much additional grid capacity as compared to the planned expansion in the current decade. Lower levels of grid expansion are also feasible but involve trade-offs with higher levels of capital investment, greater price volatility and higher diverse RES curtailment.

2. **It is important to promote a diverse portfolio of low-carbon generation technologies across Europe**, including wind, solar, hydro, geothermal, biomass and other promising low-carbon options to avoid dependency on a limited range of energy sources in the decarbonisation transition. **The complementarity of renewables deployment and flexible thermal generation is central to that approach.**

3. To ensure this diversification, **a perspective for renewable technologies beyond 2020 is required at the European level**. As diverse RES shares in the power mix increase beyond 2020, cross-border cooperation between Member States on planning and implementation provides opportunities to significantly reduce capital investments.

4. Adaptations to the power and carbon markets should be considered to underpin investor confidence in the transition and **steer investment to an adequate mix of resources that are technically compatible.** Traditional capacity-based mechanisms will become increasingly unfit for purpose as needs shift from simple firm capacity to the particular capabilities a resource offers to the system, such as flexibility.

5. **Demand-side resources such as energy efficiency and demand response (including distributed energy storage options and distributed production) represent an attractive means** to reduce the amount of transmission and large-scale generation investments required. Power markets need to promote energy efficiency, demand response, storage (large-scale and distributed), distributed generation and efficiency as system resources on an equal basis with utility-scale supply options.

6. **To keep the CCS option viable both for coal and gas installations**, more needs to be done to drive technology development and demonstration, and gain public support.

7. A physically and commercially integrated European electricity market combined with greater compatibility among national regulatory frameworks and a sufficiently restrictive carbon regime provide the foundation for achieving established GHG abatement objectives affordably, reliably and securely. **However, progress on market integration is lagging and the current ETS linear reduction factor of 1.74% needs to be adjusted to align with the 2050 target of 80% domestic GHG abatement.**

Power Perspectives 2030 clearly identifies some daunting challenges to remain on track to decarbonisation. It is therefore essential for policy makers to provide the right signals and incentives to all players in the value chain as soon and as clearly as possible. As shown in last year's *Roadmap 2050* report, any delay of action will only increase the overall cost and will impose significant stress on the power system. *Power Perspectives 2030* therefore calls upon policy makers on both European and national level to take appropriate action up to and beyond 2020 to remain on track to the 2050 decarbonisation goals.

Power Perspectives 2030

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www.roadmap2050.eu/pp2030