DR4EU Conference

Study on the quantification of Demand Response benefits to electricity suppliers and consumers in Europe in 2030 on its way to achieve deep decarbonisation

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CONTENTS

Context and objectives

Study context

- The European institutions **have reaffirmed their commitment to accelerate the decarbonisation of the European economy and reach carbon neutrality by 2050** within the Green Deal.

- Several recent studies have explored the potential for increased ambition for the decarbonisation of the power sector. These studies suggest a **growing role of electricity, from circa 20% of the European final energy consumption in 2015 to more than 40% by 2050** through electrification of transport, heating and cooling and industrial processes.

- This creates **new challenges and opportunities for the power system** and highlights the need for new ways in which the **power sector can meet this ambition whilst ensuring security of supply at the least cost for consumers.**

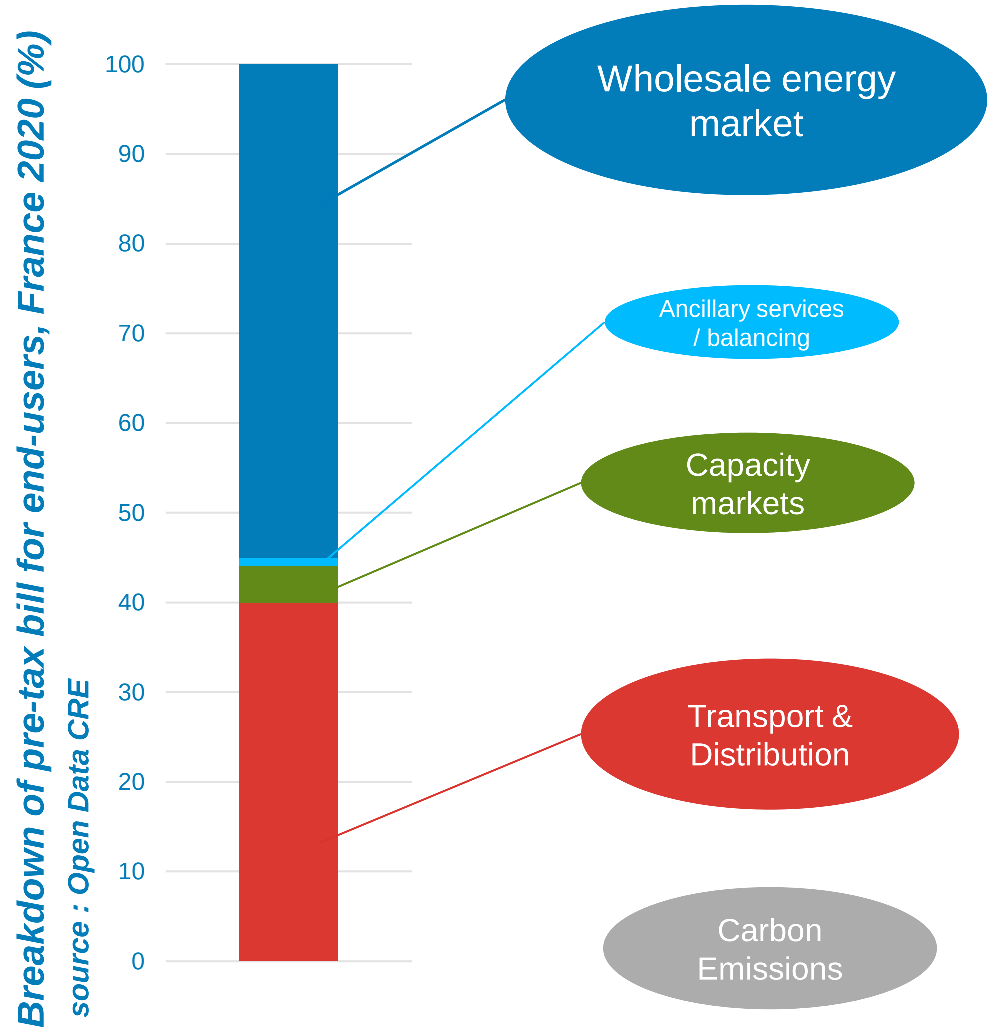
- **Increasing demand-side flexibility** is considered as key to improve efficiency and reliability of the power system, and particularly to use more effectively intermittent renewable and distributed resources.

- **<u>Our mandate:</u>** Considering this background, DR4EU sponsored by Voltalis, Sympower and EnergyPool has mandated Compass Lexecon to provide an assessment of DR benefits to electricity suppliers and consumers in 2030 using our model of the interconnected wholesale EU power market.

Study scope and modelling approach

Benefits of Demand Response span over the full range of direct and indirect cost components for end-users

- **In this study, we focus on the wholesale energy market as it leads to the highest costs for consumers and subsequently the greater market size for DSR**



Associated DR benefits

- Reduced price volatility and average price on the wholesale market, in substitution for peaking plants;
- Lower balancing costs, with cheaper flexibility to contain system imbalances and provide ancillary services.
- Reduced need for flexible generation capacity and capacity remuneration mechanism;
- Lowering the magnitude of load peaks and participating in local flexibility operations, DR could lead to lower needs for network reinforcements
- In substitution for peaking carbon intensive generation technologies, DR can lower overall CO_2 emissions of power systems*

* In the study CO_2 avoided costs are considered to be included in the wholesale market costs

DR benefits assessment methodology relies on simulating the dispatch with a realistic DR portfolio

Simulation of wholesale power market using CL Dispatch Model

- **Our analysis focuses on DR benefits for the wholesale power market in 2030**
- **The modelling relies on the CL pan European electricity market model**
  - Inputs:
    - **installed capacities** per technology, share of RES, level of demand in countries are all in line with the latest announcements of member states
    - **commodities** are updated with EC, IEA or with market data to be in line with recent trends
  - Outputs:
    - **hourly dispatch** of generation/ cross border flows / power prices

DR modelling approach relies on a set of assumptions

- **To determine DR benefits in this market, we make the following assumptions**
  - DR capacity is distributed between EU countries
  - DR capacity is calibrated to represent a possible potential in Europe
  - A realistic mix of capacity and energy (activation hours) is chosen to model a representative DR portfolio
  - Several sensitivities are performed: RES development, DR capacity, DR activation hours.

Note that some of our modelling assumptions lead to a conservative assessment of DR benefits:

1) Thermal capacities are assumed to be the same in scenarios with or without deployment of DR, limiting the benefits resulting from having DR
2) Interconnexion development is supposed to follow historical trends and TSO's announcements with a perfect market coupling
3) The optimisation runs on a representative climate year, and does not consider extreme climate years featuring extreme cold spell.
4) All price spikes are not systematically captured due to intrinsic and necessary modelling constraints

CL European power market dispatch model covers all European power markets

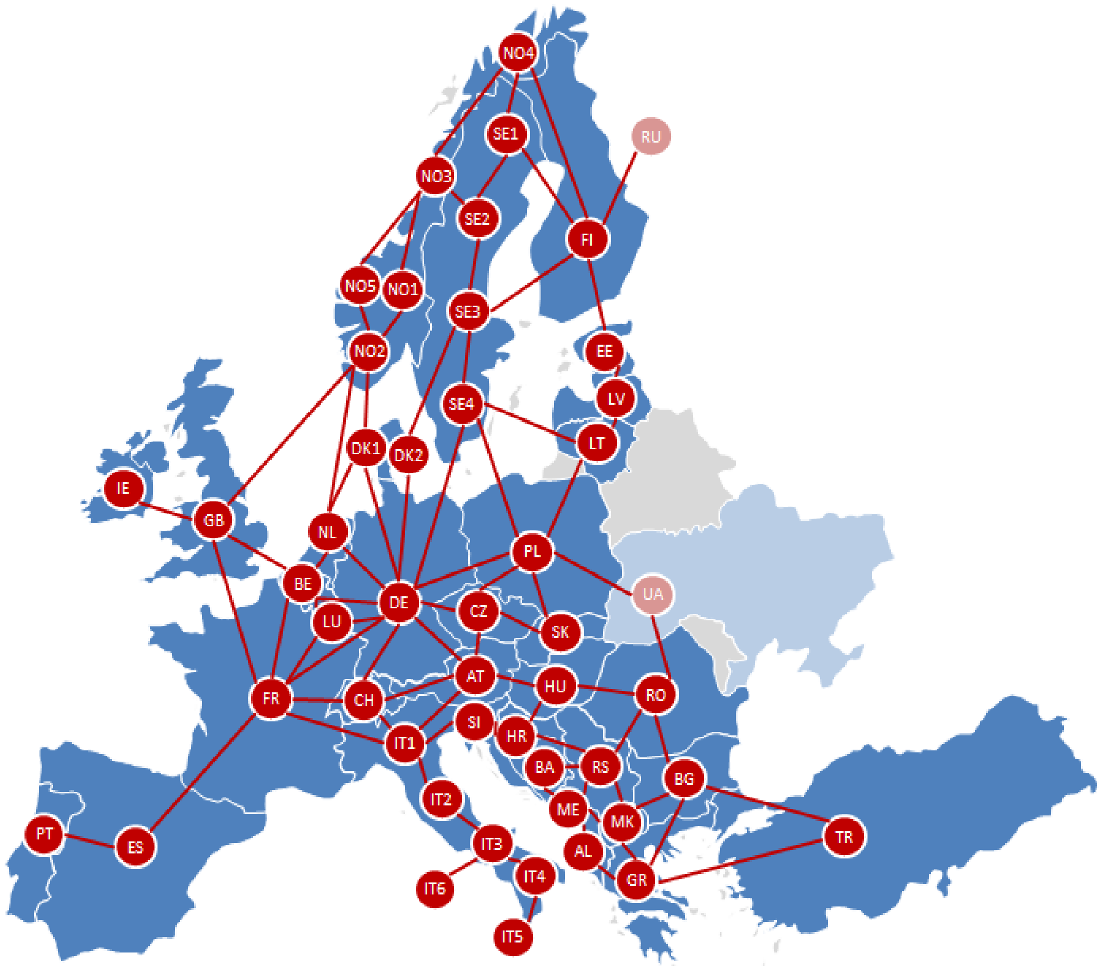
Overview of CL Energy power market model

- GB and Ireland
- France, Germany, Belgium, Switzerland, Austria and the Netherlands
- Spain, Portugal and Italy
- Nordic and Baltic countries
- Poland
- Eastern Europe and Greece, as well as Turkey

Model structure

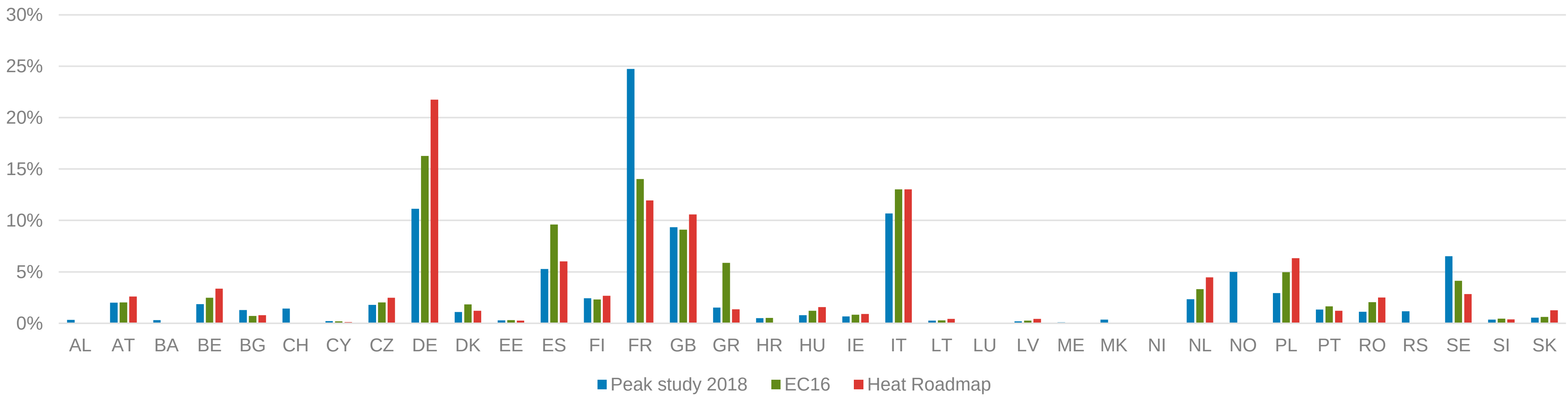
- The model constructs supply in each price zone based on individual plants.
- Zonal prices are found as the marginal value of energy accounting for generators' bidding strategies
- Takes into account the cross-border transmission and interconnectors and unit-commitment plant constraints
- The model is run on the commercial modelling platform Plexos® using data and assumptions constructed by FTI-CL Energy

Geographic scope of the model



The modelling of country by country distribution of DR capacity is based on existing studies of pan European DR potential

DR distribution in Europe (% of overall DR considered capacity)



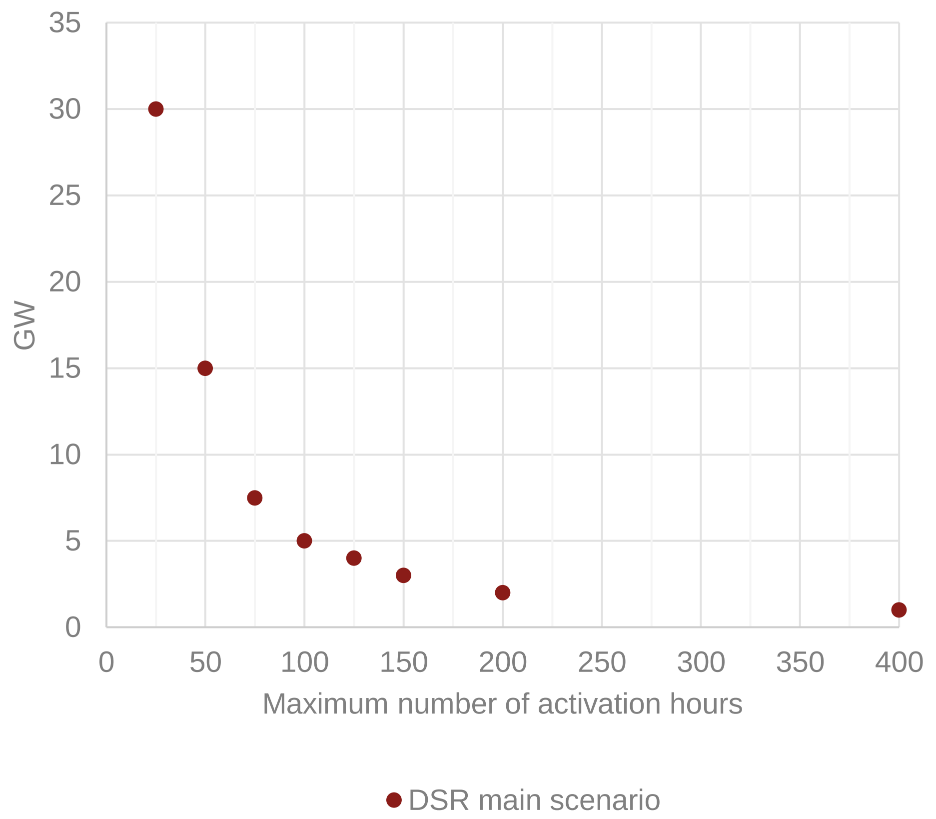
- **The country distribution of the DR potential is considered in this study as an average based on three main sources/studies:**
  - European Commission, 2016, Impact assessment study on downstream flexibility, price flexibility, demand response & smart metering
  - Heat Roadmap for Europe
  - Peak study with ENTSO-E data for 2018

- We assume a conservative capacity of **DR in Europe in 2030: 30GW representing only roughly 20% of the 160 GW potential for 2030** mentioned by the European Commission in their impact assessment**.**

DR durations of activation to consider a realistic DR portfolio

- **We simulate a selected realistic DR client type portfolio of activation hours and capacities** where the maximum DR power can only be reached for a limited time while longer activation DR is possible but with limited capacity,
- We calculate **benefits (avoided costs of energy sourcing)** and **costs (revenues of DR)** for electricity suppliers (hence ultimately for all consumers).

DR potential distribution



DR benefits assessment

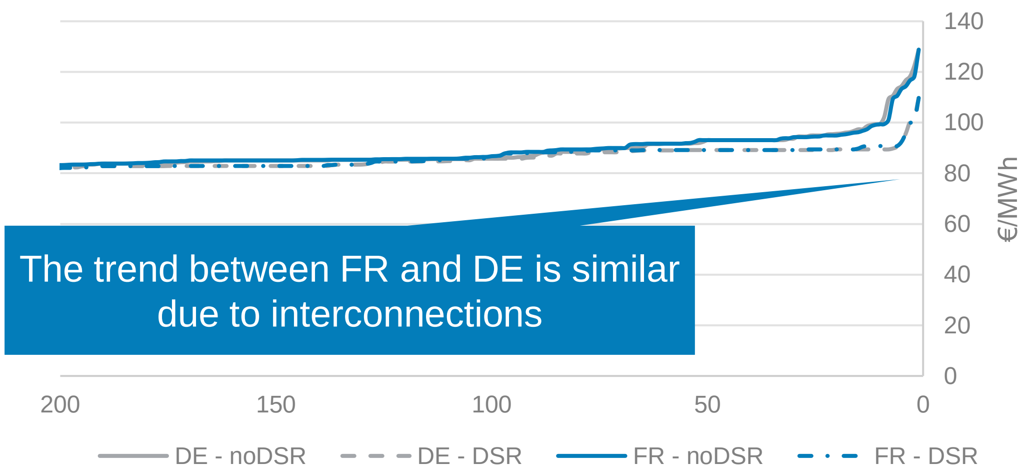
DR contributes to reducing spikes in wholesale prices

- **DR gives the maximum benefit to the system during peak hours as the marginal units lead to a steep supply curve**

- **Prices can be reduced thanks to DR activation abroad and not only on the national market (/price zone)**
  - Activation of DR in neighbouring countries can be simultaneous
  - Less often, it can also happen that activation in one country answers a neighbour's needs

- **For the French market:**
  - The activation for the 50 highest hours reduces the French prices by an average of about -7.5€/MWh
  - For the highest peak price, DR activation allows to decrease the price by almost - 40 €/MWh
  - For other hours the spread between situations with and without DR decreases as the supply curves is not as steep

Prices evolution – DR Central Scenario – FR / DE 2030



Note : The chart is for the 200 highest prices of the monotone

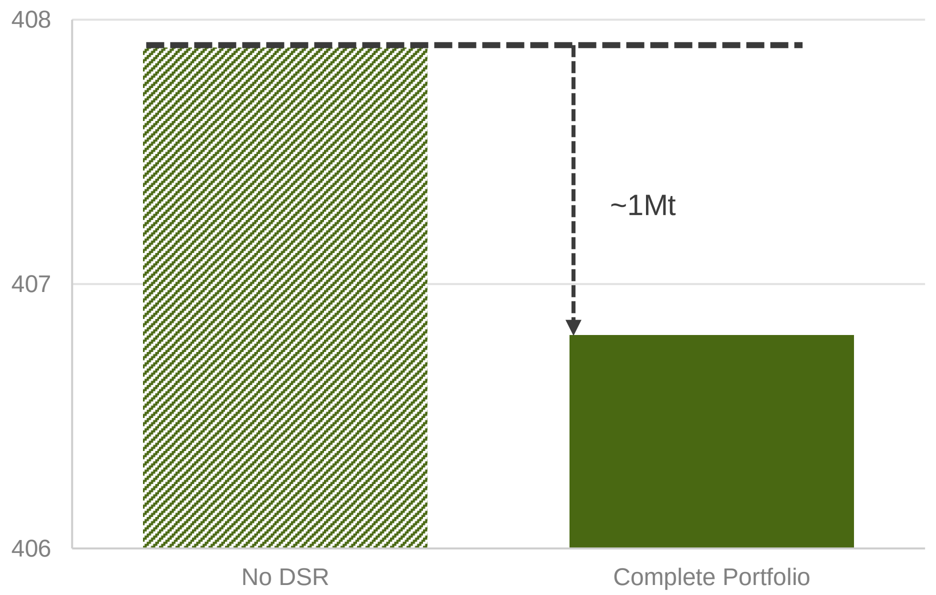
Comparison of prices for the 50 first hours of activation in France

€/MWh	No DR	DR
Average prices	*97.7*	*90.1*
Highest price	*128.8*	*89.1*

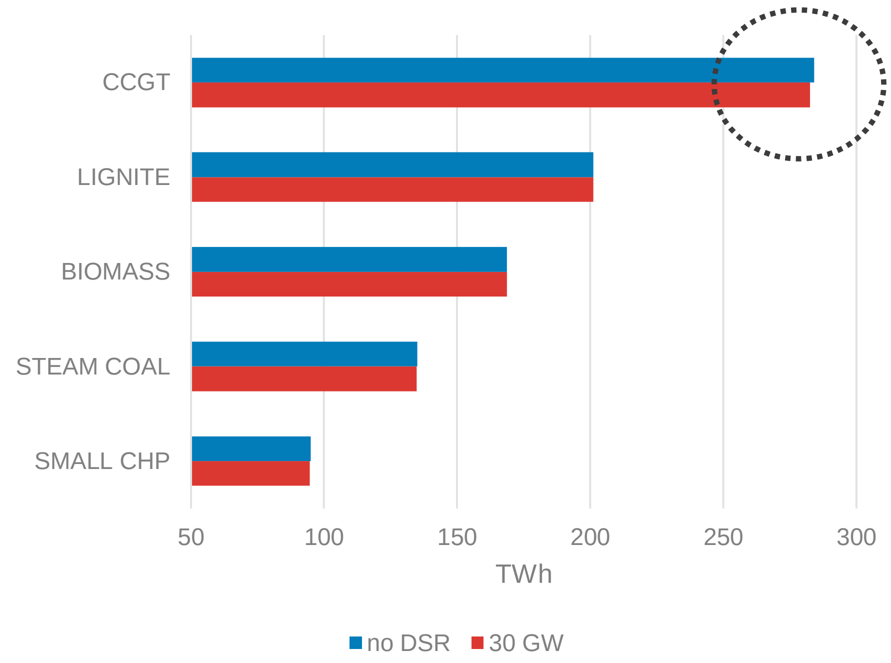
A reduction of 40€/MWh for the peak price in France

DR avoids electricity generation with carbon intensive technologies

CO_2 Emissions (Mt) - Sensitivity



Generation (TWh) – Central Scenario

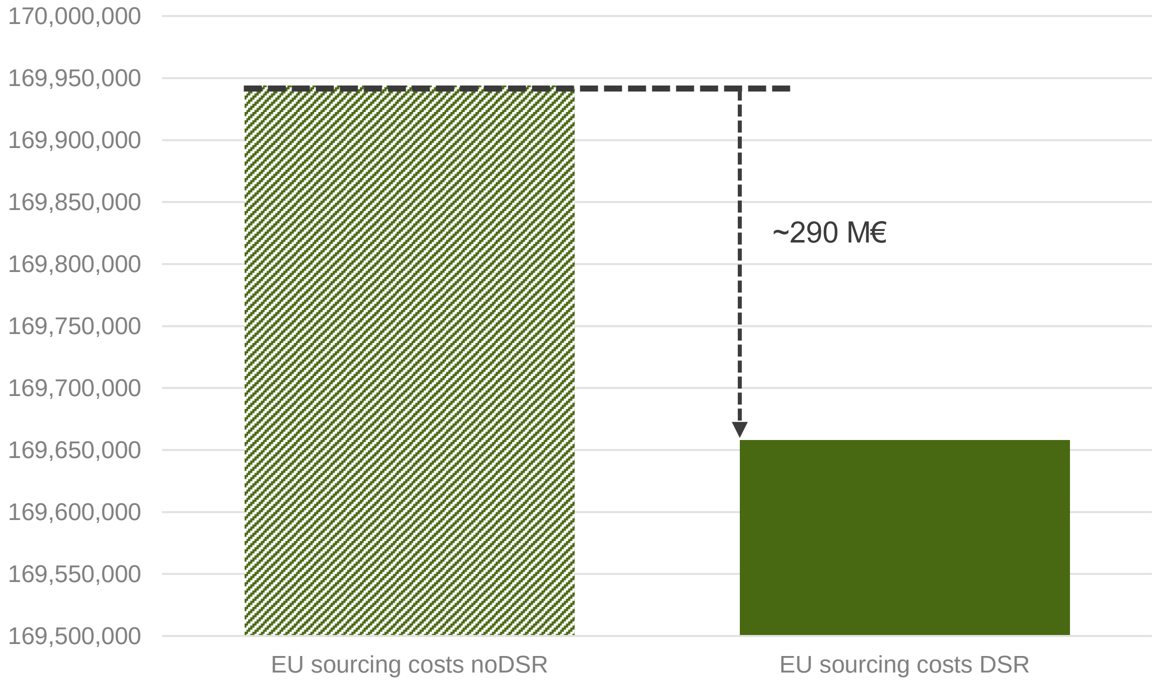


- **Our realistic DR portfolio allows a reduction in CO_2 emissions of more than 1 $MtCO_2eq/y$ in 2030**
- **This DR portfolio has a total volume of 2 TWh and mostly substitutes for CCGT production during peak hours**
  - This is due to the DR country repartition considered. If DR was deployed in countries with more coal power plants, CO_2 emissions avoided could be higher.

DR portfolio reduces energy sourcing costs of about 290 M€ in Europe, benefitting suppliers, hence ultimately end-users

- **Gross benefits of the chosen DR portfolio are defined as the avoided costs of sourcing energy on the market for suppliers**
  - DR allows a reduction in sourcing costs of about 290M€ in 2030
- The net between these total benefits and costs for suppliers will be passed on to customers through the energy bill

Impact of DR in wholesale market for the portfolio (000€) – EU 2030



Several assumptions contribute to a conservative assessment of benefits:

- No disinvestment of in thermal peak capacity even though DR could cannibalize revenue over time and push them out of the market
- Perfect market coupling and cross-border interconnexions development
- Representative climate year, no extreme events
- The two-step optimisation in the modelling might not catch all the price spikes for the short activation duration
- Benefits of a better resource adequacy (e.g. via savings on capacity mechanisms) are not taken in to account here

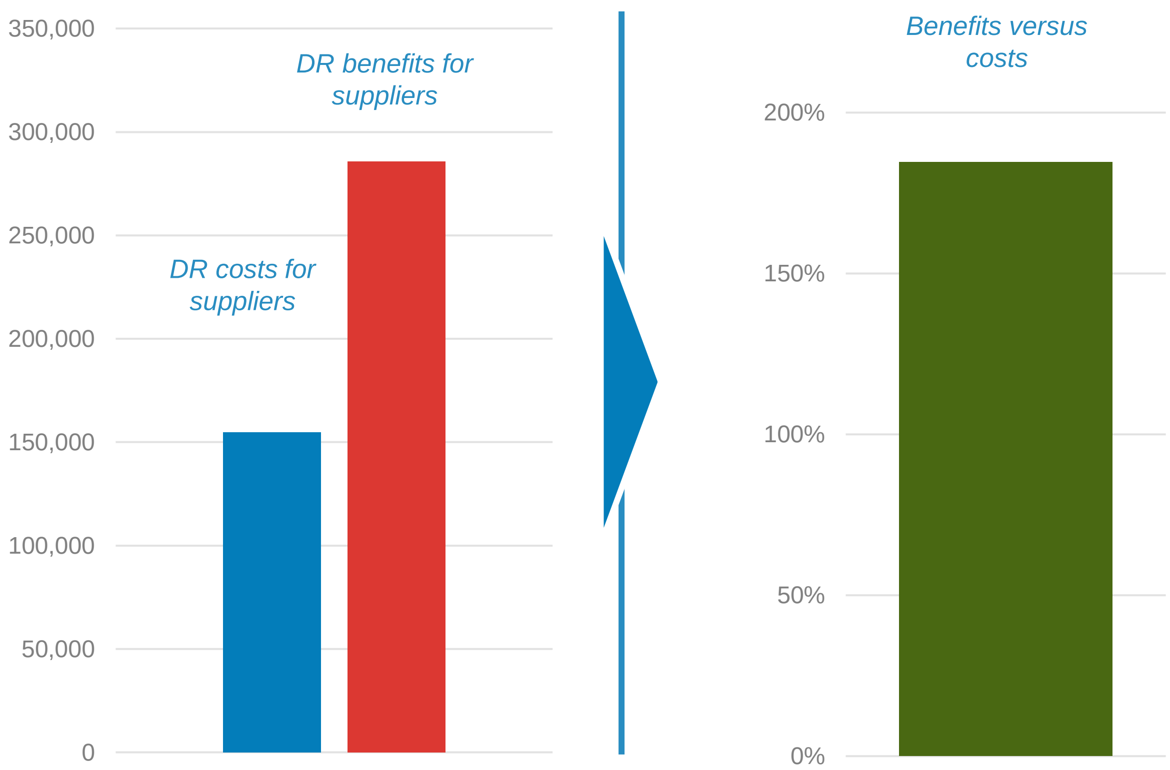
With the 30 GW DR portfolio, market benefits for suppliers in their energy sourcing are 190% of DR market costs for suppliers

- Gross market-wide benefits are defined as the reduction in suppliers' sourcing costs in the wholesale energy market
  - Not taking into account indirect benefits e.g. on capacity markets/mechanisms.

- Suppliers' extra costs related to DR are the market remuneration of DR:
  - DR being offered as "production" on the market it receives the market clearing prices

- **With several assumptions leading to a prudent estimation of market wide gross benefits (i.e. for all suppliers) and maximising the market costs of DR, benefits account for twice the market costs**

Costs of energy sourcing with DR (€) and benefits versus costs analysis for DR portfolio - Central Scenario - EU 2030



Conclusion

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The 30 GW DR portfolio brings benefits to the power system, and eventually to final consumers

- Our study of a DR portfolio of 30GW in the wholesale power market in 2030 allowed to quantify some of the benefits of DR brings to the European power system. We focus on the wholesale markets and find with our set of conservative assumptions that:

  - **DR helps reduce spikes in wholesale prices by** up to 40 €/MWh in some cases

  - **DR avoids electricity generation with carbon intensive technologies:** by 2030, 30 GW of DR could reduce CO2 emissions by 1MtCO2

  - **DR portfolio reduces energy sourcing costs**: about 290 M€ of cost reduction in Europe in 2030 for suppliers, ultimately benefitting end-users

  - **DR benefits exceed costs**: with the 30 GW DR portfolio, market benefits for suppliers in their energy sourcing are 190% of DR market costs for suppliers

⇒ **With this DR portfolio of 30 GW and the assumptions previously described, the management of about 0.1% of annual European load results in a net reduction of 0.2% in pan-European energy sourcing costs**

⇒ **DR is therefore a no regret option for the European power system**

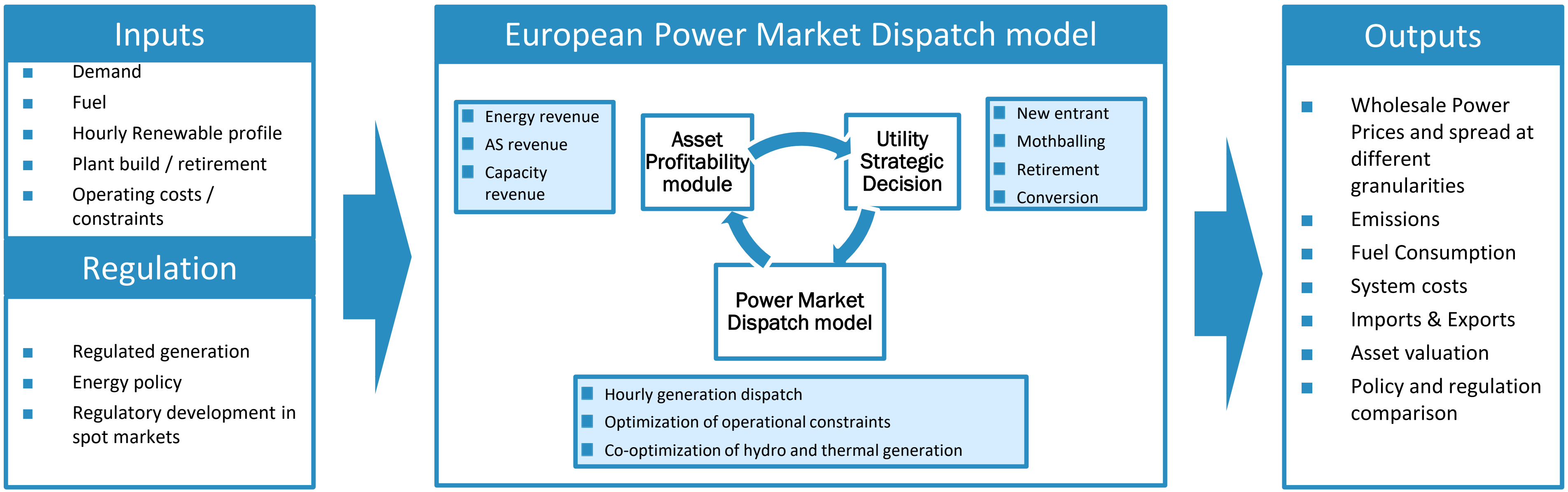
Annex
Detailed modelling approach and assumptions

FTI-CL energy's power market model relies on a dispatch optimisation software with detailed representation of market fundamentals

Dispatch optimisation based on detailed representation of power market fundamentals

- At the heart of FTI-CL Energy's market modelling capability lies a dispatch optimisation software, Plexos®, based on a detailed representation of market supply and demand fundamentals at an hourly granularity. Plexos® is globally used by regulators, TSOs, and power market participants.
- FTI-CL Energy's power market model is specifically designed to model renewable generation:
  - Wind: Hourly profiles are derived from our in-house methodology that converts consolidated wind speeds into power output.
  - Solar: Hourly profiles are derived from our in-house methodology that converts solar radiation into power output.
  - Hydro: Weekly natural inflows are derived from our in-house methodology that convert rainfall, ice-melt and hydrological drainage basin into energy. Generation is derived from a state-of-the-art hydrothermal co-optimization algorithm embedded at the heart of Plexos®.

FTI-CL Energy's modelling approach (input, modules and output)



The power market model is set up with a range of inputs derived from latest announcements from TSOs, regulators and market players

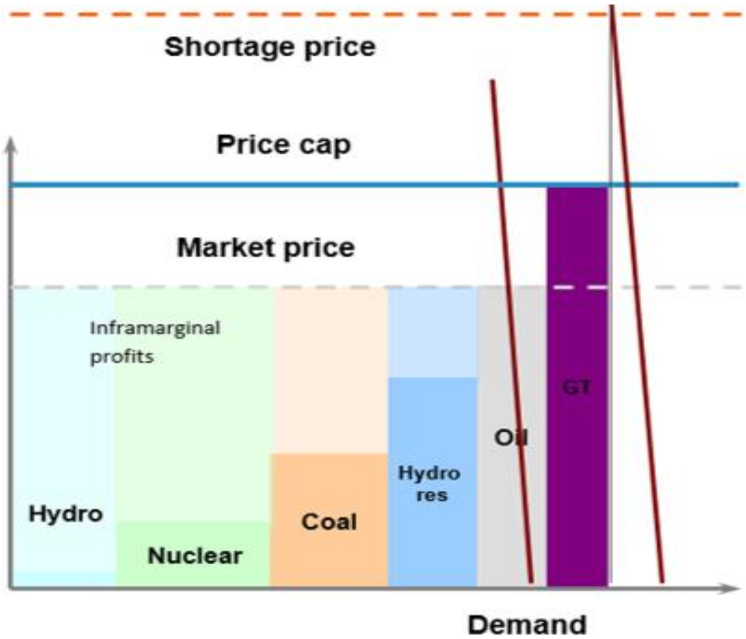
Key power price driver	Sources	Optimization
Demand		
Power demand	■ Long term electrification based on decarbonisation scenario	■ Fixed set as demand to be met
Supply		
RES capacity	■ Meet EU objective of 56% RES-E penetration share by 2030 ■ CAPEX and OPEX outlook based on latest data from EC and E3M (June 2018)	■ Capacity dynamically optimised thereafter based NPV of anticipated costs and revenues ■ End of Feed-in-Tariffs for new capacities, no <0 prices
Nuclear capacity	■ Latest National plans on phase-down or phase-out ■ Latest announcement on plants' life extension and new projects	■ Dispatch optimized by hourly dispatch model
Thermal capacity	■ Latest announcements from operators and National plans on phase-out or conversion to biomass ■ Latest announcement on refurbishment and new projects in the short-term ■ CAPEX and OPEX outlook based on latest data from EC and E3M (June 2018)	■ Capacity dynamically optimised in the longer term based on NPV of anticipated costs and revenues ■ Dispatch optimized by hourly dispatch model
Storage technologies	■ CAPEX and OPEX outlook based on latest data from EC and E3M (June 2018)	
Commodity prices		
Gas	■ Forwards until 2020, converge to IEA WEO 2019 New Policy by 2030	■ Fixed set as an input
Coal ARA CIF	■ Forwards until 2021, converge to IEA WEO 2019 New Policy by 2030	■ Fixed set as an input
CO2 EUA	■ Forwards until 2021, converge to EUCO33 by 2025, EUCO30 by 2030/35	■ Fixed set as an input
Interconnections		
Interconnection	■ ENTSO-E TYNDP 2018 outlook for new and existing interconnections	■ Fixed set as an input

(1) MAF: Medium term adequacy forecast; (2) TYNDP: Ten Years Network Development Plan; (3) WEO: International Energy Agency World Energy Outlook

CL model relies on a dispatch optimisation software applied to short to long term capacity scenarios

Dispatch optimisation for a given time period

- **Model constructs supply hourly in each price zone based on individual plants unit commitment constraints:**
  - European power plants database containing technical parameters of all thermal European plants
  - Zonal prices are found as the marginal value of energy accounting for generators' bidding strategies
  - Model takes into account cross-border transmission and interconnectors



A two-step problem solving

- **In order to be able to simulate intertemporal arbitrages allowed by hydro generation, storages, and DR, with acceptable computational time, the optimisation problem needs two steps of calculation:**

  First, the Medium-Term Schedule solves the annual optimisation problem by:
  - reducing the number of simulated periods by combining together dispatch intervals in the horizon into 'blocks;
  - optimizing decisions over this reduced chronology; then
  - decomposing medium-term constraints and objectives into a set of equivalent short-term constraints and objectives.

  Second, the Short-Term Schedule is designed to emulate the dispatch and pricing of real market-clearing engines with the full desired resolution (e.g., hourly).

  MT Schedule thus simplifies input data for intertemporal arbitrages. The allocation of storage energy (hydro, DR, batteries) is an approach with an interval that might differ from a perfect allocation.

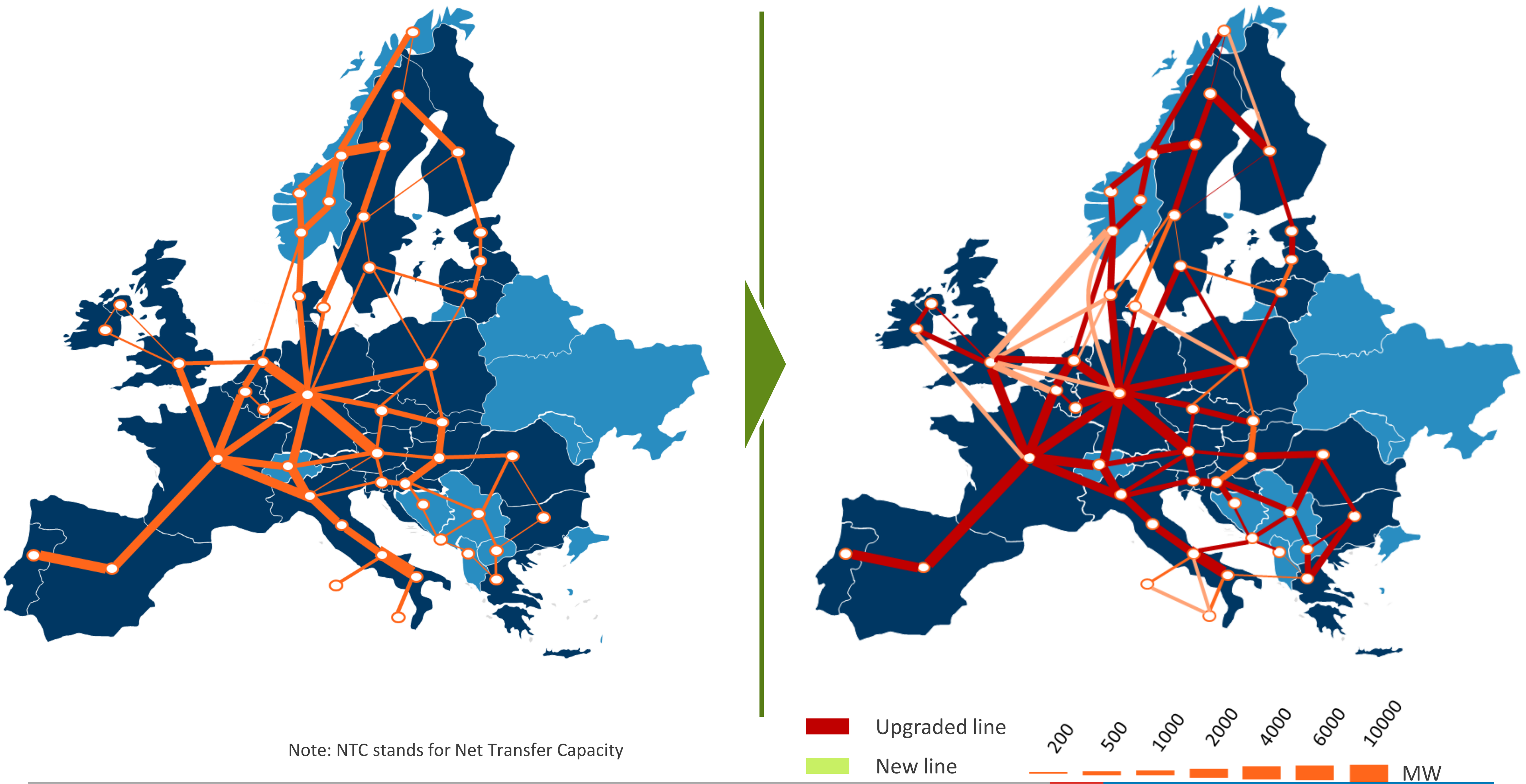
  It contributes to underestimating benefits in DR assessment

Source: CL Energy

Our interconnection NTC development is based on ENTSOE TYNDP 2018 development plan featuring a doubling of NTC by 2050

Network in 2015 **NTC: 225 GW**

Network in 2050 **NTC: 439 GW**



Note: NTC stands for Net Transfer Capacity

Assumptions contribute to a conservative assessment of DR benefits

A range of assumptions for modelling could lead to conservative assessment of DR benefits:

- **Thermal capacities are assumed to be the same in scenarios with or without deployment of DR, thus limiting the benefits resulting from having DR**
  - Beyond announced coal phase-outs, it is considered there would be no disinvestment in thermal peak capacity thanks to the development of DR in the system;
  - As a result, the difference in price peaks depending on the scenario (with or without DR) is limited due to the availability in both scenarios of peaking capacity up to the level that is necessary to ensure security of supply without DR.

- **Interconnexion development is supposed to follow historical trends and TSO's announcements with a perfect market coupling**
  - A delayed development of new projects or outage of some cross-border interconnexion would limit price convergence between price zones and lead to higher upward volatility of prices, and greater benefits of having DR

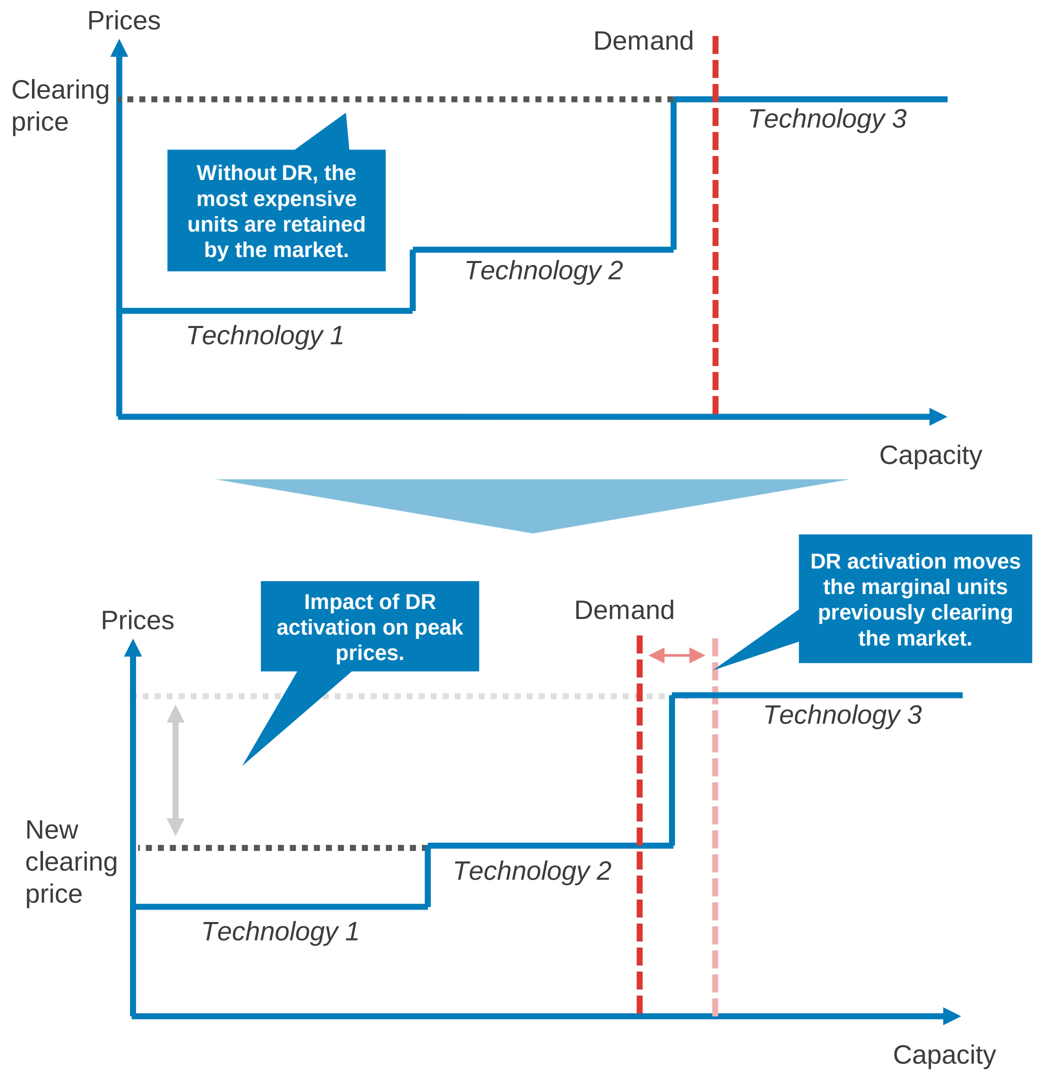
- **The optimisation runs on a representative climate year, and does not consider extreme climate years featuring extreme cold spell.**
  - DR benefits would be even higher when such events occur, and they do, and may tend to occur more frequently with climate change,

- **A two-step optimisation to solve a complex dispatch modelling issue**
  - For mathematical reasons, the dispatch optimisation problem is solved in two-step
    - First a simplified all-year optimisation occurs, with low resolution (6h blocks) to determine optimal dispatch of capacity with intertemporal arbitrages such as hydro, storage, P2G and DR
    - Second, a detailed hourly dispatch optimisation selects the best mix of generation to minimise costs at every hourly step
  - The existence of the first simplified optimisation, although necessary, does not allow to catch systematically all price spikes as the model selects hours when to allocate DR "generation".

The study aims at assessing the benefits of DR in 2030 for the wholesale power market

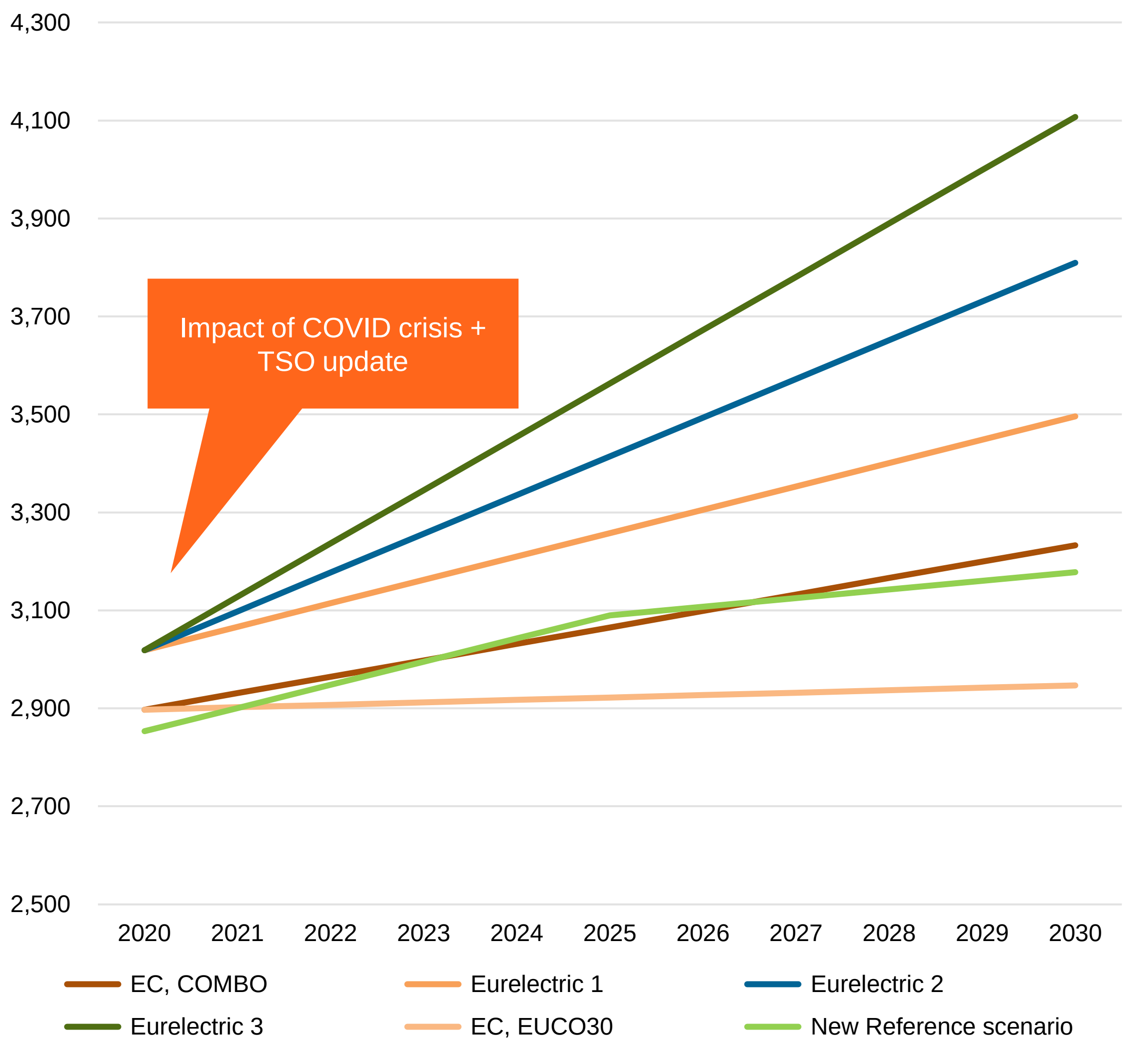
- **If we focus on the wholesale market, the impact of DR on peak prices can be explained by a change in clearing marginal unit when activated.**
- **Hence the resulting clearing price of the market is lower than without DR, which results in avoided costs for electricity suppliers.**
- **To evaluate the benefits entailed by DR to the system, several indicators can be analysed:**
  - Benefits on a market-wide basis, for all electricity suppliers, hence ultimately for all customers,
  - Costs to the suppliers, on a similar basis for the same reason,
  - Benefits to cost ratios (i.e. sourcing costs that electricity suppliers avoid thanks to DR compared to costs for them);
  - Spot price volatility,
  - Peak prices and average prices,
  - CO_2 emissions, etc.

The DR activation in the wholesale market will decrease prices



To meet net zero, European electricity demand is projected to rebound strongly by 2030

Annual Demand Outlook (TWh), Europe

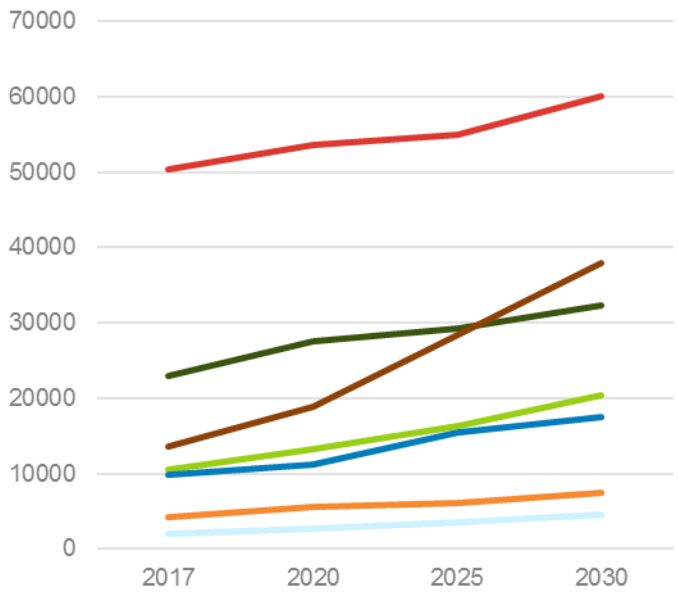


- The objectives of 2030 carbon neutrality targets are:
  - Improve energy **efficiency** (with the objective of a 32.5% reduction)
  - A cut of 46% of **greenhouse gas emissions** from 1990 levels
  - Electrification of the economy, in particular the **transport sector** via EVs, and **buildings** through heat pumps (direct electrification).
  - A variety of final energy carriers, with the emergence in particular of Hydrogen, and the use of electricity to produce these energy carriers via Power-to-X (H2, CH4, e-fuels etc.) - indirect electrification.
- Different trajectories are possible on a European scale, depending on the relative weight of each of the energy carriers.
- **Our reference scenario assumes a 2030 demand at 3200TWh, assuming a partial direct or indirect electrification of industry.**

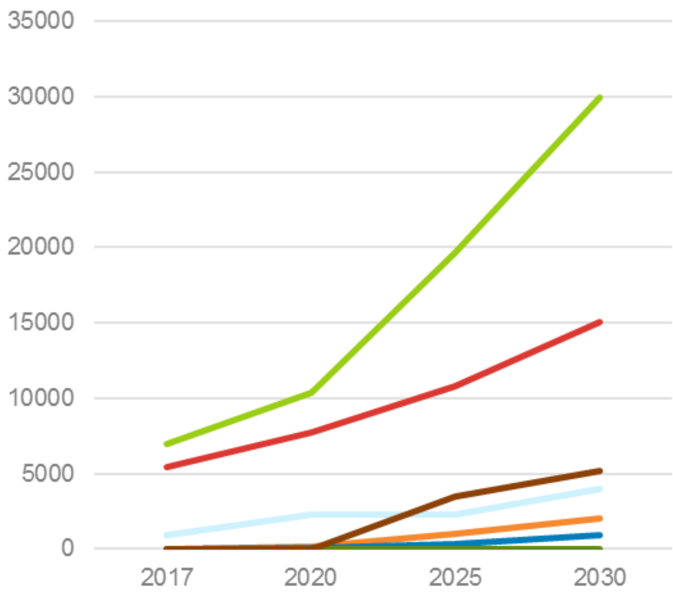
Solar and wind capacity will develop steeply in European countries by 2030

To reach the objectives for RES development by 2030 (32% of final energy versus 17.6%* in 2017 and 56% of electric demand versus 30.7%* in 2017), the NECPs submitted in December 2018 to the European Commission plan to continue or even accelerate RES roll-out (mainly onshore/offshore wind turbines and solar PV).

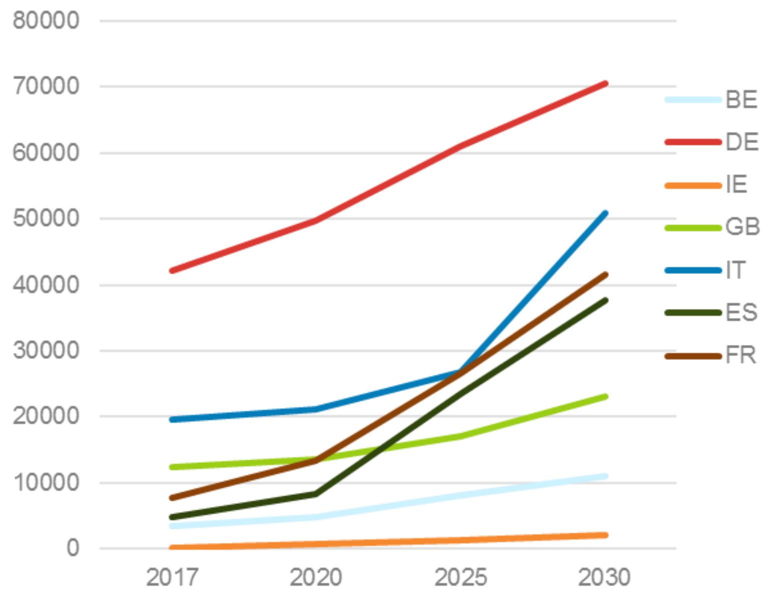
Onshore wind development in Europe (MW)



Offfshore wind development in Europe (MW)



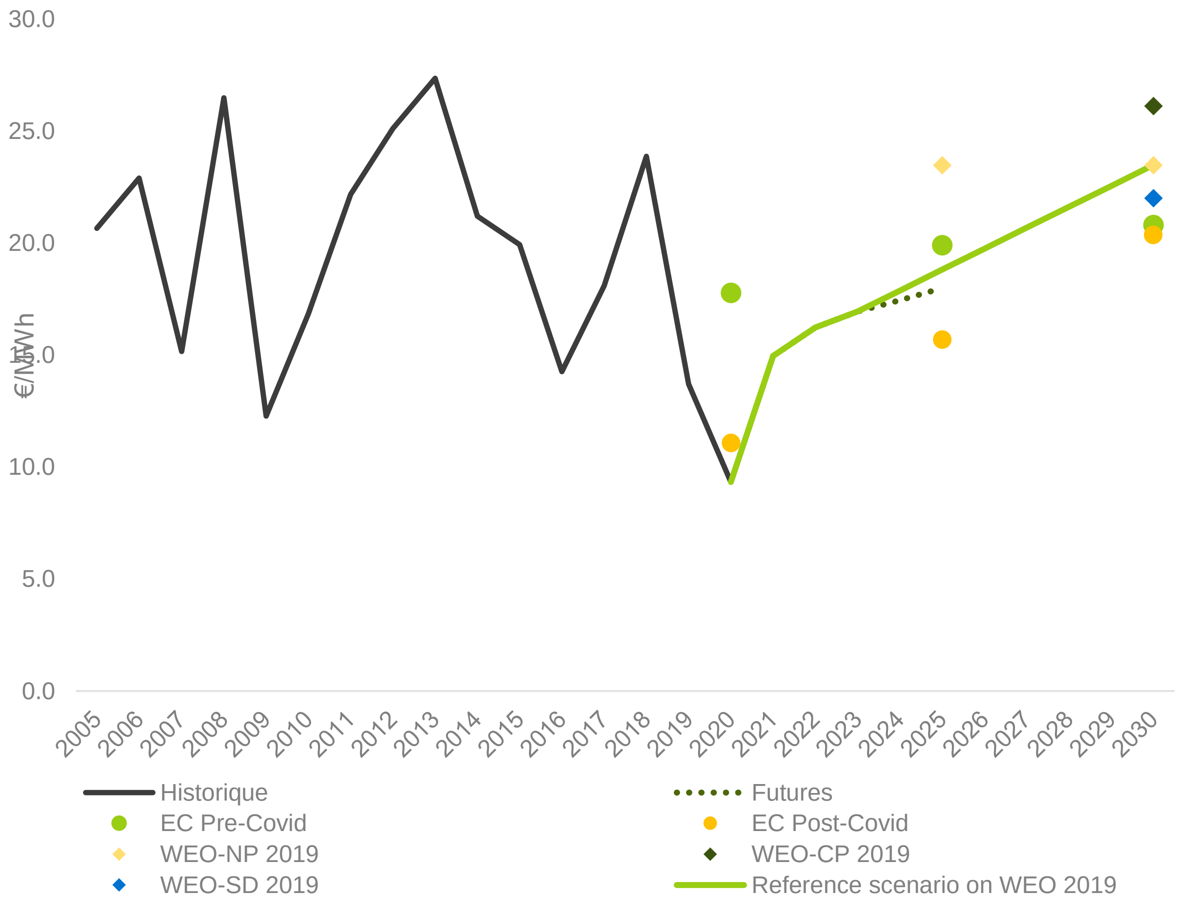
Solar PV development in Europe (MW)



*Source: European Environmental Agency – Share of renewable energy in gross final energy consumption in Europe

Outlook for gas prices

Gas price outlook (real 2020)



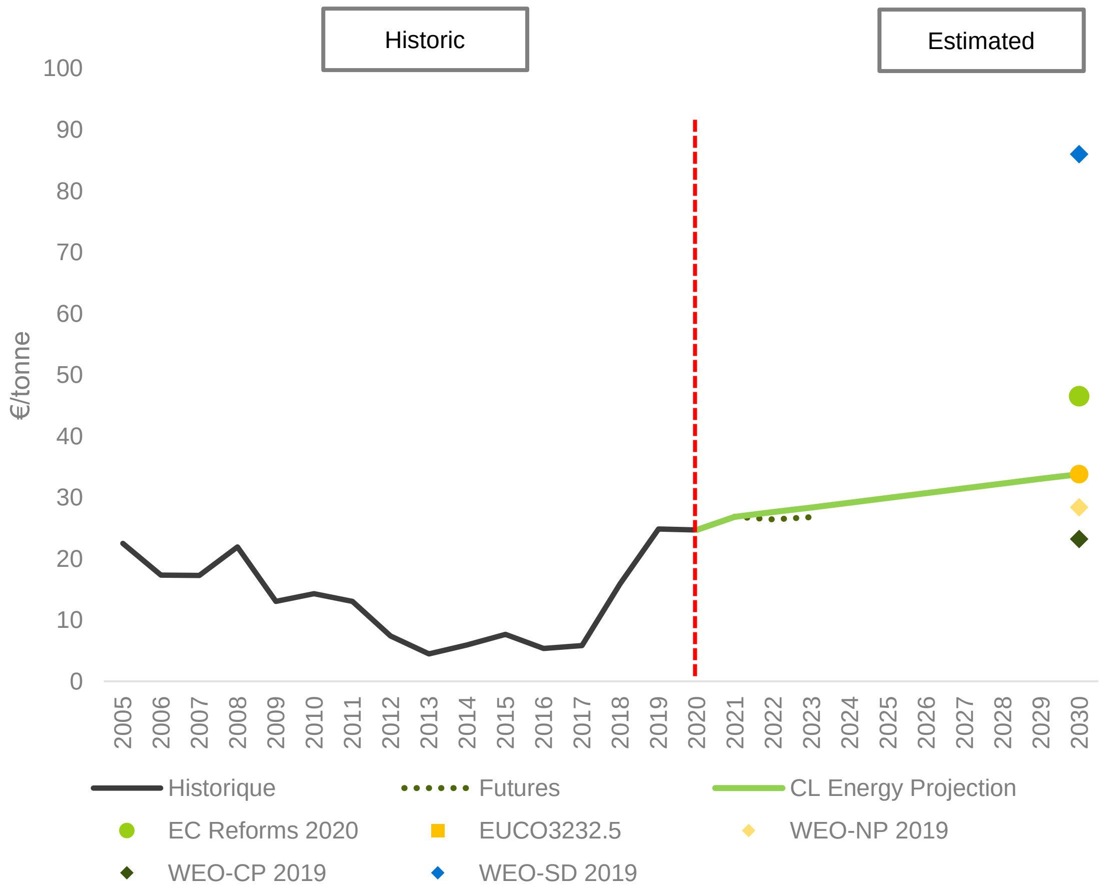
- The high volatility of European gas prices over the last couple of years reflects the numerous uncertainties in the European and global gas markets.
- **Uncertainties are expected to continue** due to:
  - The levels of LNG flows choosing Europe over Asia
    - Higher demand in Asia will push prices up in Europe
  - The levels of power coal to gas switching in Europe
    - Higher use of gas (instead of coal) will increase demand and thus prices
  - The levels of Russian flows to Europe
    - If Russia decides to increase its exports to Europe, it will tend to reduce European prices
- These different drivers will impact European gas prices outlook translating into **different trajectories**. To illustrate this large diversity, we show on the graph the different gas prices projections presented by the IEA on the World Energy Outlook
- The same level of uncertainties is visible **on the coal prices driven by the Asian demand and the level of supply**.

Important uncertainties on Europe gas prices are driven by fundamental drivers such as LNG and Russian imports as well as global demand after the Covid-19 crisis.

Source: CL Energy based on Bloomberg and IEA World Energy Outlook

Outlook for CO_2 prices

CO_2 EU ETS outlook (real 2020)



Source: CL Energy based on Bloomberg, IEA World Energy Outlook

- In February 2018, the approval of the EU ETS reform pushed prices to higher levels. Market is currently trading at ~20€/t. This reforms aim at reducing the current surplus of emission allowances in the EU ETS market.
- Despite this new reform, **important uncertainties remain** regarding the level of carbon prices, driven by:
  - Overlapping policies with the EU ETS market : energy efficiency, renewable generation, coal phase-out …
  - Economic development
  - Decarbonisation objectives
  - EU ETS rules in the long term
- These uncertainties are illustrated by the different scenarios provided by the IEA and the EC.
- In the CL Energy projection, we assume that the future ETS reform will lead to an increase of CO2 prices to 34€/t in 2030.

Despite a recent rebound due to the 2018 EU ETS reforms, the carbon price outlooks remain difficult to determinate due to uncertainties about the installed capacity, demand and long term objectives as well as the post Covid-19 crisis.

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