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Electricity Prices under Climate Policy

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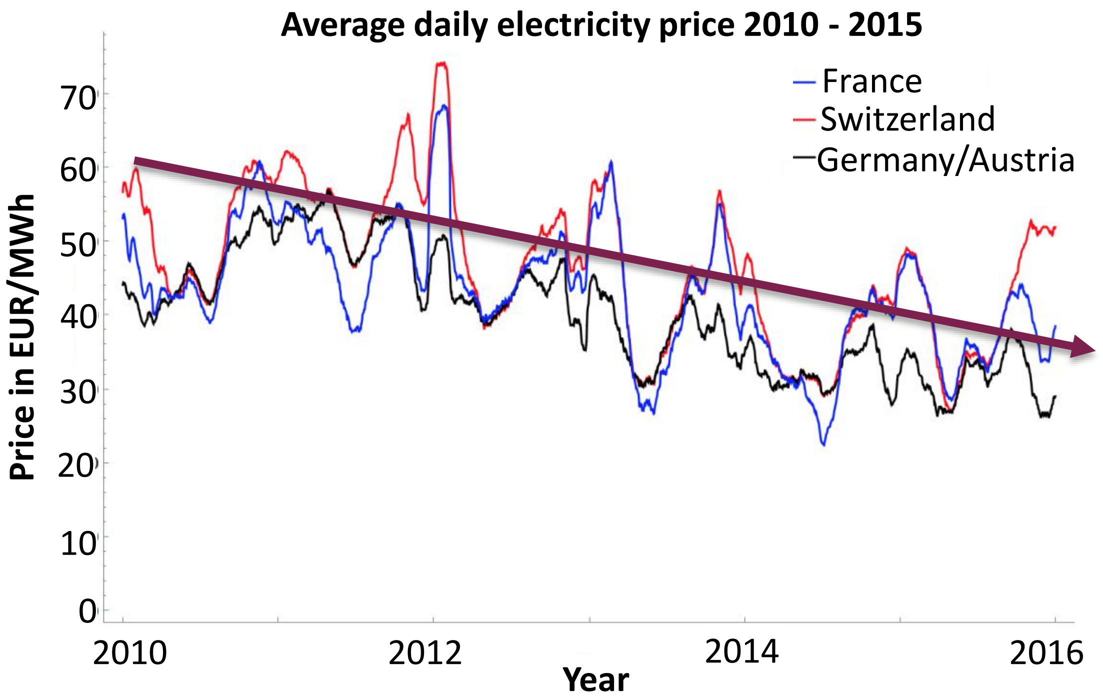
Research question of the study

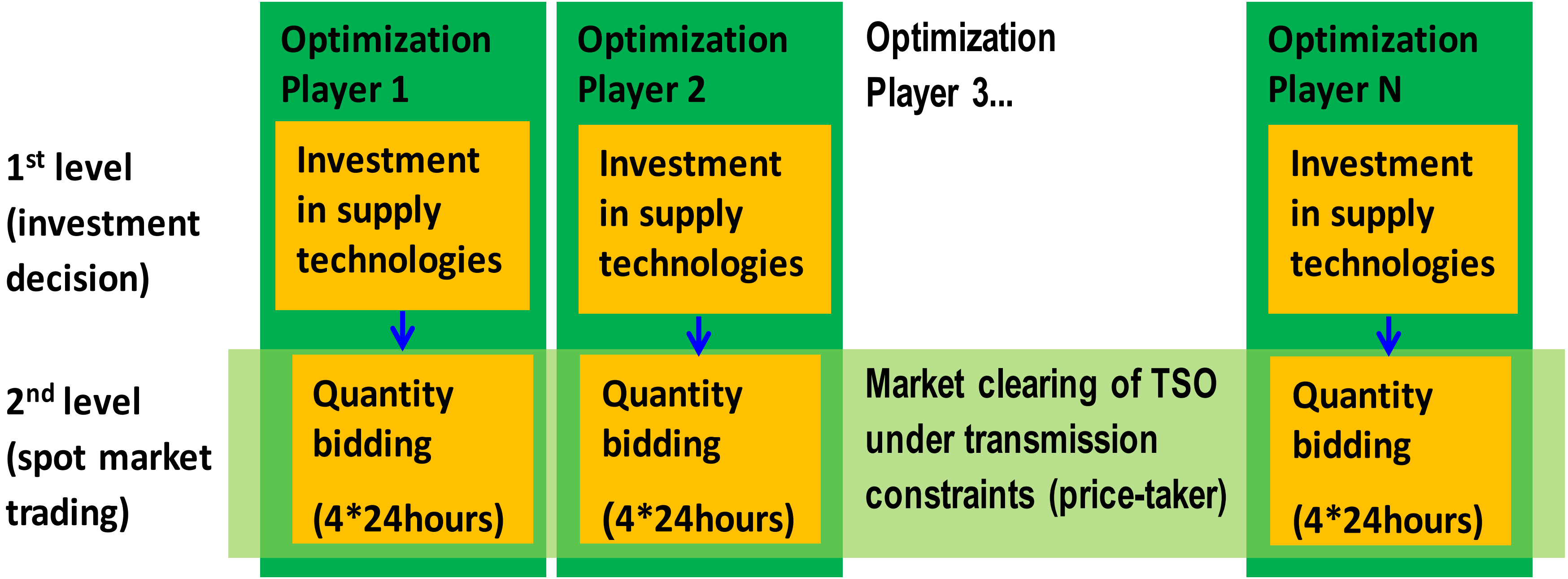
Could it be a reversal of the current trends in electricity prices ahead?

Especially under the implementation of the “Clean Energy for all Europeans Package”



The Bi-level Electricity Market (BEM) model

Bi-level Nash-Cournot game to understand price formation & investments

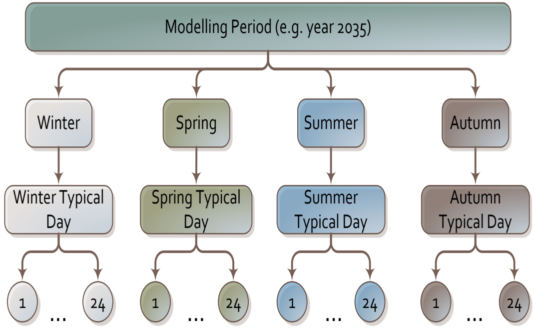


- The model can also run in different modes: (i) Investment and production decision on same level; (ii) Deterministic or Stochastic; (iii) Social welfare maximisation

Main features of the BEM model

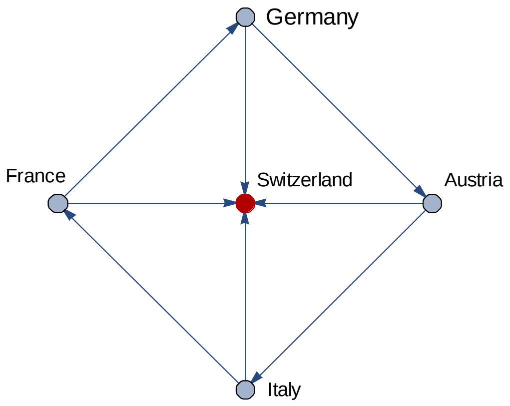
01 Long term horizon & high intra-annual resolution

Each modelling period is divided into 96 typical operating hours, corresponding to 1 typical day per season; the framework is flexible allowing for defining more types of days within a season



02 Grid Transmission constraints between the players

A DC power flow approximation is modelled for representing the grid transmission constraints between the nodes/players; in each node power plants can be located belonging to player(s); **in the current setup of the model the players are Switzerland and its neighbouring countries**



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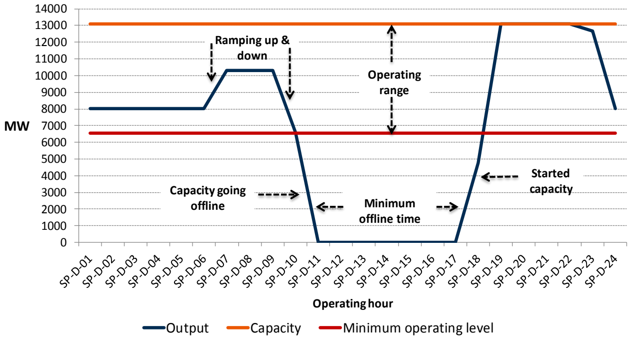
Main features of the BEM model

03

Operating constraints for power plants

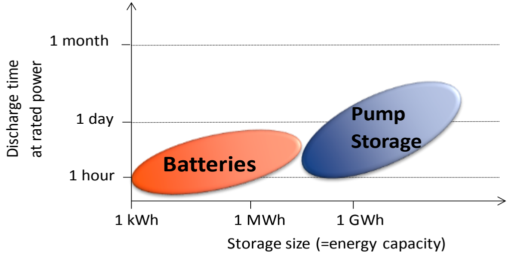
A linearized approximation of the unit commitment problem is formulated based on clustering of similar units to represent: part load efficiency losses, ramping constraints, minimum operating levels, online/offline times, start-up costs, etc.



04

Representation of RES variability & storage

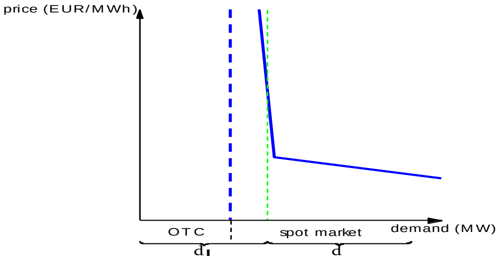
Based on a historical sample of solar and wind generation the model ensures that there is enough storage and dispatchable capacity to accommodate residual load curve variations and curtailment.



05

Elastic and inelastic electricity markets

The model can represent both elastic (i.e. traded) electricity demand and inelastic (i.e. over the counter - OTC) demand; the OTC demand is considered to be perfect competitive to avoid an exponential demand function representing both markets



Stylised formulation of the BEM model

For each player* *i*:

max expected total profit = (profit from selling power – capital costs)

s.t.

- $capacity_i \leq max\_capacity_i$
- constraint on player's risk
- production-, imports-amounts, and prices given by:

  max total profit of player *i'*:

  s.t.

  - $production_{i'} \leq capacity_{i'}$
  - dispatching constraints (ramping rates, online/offline times, part load efficiency losses, minimum operating levels)
  - $price_{i'} = f_{i'}(production_{i'} + net\ import_{i'})$

** In the current model setup the players are Switzerland and its neighboring countries*

Stylised formulation of the BEM model

The TSO (price-taker) maximizes profit of redistributing electricity:

max total profit from distributing power across all nodes

s.t.
- constraint on no arbitrage (zero sum of distributed power)
- transmission grid constraints
- constraint on system security (enough dispatchable and storage capacity to accommodate variations of non-dispatchable generation and residual load curve)
- constraint on electricity balance of each node: demand = production +net imports)

Calibration procedure of the BEM model

- The model has an estimation mode for the conjecture of a player regarding the aggregated reaction of its rivals, which is used to reproduce the historical prices

In a quantity offering setting q_i , each producer i tries to maximises its own profit (sales at price $p(q_i, q_{-i})$ minus production costs $C_i(q_i)$) without anticipating the market equilibrium:

$$\max_{q_i \in R^+} p(q_i, q_{-i}) q_i - C_i(q_i)$$

The first order condition of the above problem is:

$$p(q_i, q_{-i}) - \frac{\partial q_{-i}(q_i)}{\partial q_i} \cdot \frac{\partial p(q_i, q_{-i})}{\partial q_i} \cdot q_i - C_i'(q_i) \leq 0 \perp q_i \geq 0$$

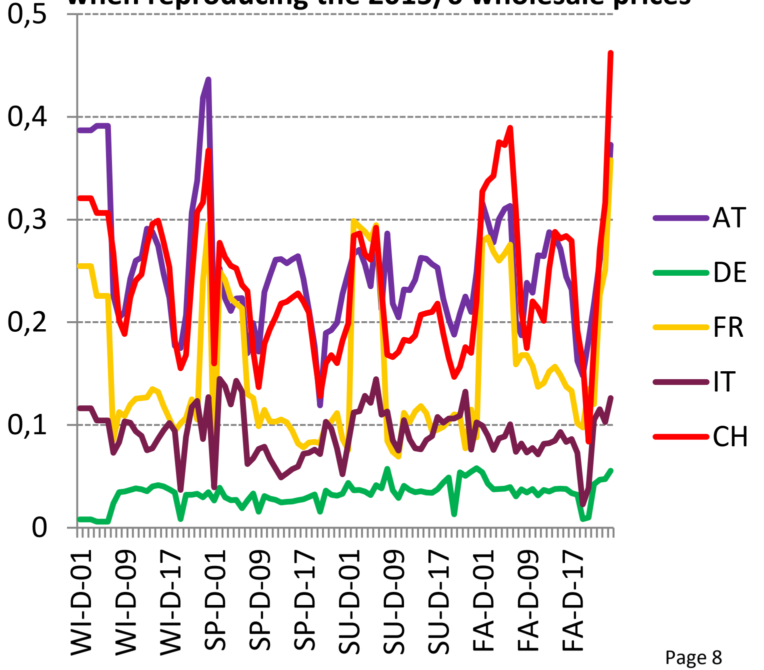
$\theta_i := \frac{\partial q_{-i}(q_i)}{\partial q_i}$ is the conjecture of producer i

$\theta_i = 0$ perfect competition conjecture

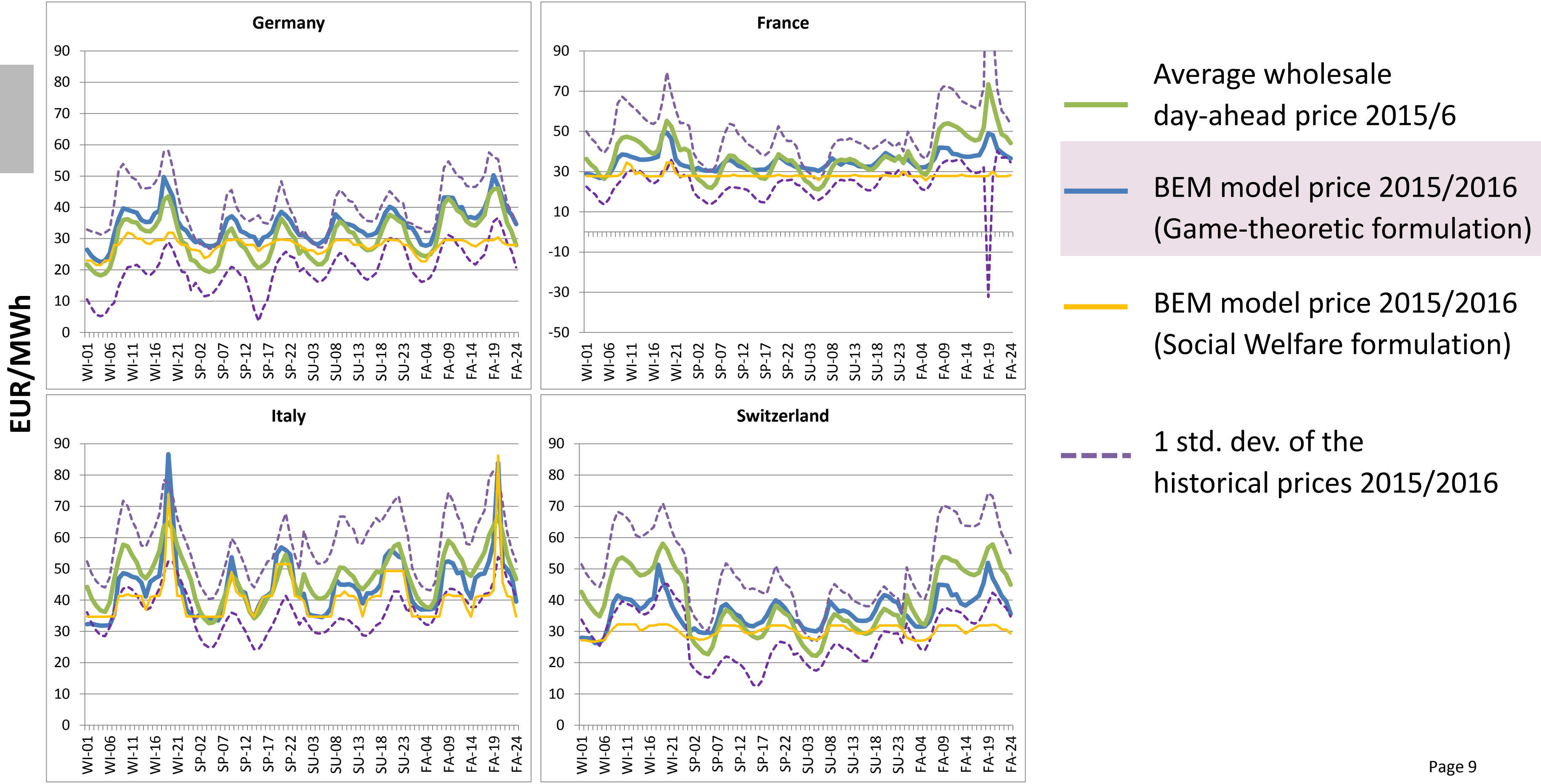
$\theta_i = 1$ Nash conjectures

$\theta_i \in (0, 1)$ Intermediate imperfect competition conjectures

Estimated deviation of θ_i from the model's cost-curve when reproducing the 2015/6 wholesale prices



Calibration of the BEM model to 2015/6 prices



Definition of the scenarios

- Two core scenarios emphasizing the year 2030 are assessed:

	Base	Low Carbon
Description	Reference scenario, based on the EU TRENDS 2016 scenario	Climate scenario -40% reduction of CO_2 in 2030 from 1990 levels (Clean Energy for All Europeans)
Fuel prices in 2030 [1]	Gas: 28 €/MWh, Coal: 12 €/MWh (EUR of 2015)	
CO_2 price in 2030 [2]	30 €/tCO2	80 €/tCO2

[1] IEA World Energy Outlook 2017, New Policies Scenario
[2] IEA World Energy Outlook 2017, Sustainable Development Scenario
Today's gas price (2015/6) 14 €/MWh, today's coal price 9 €/MWh

- Two additional variants:

a) Enabling batteries for additional flexibility
b) Maintaining the fuel costs and CO_2 prices of today

Marginal production costs in the scenarios

- The increase of the fossil and CO_2 prices in 2030 from today's level, results in a substantial increase of the marginal electricity production cost

Scenario	Lignite	Coal	Nuclear	Gas CC	Biomass/Waste
Marginal cost in EUR/MWh when including the CO_2 price:					
Today	17	27 – 30	18	27 – 36	23 – 30
Base	40	54 – 57	18	56 – 65	23 – 30
Low Carbon	83	96 – 98	18	103 – 113	23 – 30
Marginal cost in EUR/MWh when excluding the CO_2 price:					
Today	13	23 – 26	18	25 – 34	23 – 30
Base	15	29 – 32	18	46 – 55	23 – 30
Low Carbon	15	29 – 32	18	46 – 55	23 – 30

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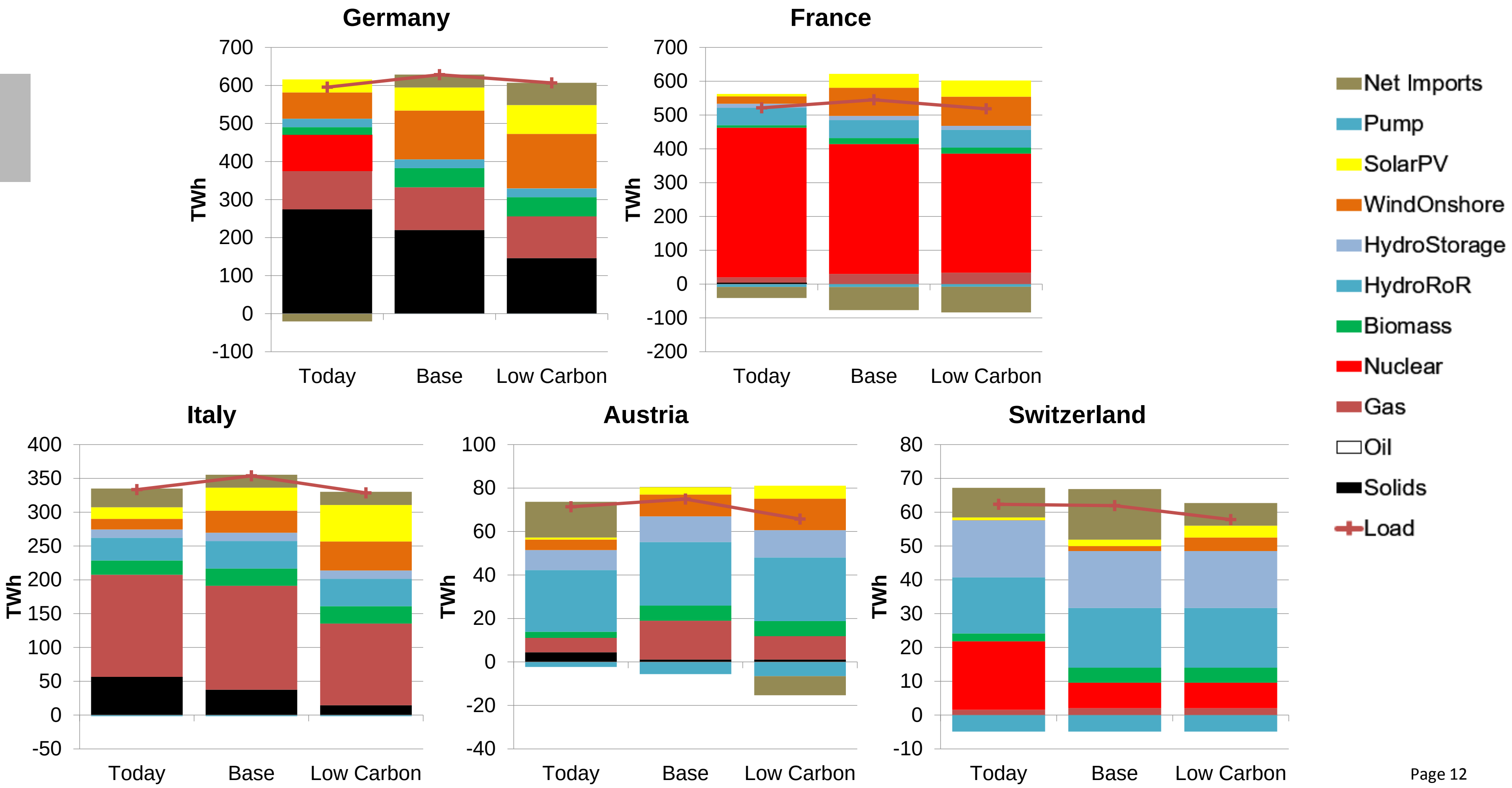
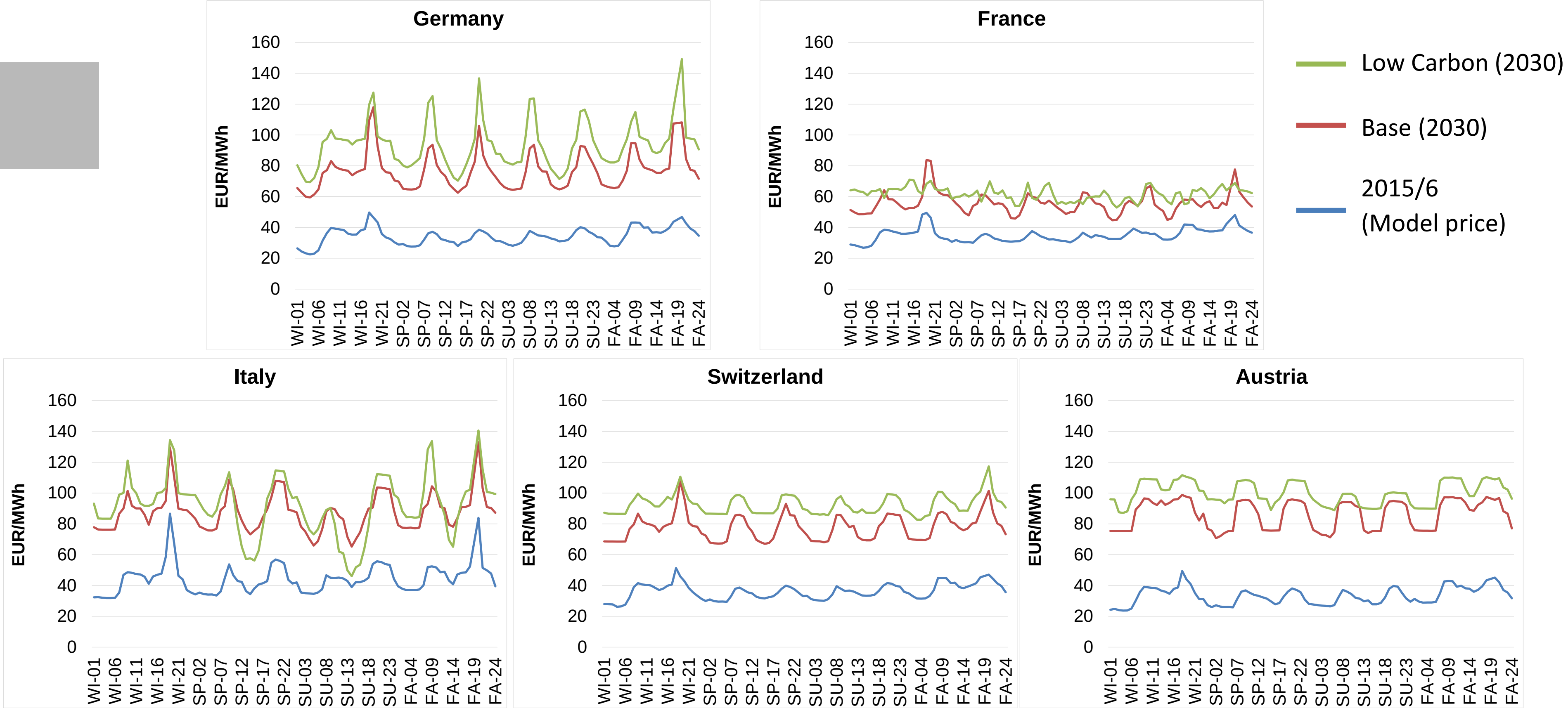
Results: Electricity generation mix today & in 2030

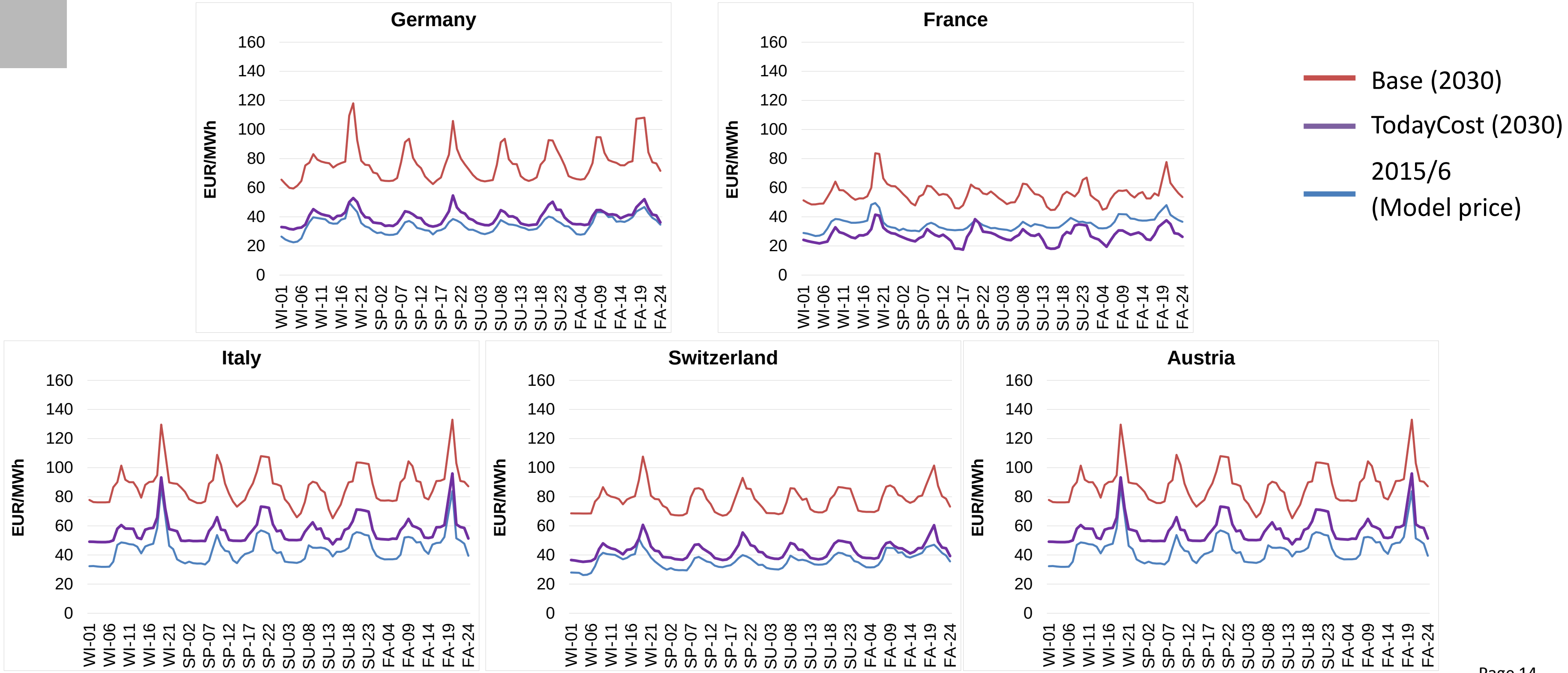


Results: Electricity prices today and in 2030



Results: Drivers influencing the prices in 2030

- The comparison between the Base scenario and its variant with today's prices (TodayCost scenario) reveals the important role of gas and CO_2 prices in the electricity price increase



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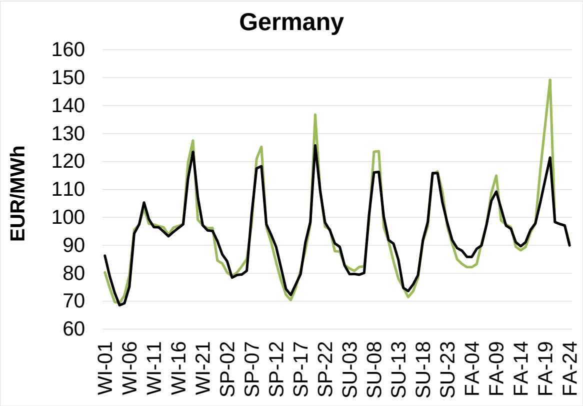
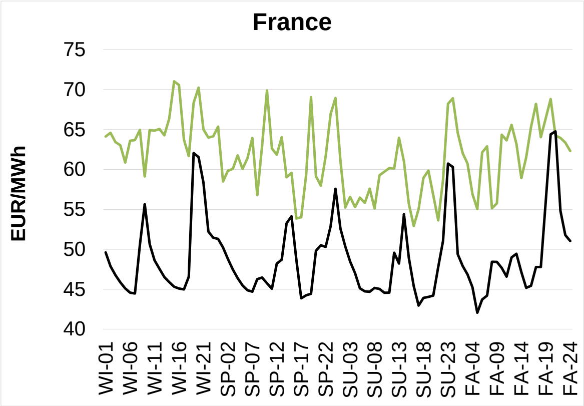
Results: Electricity prices and storage in 2030

- Comparison between having and not having batteries in the Low Carbon scenario

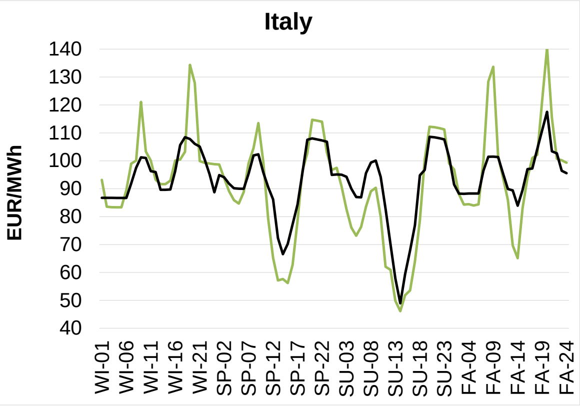


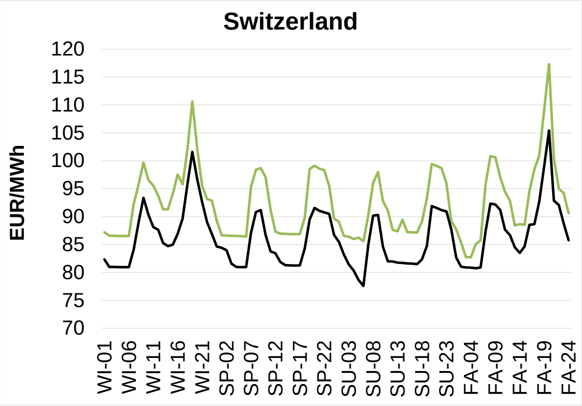


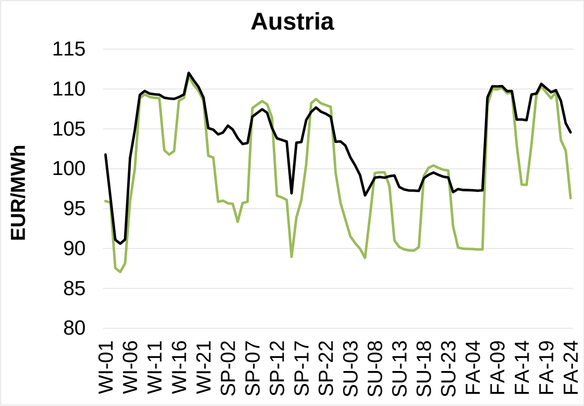
Low Carbon (2030)

Low Carbon bat (2030)

Investments in batteries:
Germany: 4 GW
France: 4.5 GW
Italy: 7 GW







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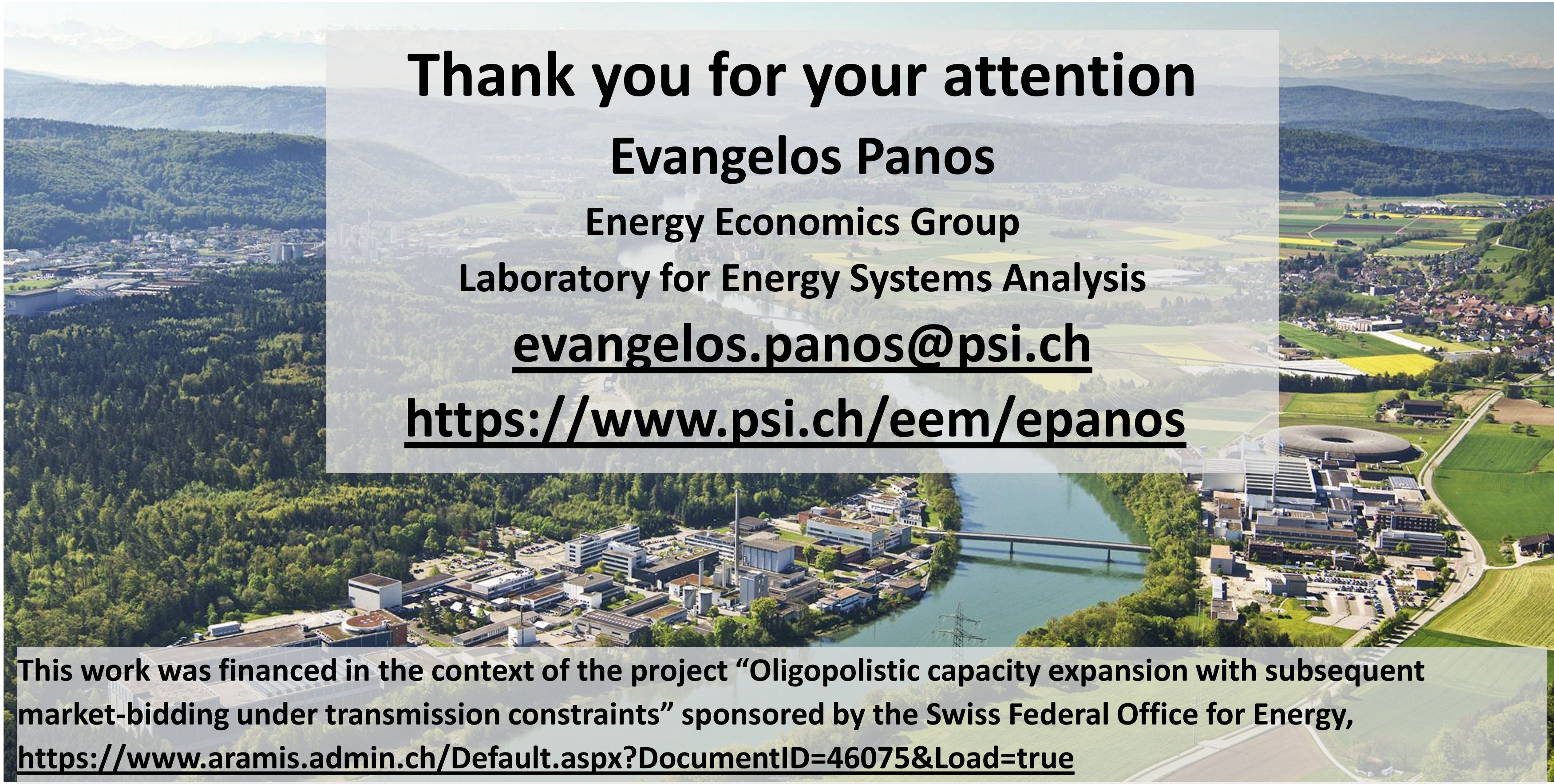
Conclusions

- A **reversal** of the recent trends of the electricity prices is ahead, driven by the **gas and CO_2 prices**
  - In **Germany**, the CO_2 prices have a greater impact on electricity prices than in the other countries due to the retaining in the solid-based generation in the domestic supply mix
  - In **France**, the prices follow those of neighbours ; in the Low Carbon scenario the increased wind power pushes the more expensive gas-based generation further out of the merit order curve and results in lower prices than in Base
  - **Italy** remains the country with the highest prices due to the high contribution of gas in the domestic electricity supply ; the high capacity factor of solar PV accentuates price dampening during the noon
  - In **Switzerland**, the prices closely follow the increase in the gas price, even though the country does not build gas power plants, as the country is a hub influenced by its neighbors

- Intra-day **storage helps in mitigating peak prices and reduces volatility**, and in large scales complements hydrostorage and also participates in the arbitrage trade



Thank you for your attention

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