Portuguese Market Outlook up to 2040

POYRY

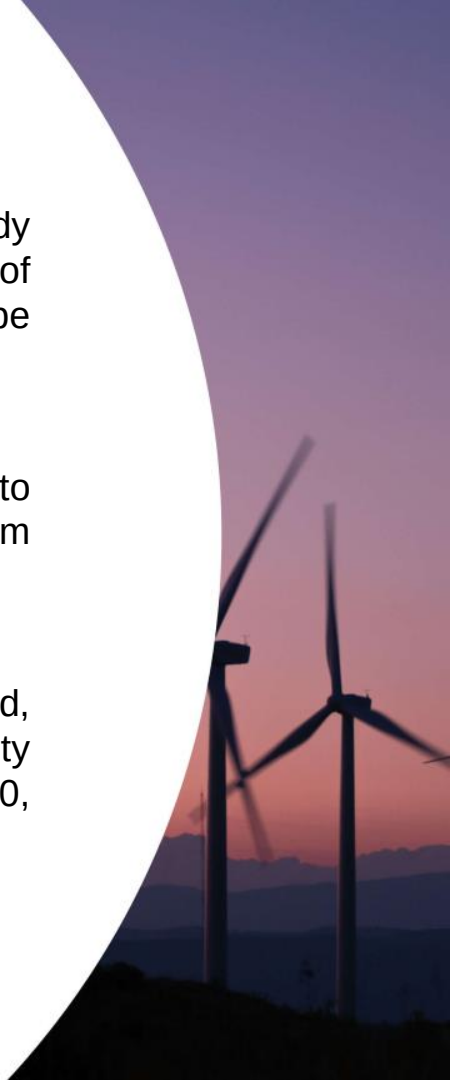
A report to APREN

Disclaimer

The results and conclusions here presented are the outcome of an outsourced study developed by Pöyry, with APREN's guidance, but do not define a closed view of APREN's position on the future of the Iberian electricity system nor can they be regarded as the only possible trajectory.

This study contains projections based on assumptions that are subject to uncertainties and contingencies, hence these cannot be regarded as a firm prediction of the future.

In the last months, some occurrences could influence the results here presented, such as the sharp increase in CO_2 prices, the increase in the wholesale electricity market price, and also the complete nuclear power plants phase out until 2030, recently announced by the Spanish government.



Study's objectives

- ✓ Identify the Iberian Electricity Market behaviour under a high variable renewables penetration – solar and wind – and its interaction with the European Market (horizon 2040);
- ✓ Compare the renewables remuneration effect between two different models: one considering the pure spot market value and the other through competitive ex-ante power/energy auction mechanisms;
- ✓ Identify the possible growth trajectory for wind and solar technologies, and its ideal *mix* for both Portugal and the Iberian Peninsula;
- ✓ Analyse wind and solar "captured prices" within a pure spot market model;
- ✓ Understand the future role for storage and international interconnections.

Source: Pöyry Report to APREN

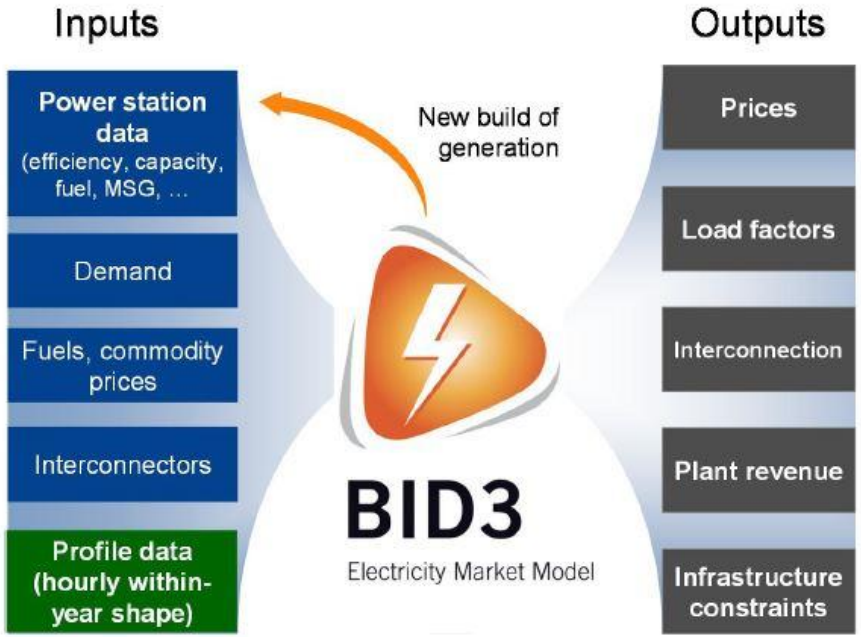
Model Used in the Study

Pöyry - BID3

BID3 – Pöyry's Electricity Market Model

BID3 projects physical operation (generator output, electricity flows, emissions) and economic behaviour (electricity prices, revenues)

Inputs and outputs of *BID3*



Basics of BID3

- BID3 is an optimisation which minimises the system cost in a year subject to constraints
- It models all 8760 hours of the year and accounts for varying renewables, demand-side management, hydro and storage
- It has the following key plant dynamics
  - Start-up, Part-loading (no-load), Minimum Stable Generation
  - Minimum on- and off-times
  - Temperature dependent start cost
  - Ramping
  - CHP and co-firing
- It also models
  - reserve constraints
  - capacity expansion (new build and retiral)
  - Flow Based Market Coupling

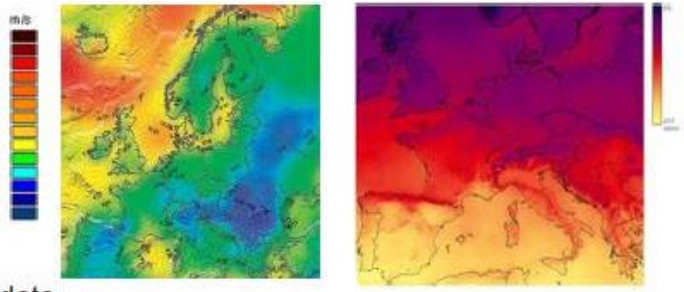
Source: Pöyry Report to APREN

Modelling of Commodities and Electricity

BID3 Coverage

- ***BID3*** models all countries in Europe and Turkey
- ***BID3*** produces hourly plants behaviour and price projections for:
  - 8,760 hours per year up to 2040,
  - 3 scenarios (+ any client scenario)
  - 5 historic hourly weather patterns
- ***BID3*** determines optimal hourly exports and imports between regions, based technical and economic constraints
- ***BID3*** enables assessing the performance of any plant / market / portfolio / interconnector

Detailed renewable resource data



- Hourly data
- Data resolution of 20km or 2km
- Temporal and spatial correlations are maintained across Europe

Source: Pöyry Report to APREN

Scenarios analysed

Scenarios developed

- **Main scenarios:**

  1) “Business as Usual” (or BaU) Scenario

  2) “High Renewable penetration” (or HighRES) Scenario

- **Sensitivity cases over the HighRes scenario:**

  1) Dry year

  2) Wet year

  3) Increased Interconnection

  4) Increased Commodity Prices

  5) New pumped storage capacity in 2030

  6) Increased Demand

Scenarios' description

"Business as Usual" - BaU Scenario

- Based on an energy framework in which the capacity investments are driven by the market evolution;
- RES (Renewables) deployment relies solely on the merchant revenues to attract investment;
- The risk exposure requires high IRR (Internal Rate of Return) values.

"High Renewable Energy penetration" - HighRES Scenario

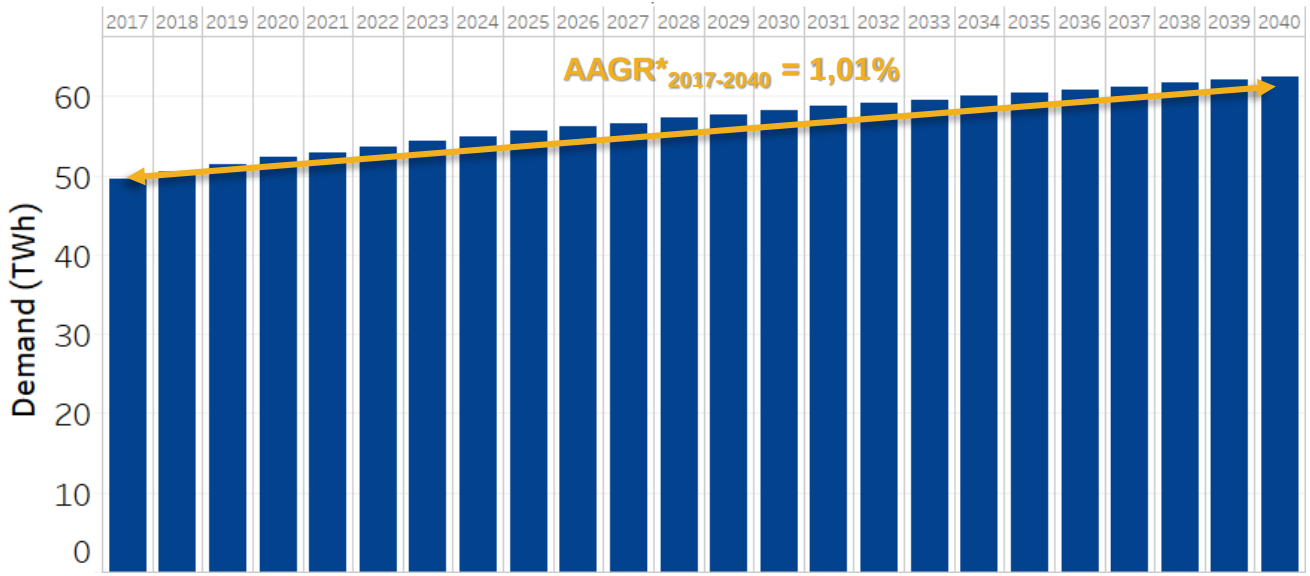
- Based on an energy framework characterized by a growing share of RES;
- More ambitious (but still feasible) assumption on renewable CAPEX/MW reduction combined with a change in the legal framework;
- The reduction of the investment uncertainty would allow the development of renewables' projects with lower IRR.

Data Inputs Assumptions

Model Inputs

Portugal – Demand

Demand profile is considered to be the same for both scenarios



- **The demand** (generation output to supply the final load) foreseen was 58 TWh and 62 TWh, respectively for 2030 and 2040.

Obs: The study carried out by UNL–CENSE for APREN in 2017 foreseen similar values: 2030 - 56 TWh and 2040 - 62TWh

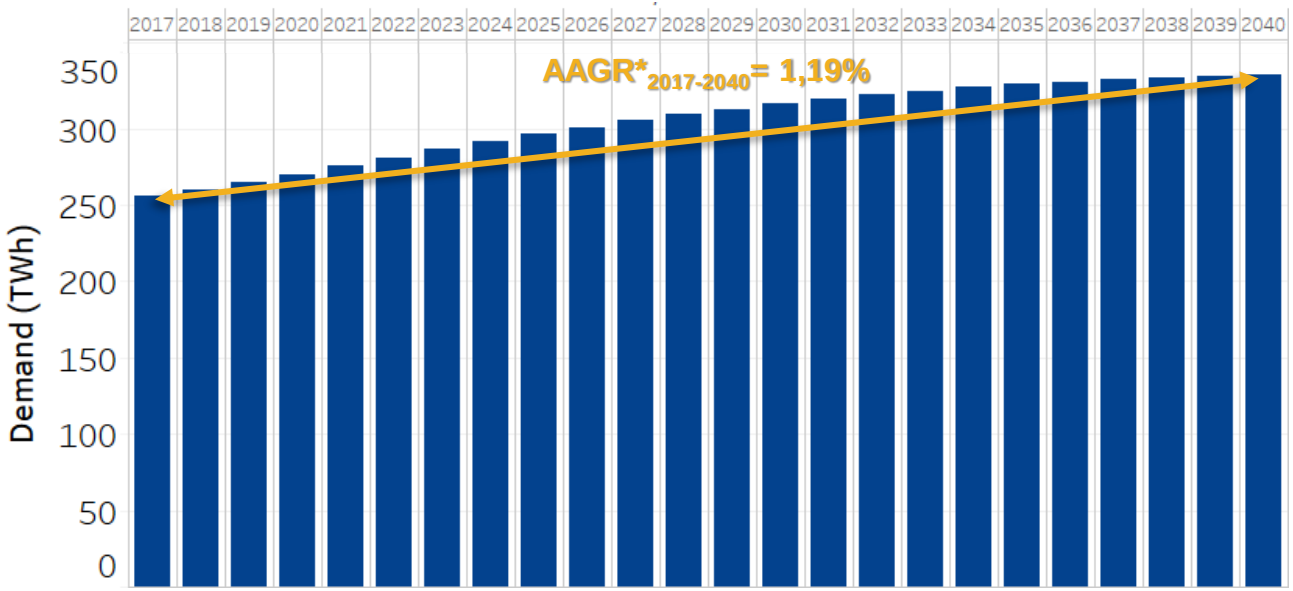
Source: Pöyry Report to APREN

*AAGR: Average annual growth rate 2017-2040

Model Inputs

SPAIN - Demand

Demand profile is considered to be the same for both scenarios



- This study assumed a demand for 2030 of 316 TWh and an AAGR of 1,19%.

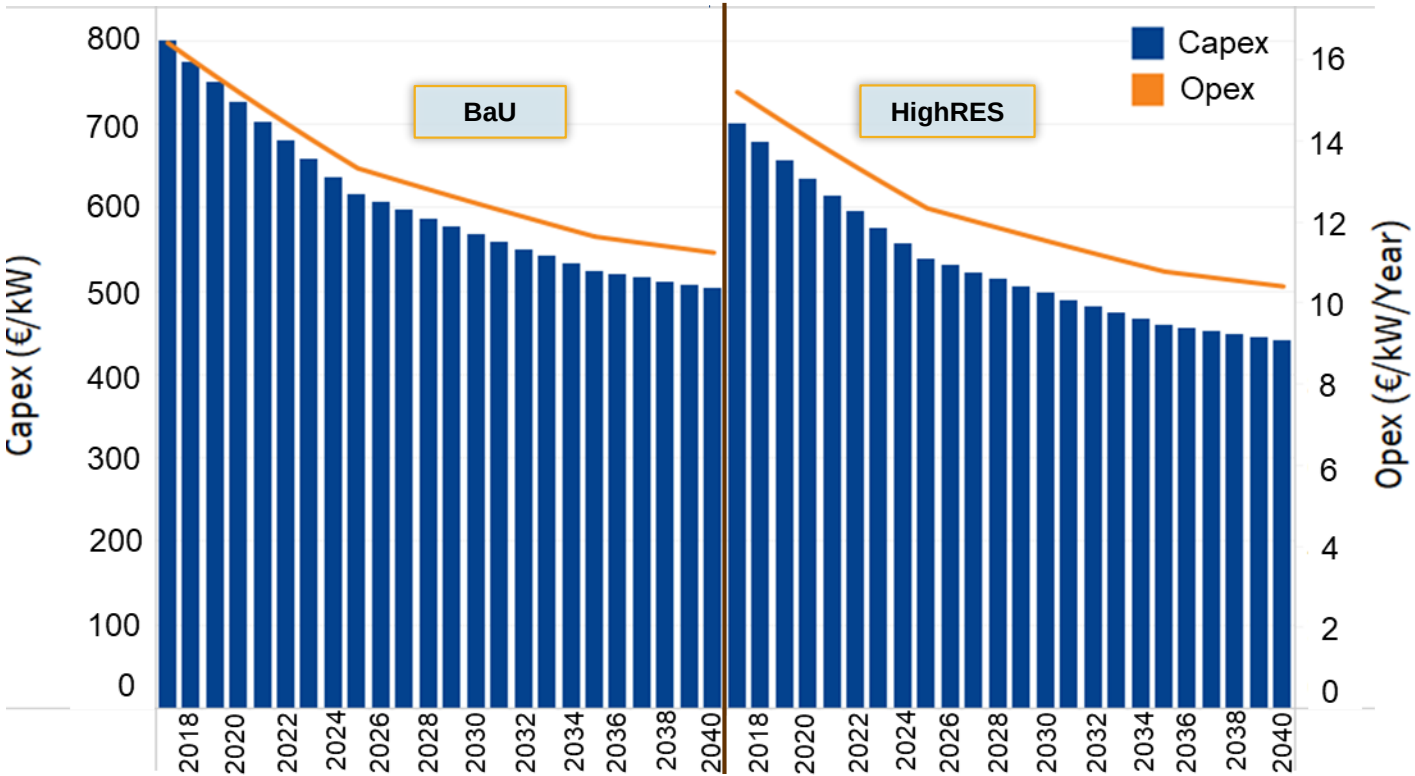
Obs: More recently, the Spanish “Comisión de expertos de Transición Energética - Análisis y propuestas para la descarbonización”, used a range between 285-320 TWh

Source: Pöyry Report to APREN

*AAGR: Average annual growth rate 2017-2040

Model Inputs

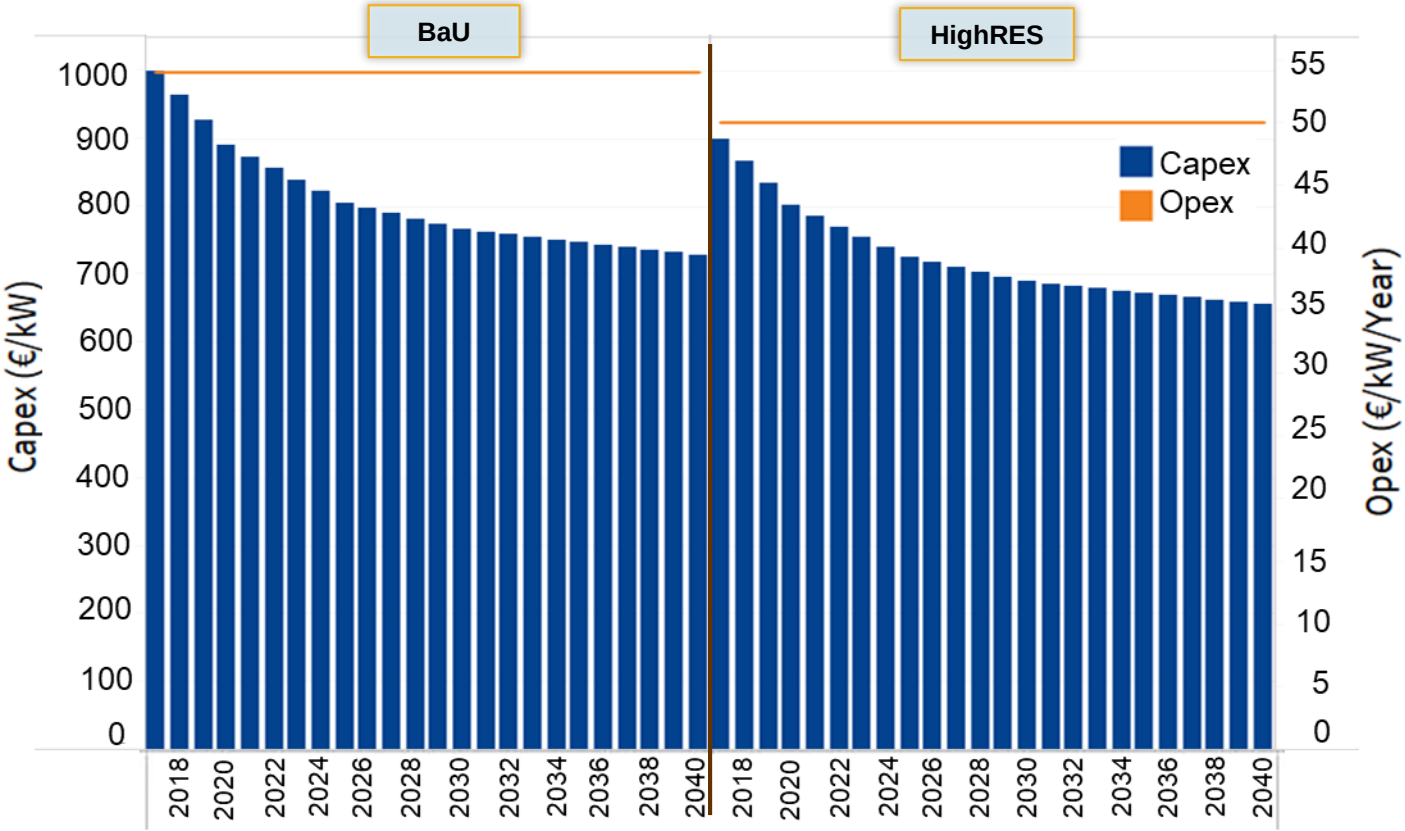
Solar PV CAPEX and OPEX [€/kW, real 2016 money]



Source: Pöyry Report to APREN

Model Inputs

Onshore Wind CAPEX and OPEX [€/kW, real 2016 money]

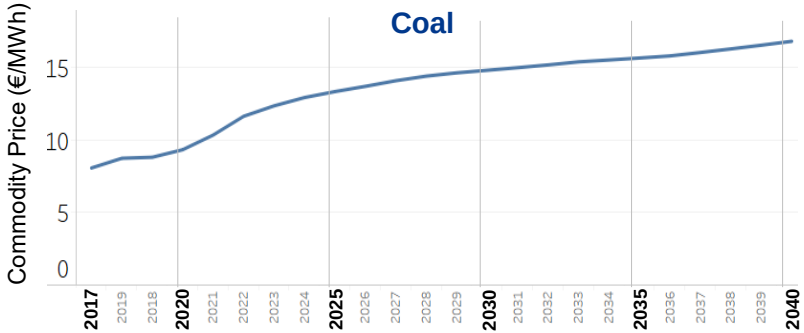


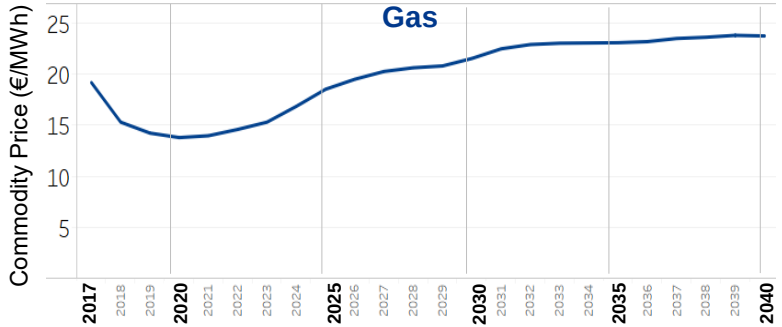
Source: Pöyry Report to APREN

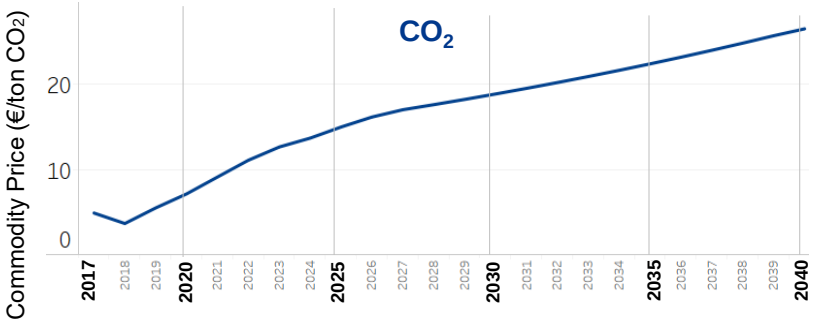
Model Inputs

Commodity Prices (real 2016 money)

Commodity prices are considered to be the same for both scenarios





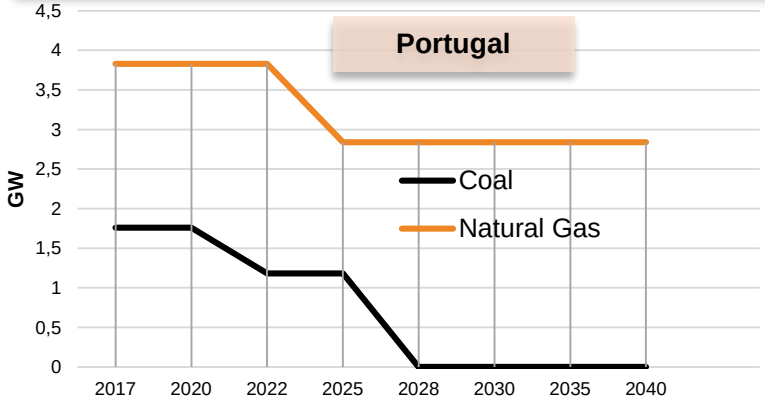


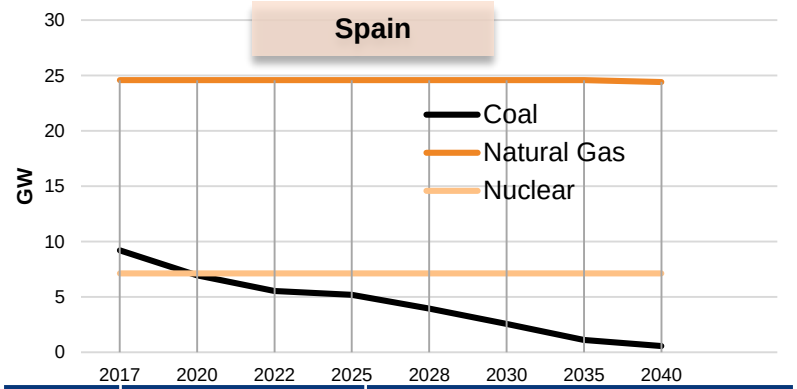
Source: Pöyry Report to APREN

Model Inputs

PT and ES – Assumptions for the decommissioning of thermal power capacity [GW]

Thermal power plants decommissioning program is the same in both scenarios, except a small change for coal in Spain in 2040





- **For Portugal** the model considers the coal decommissioning until 2028 and the reduction of natural gas installed capacity by 1GW in 2022.
- **In Spain** the nuclear and natural gas power capacities will remain constant, while the coal-fired power capacity will progressively diminish until 2040.

Year	Portugal		Spain		
	Coal [GW]	Natural Gas [GW]	Coal [GW]	Nuclear [GW]	Natural Gas [GW]
2017	1,76	3,83	9,20	7,12	24,57
2020	1,76	3,83	6,95	7,12	24,57
2025	1,18	2,84	5,20	7,12	24,57
2030	0,00	2,84	2,55	7,12	24,57
2035	0,00	2,84	1,11	7,12	24,57
2040	0,00	2,84	0,56 BaU 0 HighRES	7,12	24,42

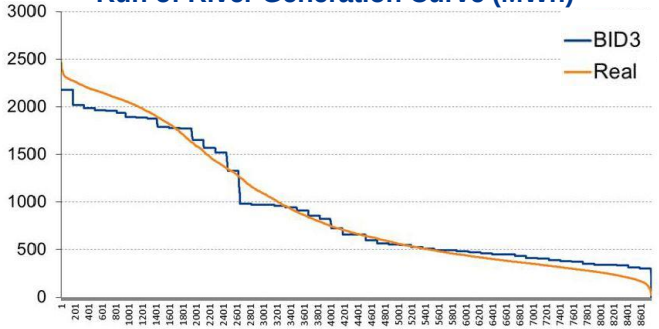
Source: Pöyry Report to APREN

Model Results

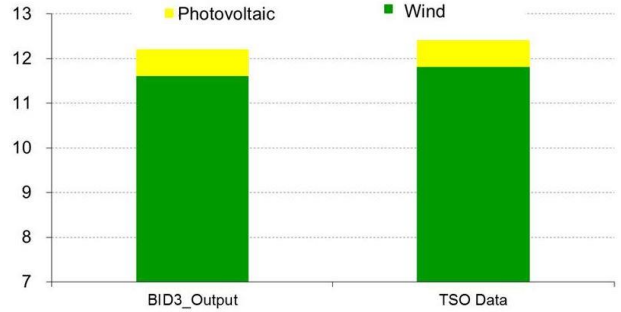
Backcast

The **model calibration** has been done by **simulating one specific year** (2014).
The results and its comparison with real values are presented in the figures below.

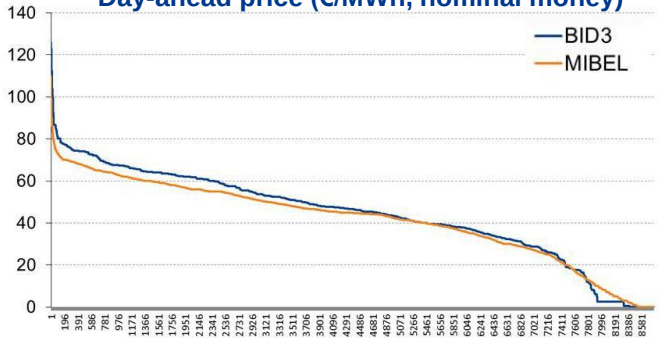
Run of River Generation Curve (MWh)



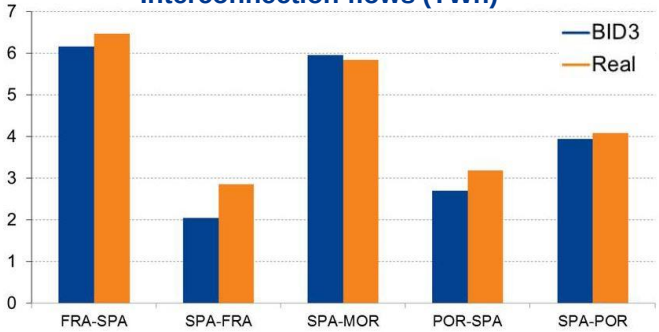
Wind and Solar Generation (TWh)



Day-ahead price (€/MWh, nominal money)



Interconnection flows (TWh)

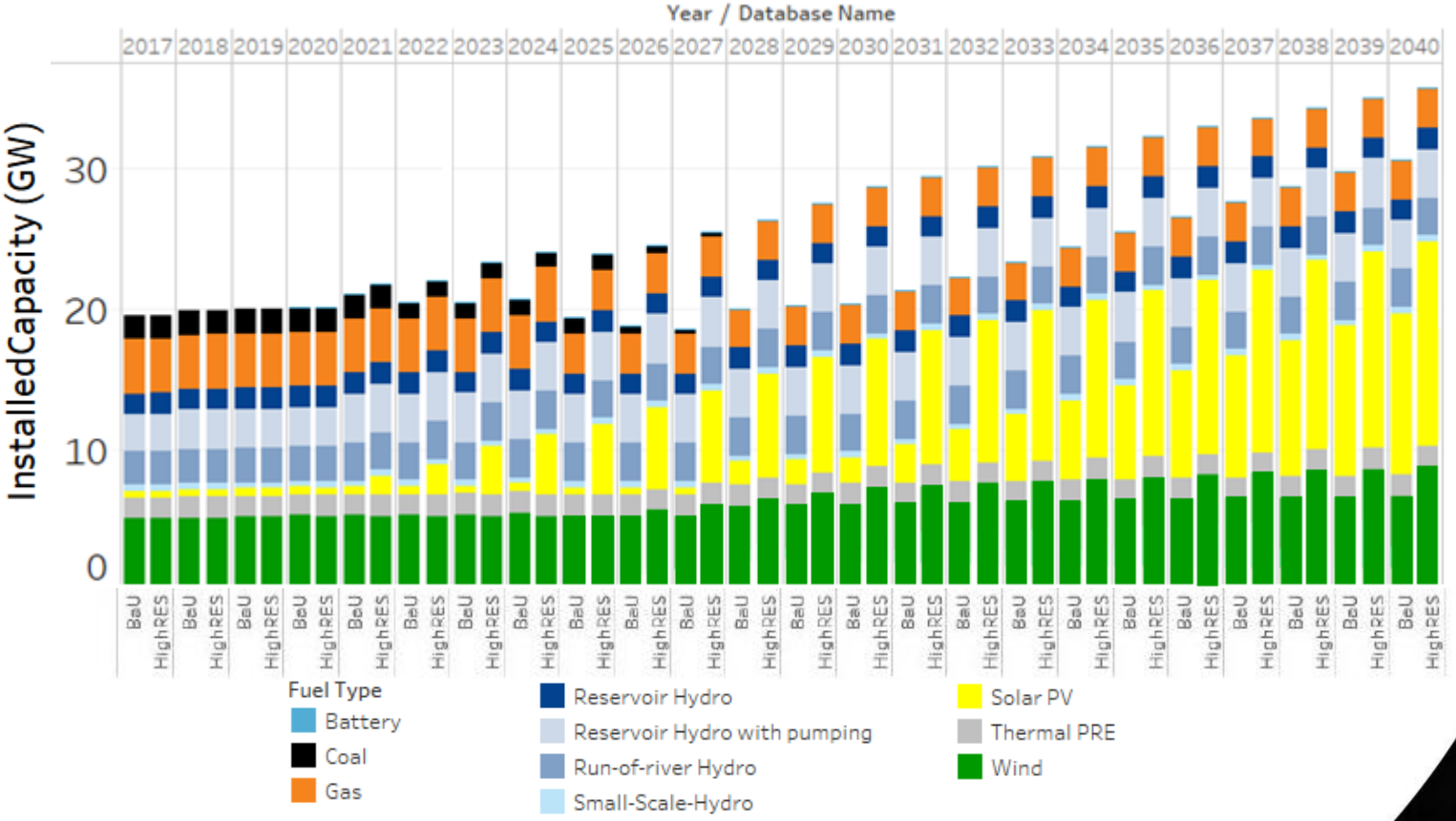


These figures show **good accuracy between the model and the real values.**

Source: Pöyry Report to APREN

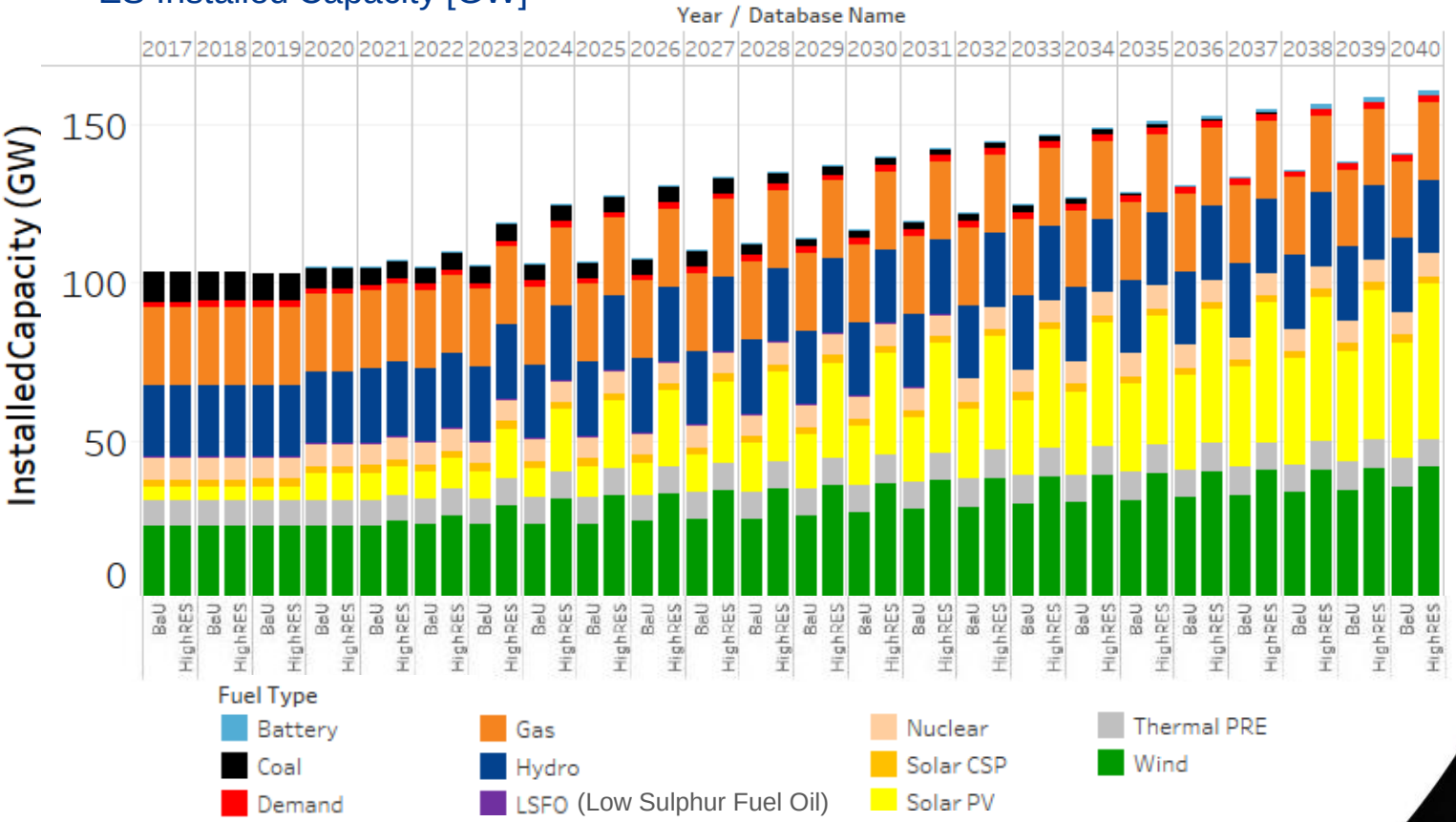
Model Results

PT Installed Capacity [GW]



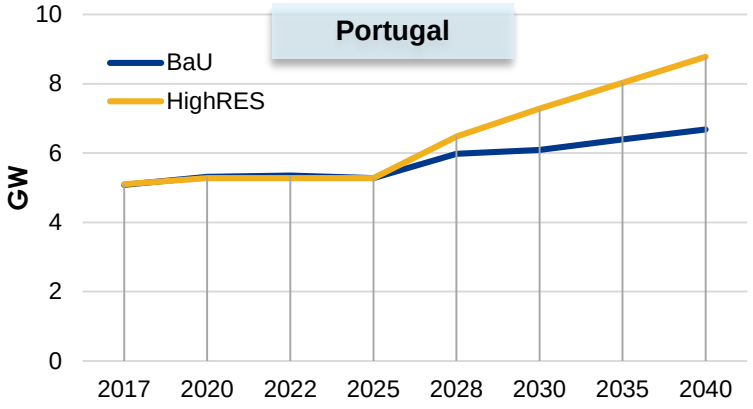
Model Results

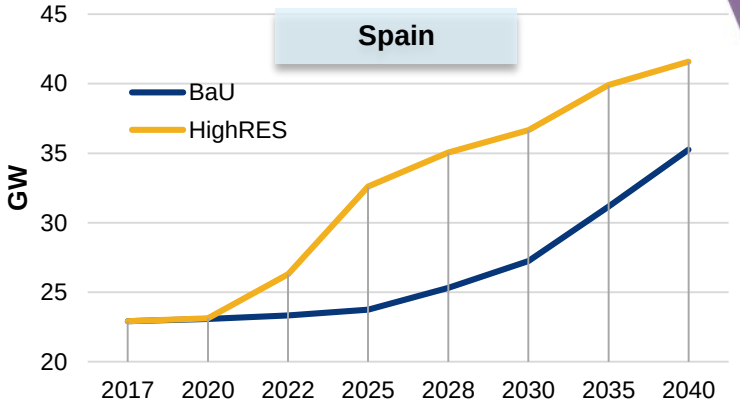
ES Installed Capacity [GW]



Model Results

PT and ES – **Wind** Installed Capacity [GW]





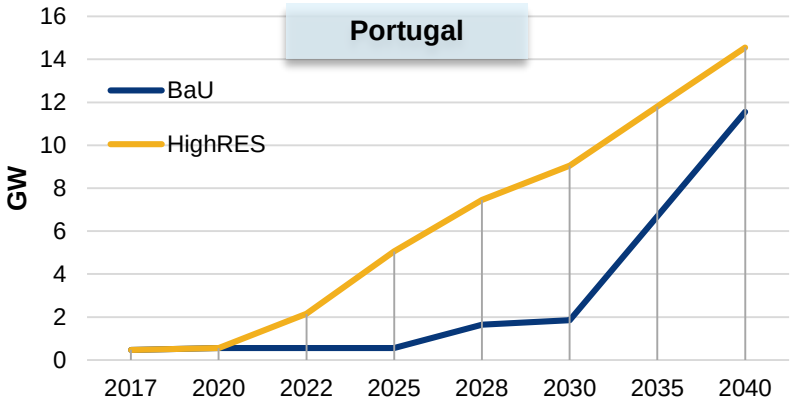
Year	Portugal		Spain	
	BaU	HighRES	BaU	HighRES
2017	5,08	5,10	22,93	22,93
2020	5,31	5,28	23,08	23,13
2025	5,28	5,28	23,75	32,60
2030	6,09*	7,28*	27,25	36,66
2035	6,39	8,03	31,15	39,90
2040	6,68**	8,78**	35,25	41,58

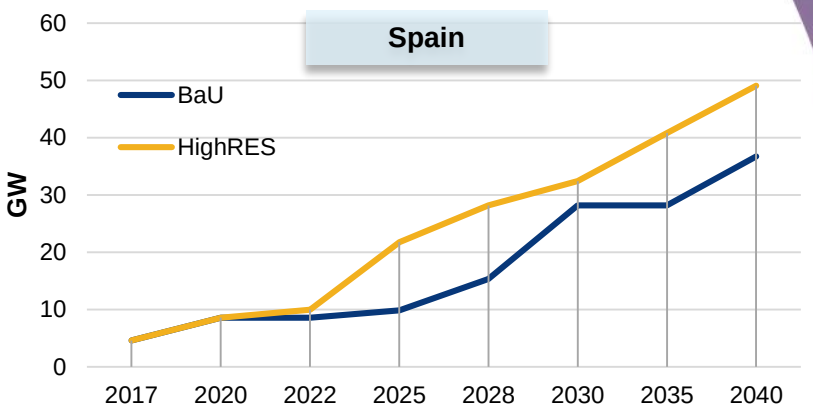
Note:
*CENSE's Study results for 2030: 7GW
**CENSE's Study results for 2040: 7,50 GW

Source: Pöyry Report to APREN

Model Results

PT and ES – **Solar PV** Installed Capacity [GW]





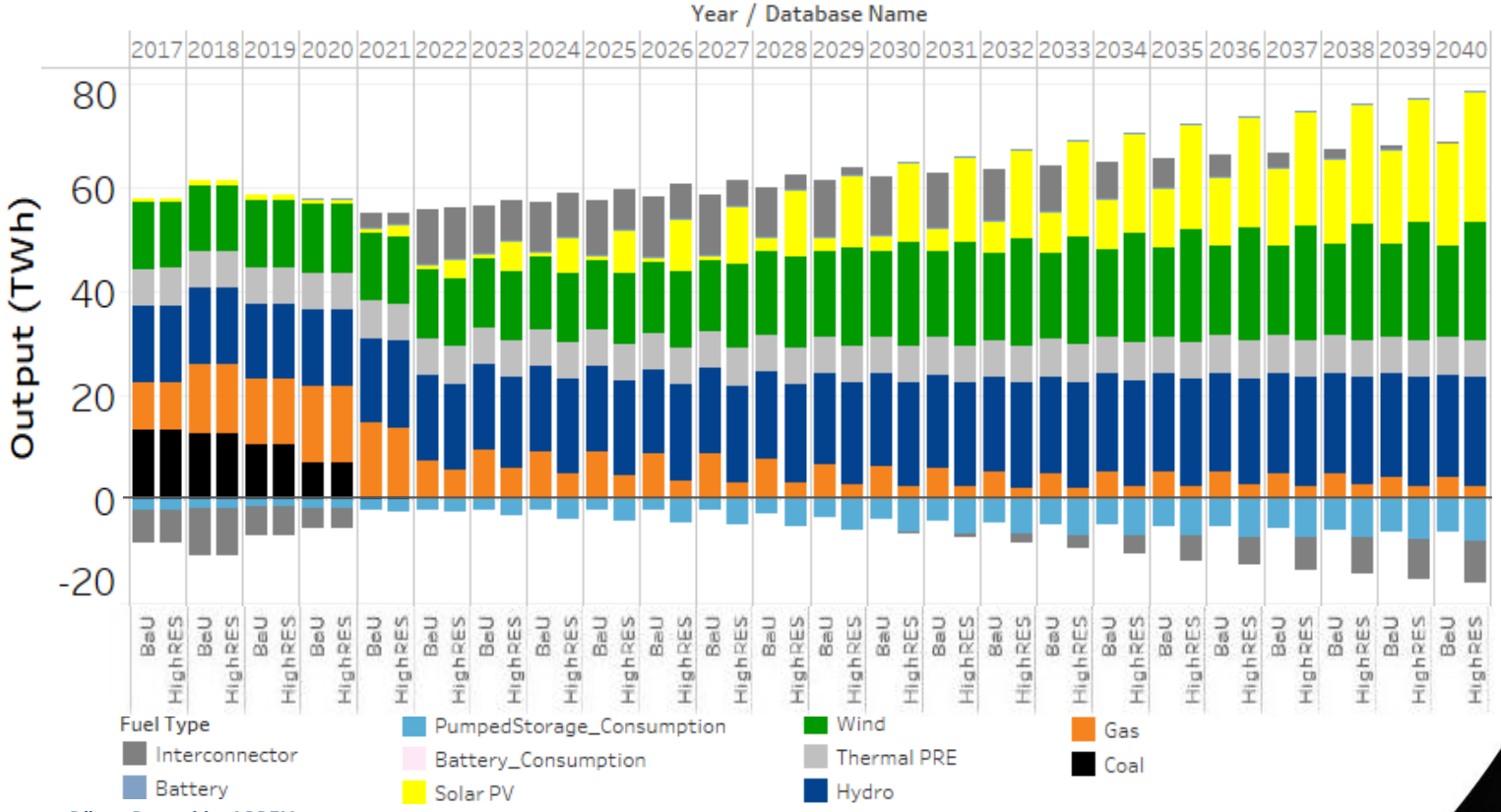
Year	Portugal		Spain	
	BaU	HighRES	BaU	HighRES
2017	0,47	0,47	4,57	4,57
2020	0,55	0,55	8,57	8,57
2025	0,55	5,05	9,82	21,77
2030	1,85	9,05*	28,15	32,41
2035	6,70	11,80	28,15	40,81
2040	11,55	14,55**	36,75	49,07

Note:
*CENSE's Study results for 2030: 3,5-4,5 GW
**CENSE's Study results for 2040: 8-9,5 GW

Source: Pöyry Report to APREN

Model Results

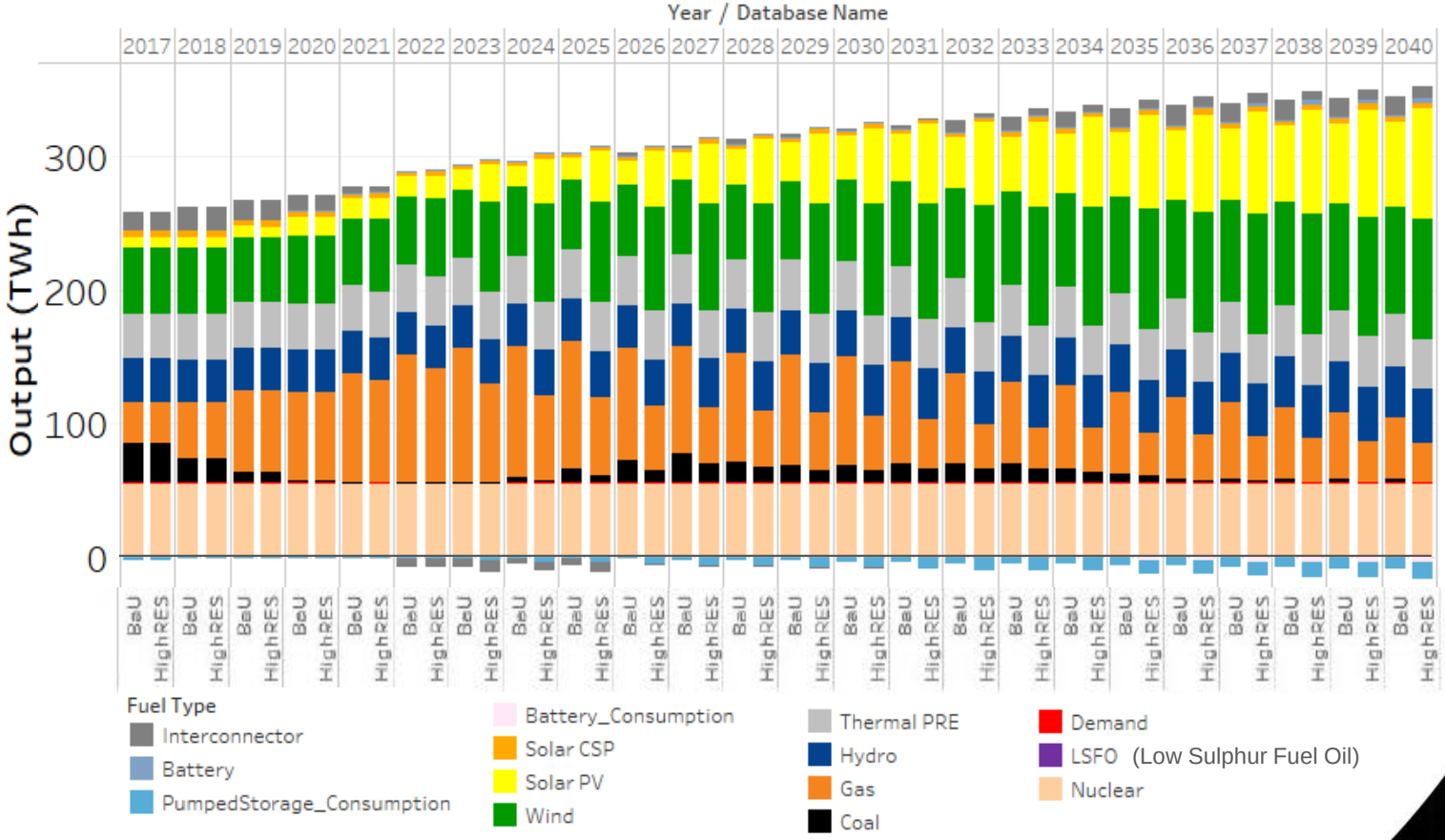
PT - Generation by technology [TWh]



Source: Pöyry Report to APREN

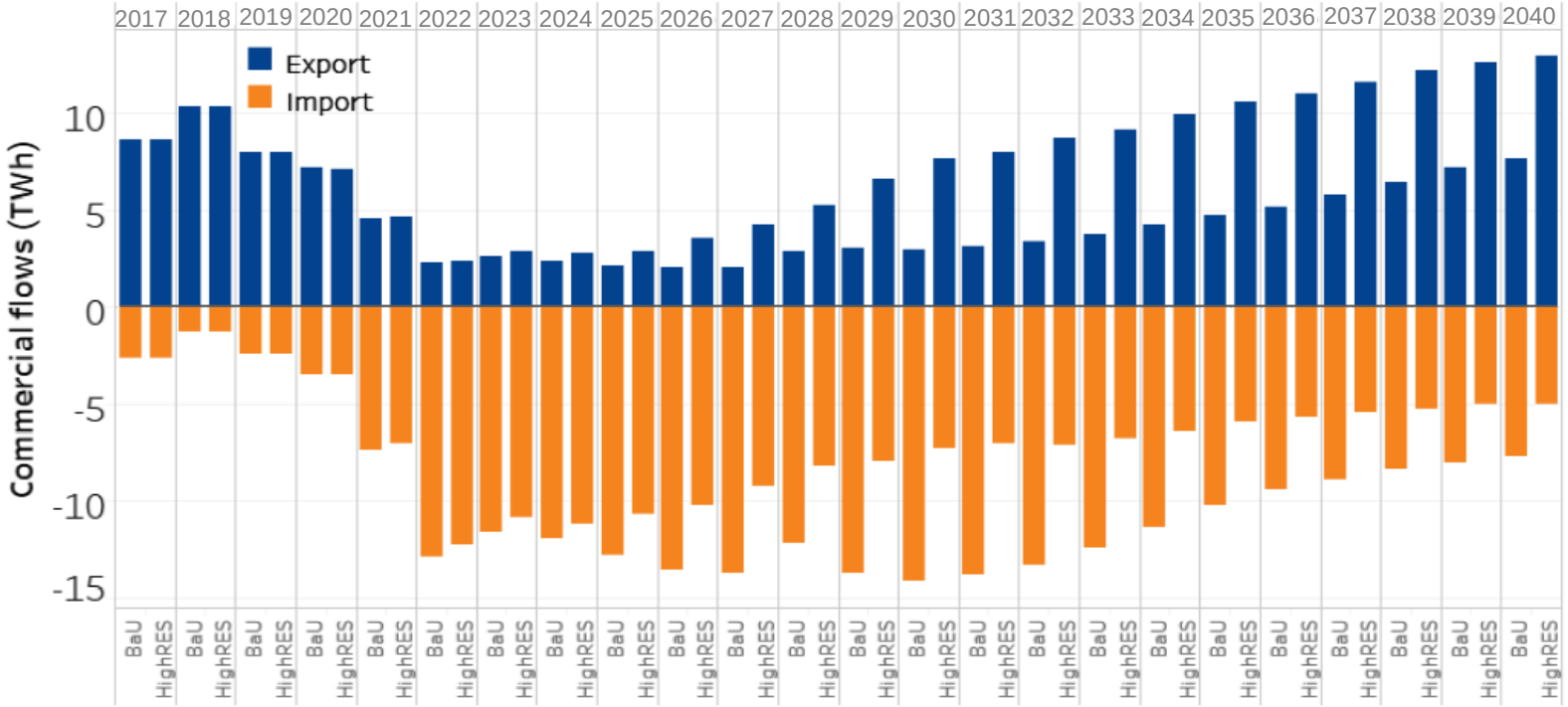
Model Results

ES - Generation by technology [TWh]



Model Results

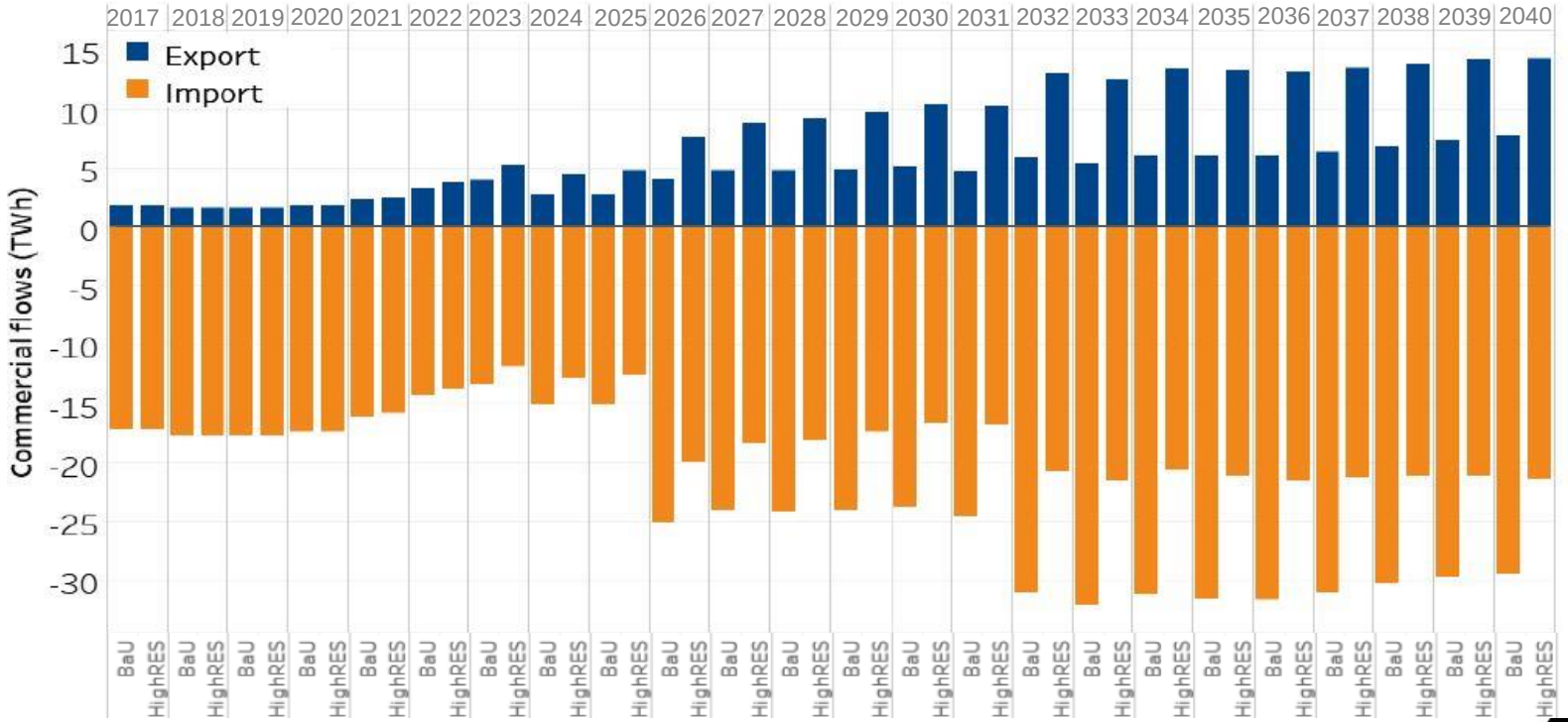
PT > ES interconnection flows [TWh]



Source: Pöyry Report to APREN

Model Results

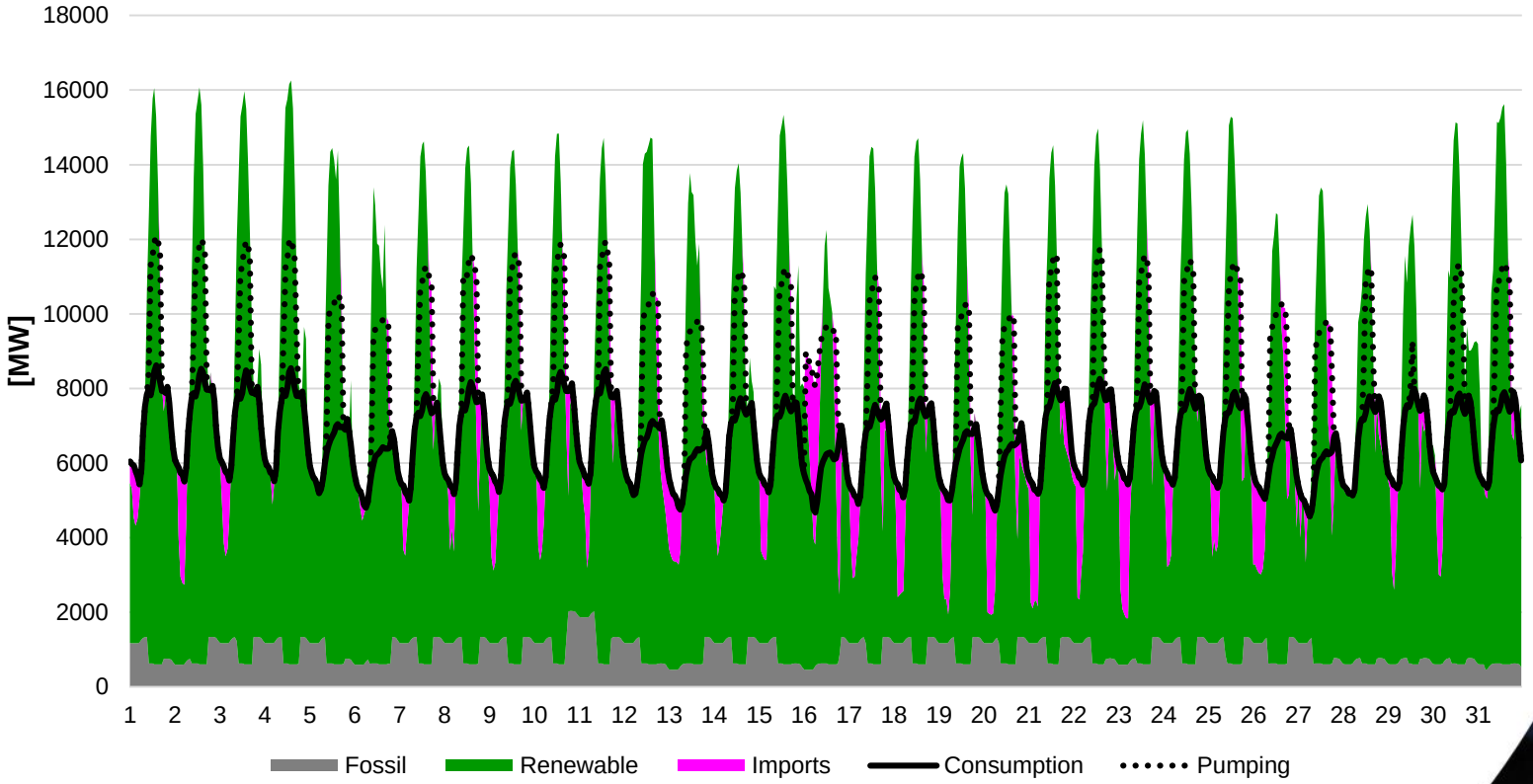
ES > FR interconnection flows [TWh]



Source: Pöyry Report to APREN

Model Results – Dry Year

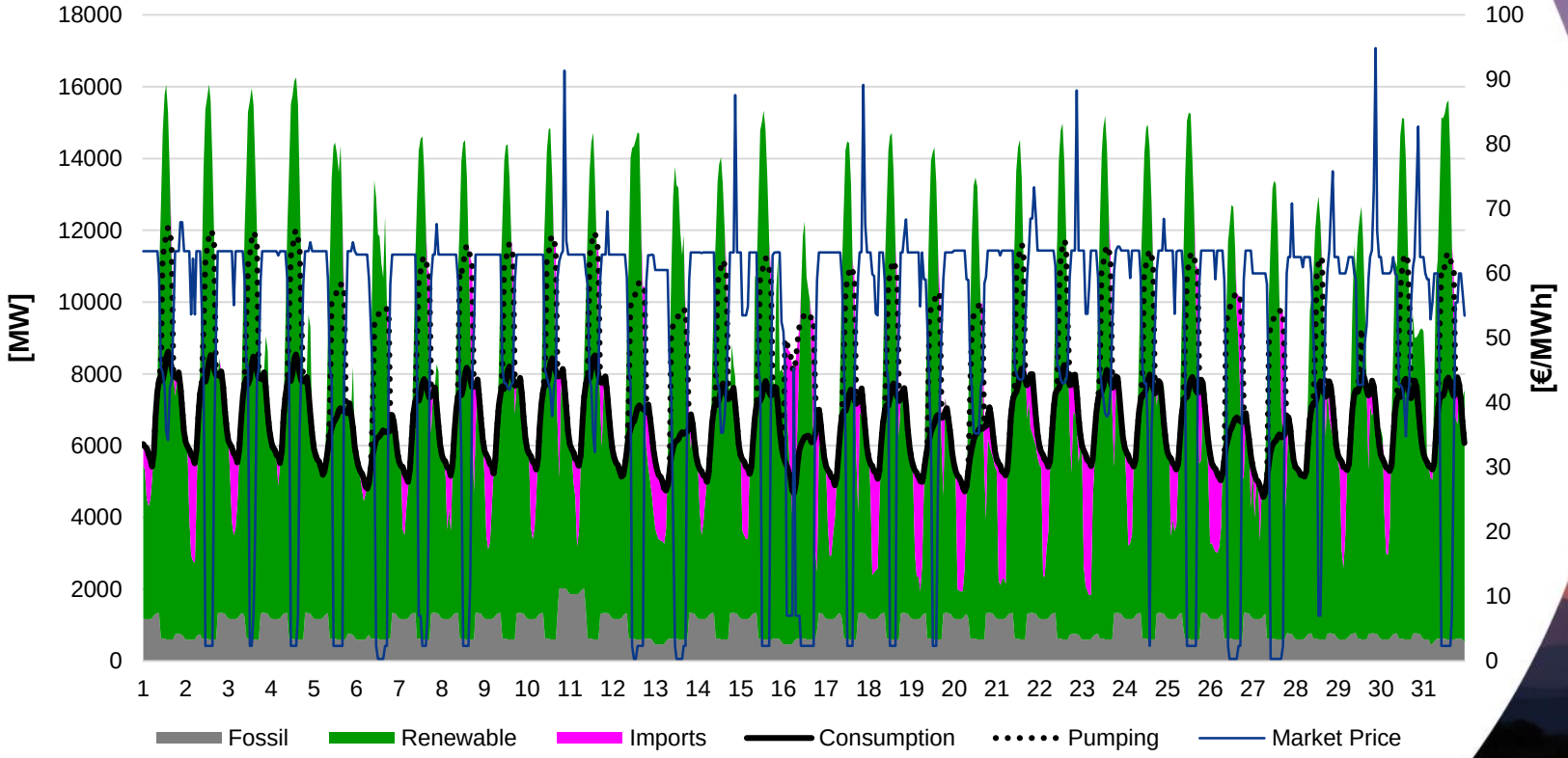
August 2040 hourly production profile - HighRES Scenario



Source: Pöyry Report to APREN; APREN's analysis

Model Results – Dry Year

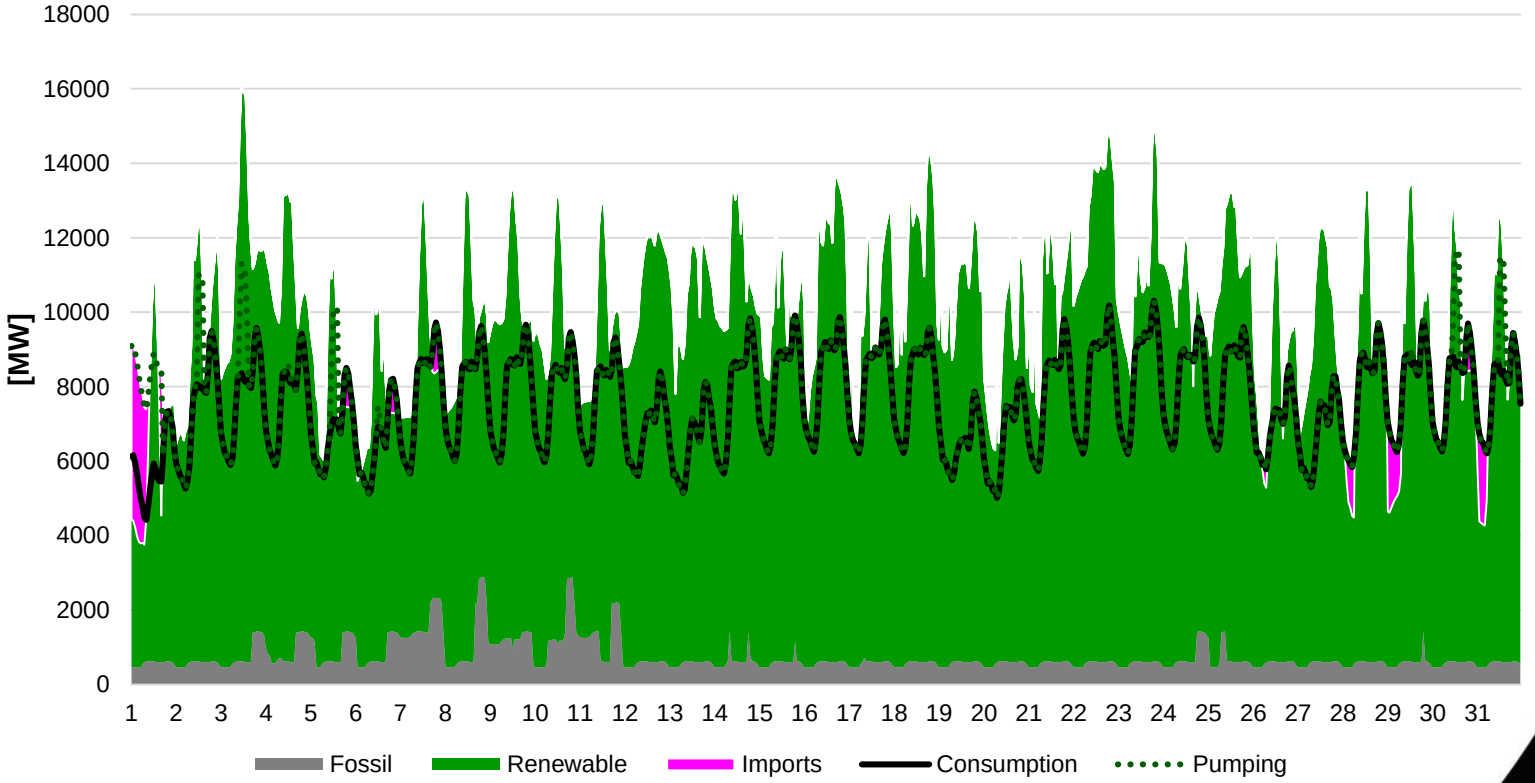
August 2040 hourly production profile and wholesale prices - HighRES Scenario



Source: Pöyry Report to APREN; APREN's analysis

Model Results – Wet Year

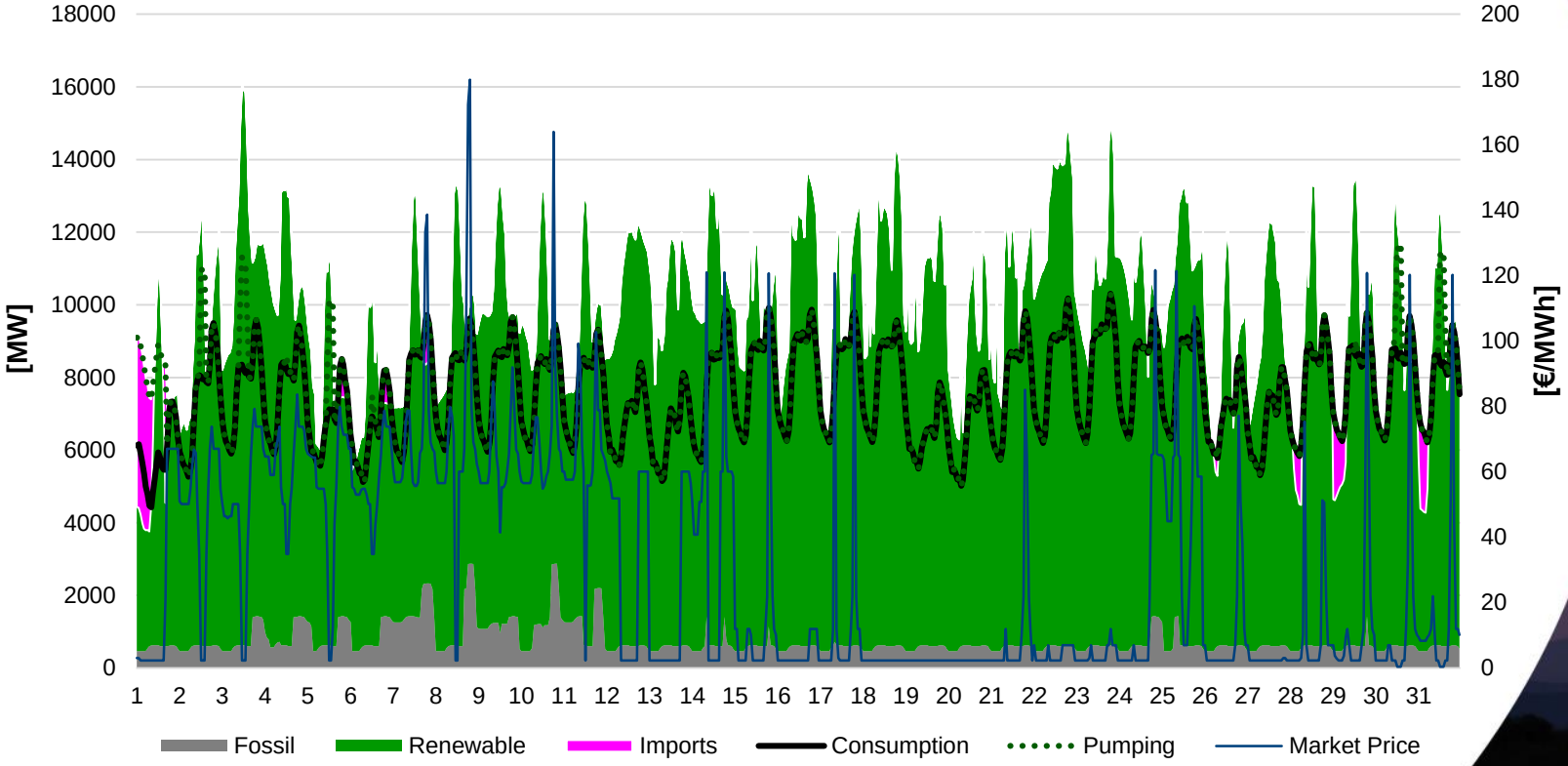
January 2040 hourly production profile - HighRES Scenario



Source: Pöyry Report to APREN; APREN's analysis

Model Results – Wet Year

January 2040 hourly production profile and wholesale prices - HighRES Scenario

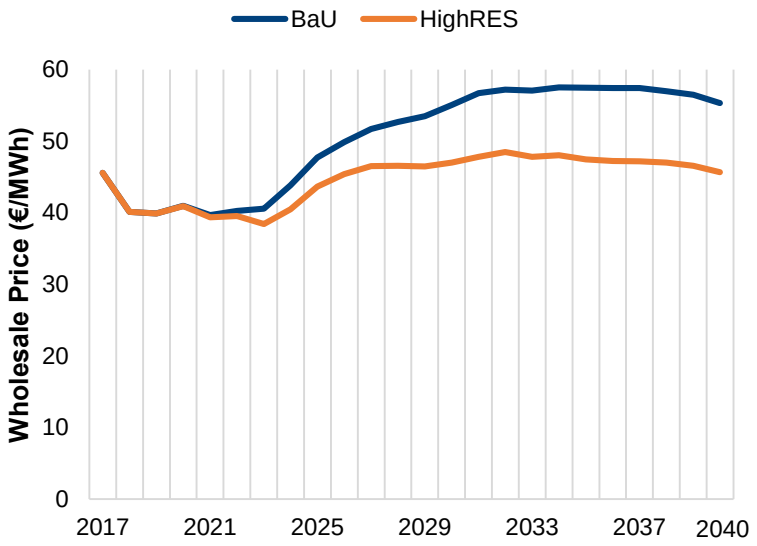


Source: Pöyry Report to APREN; APREN's analysis

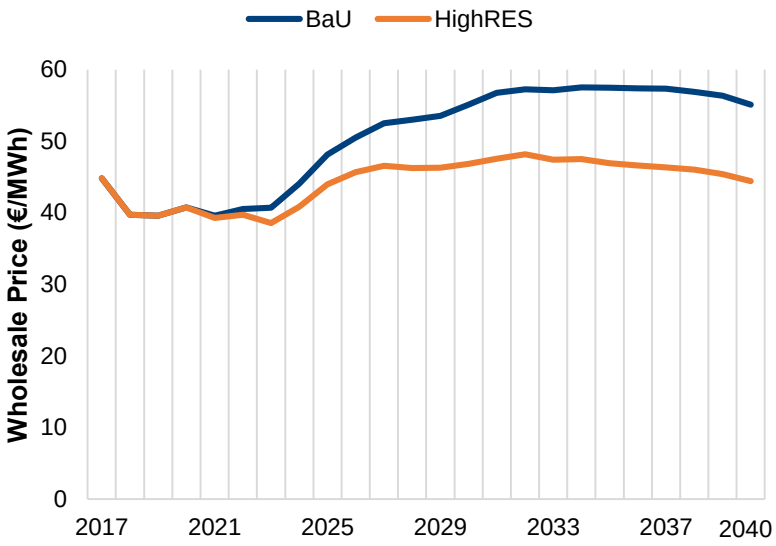
Model Results

Wholesale electricity price projections [€/MWh, real 2016 money] – PT vs ES

PT



ES

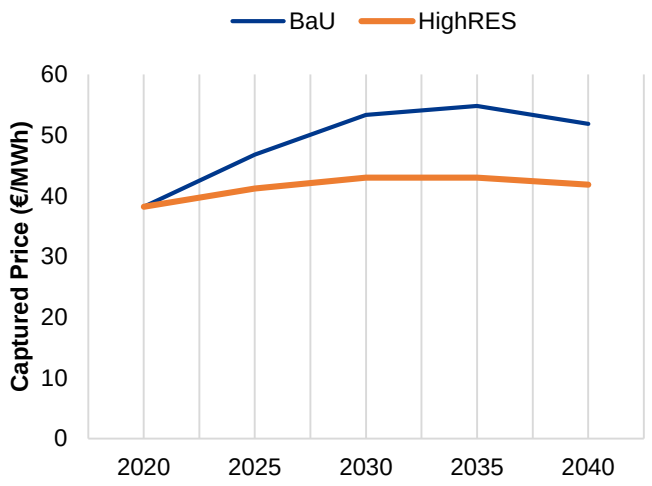


Source: Pöyry Report to APREN

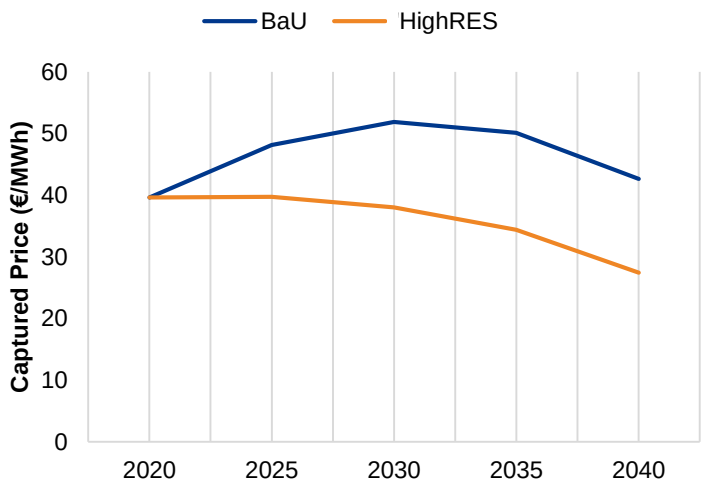
Model Results

Solar PV and Onshore Wind captured prices [€/MWh, real 2016 money]

Onshore Wind



Solar PV



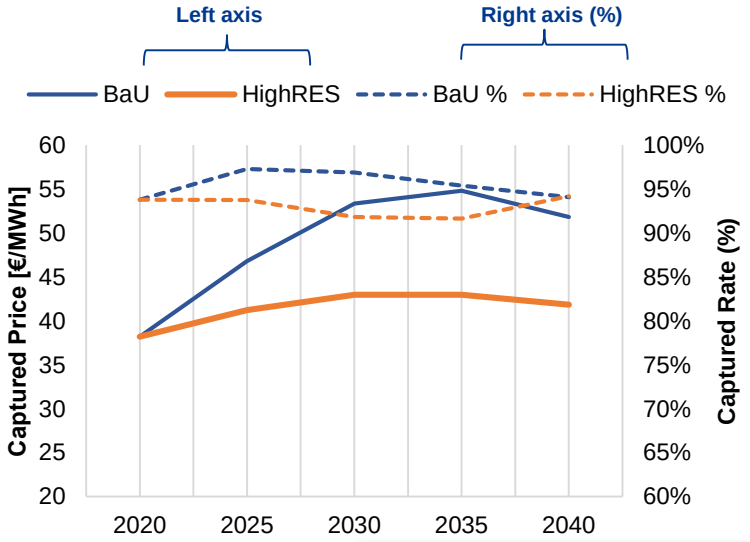
$$\text{Captured Price (€/MWh)} = \frac{\textbf{Yearly total revenues}}{\textbf{Yearly total generation}}$$

Source: Pöyry Report to APREN

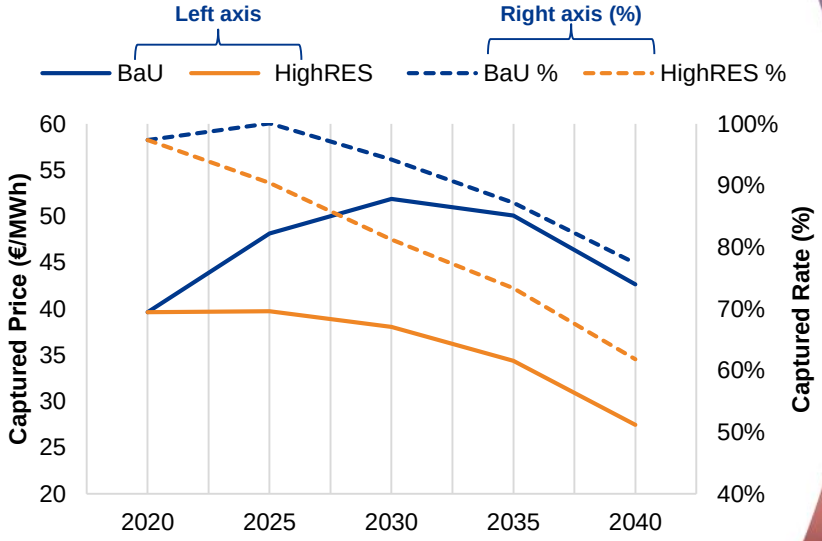
Model Results

Solar PV and Onshore Wind captured prices [€/MWh, real 2016 money]

Onshore Wind



Solar PV



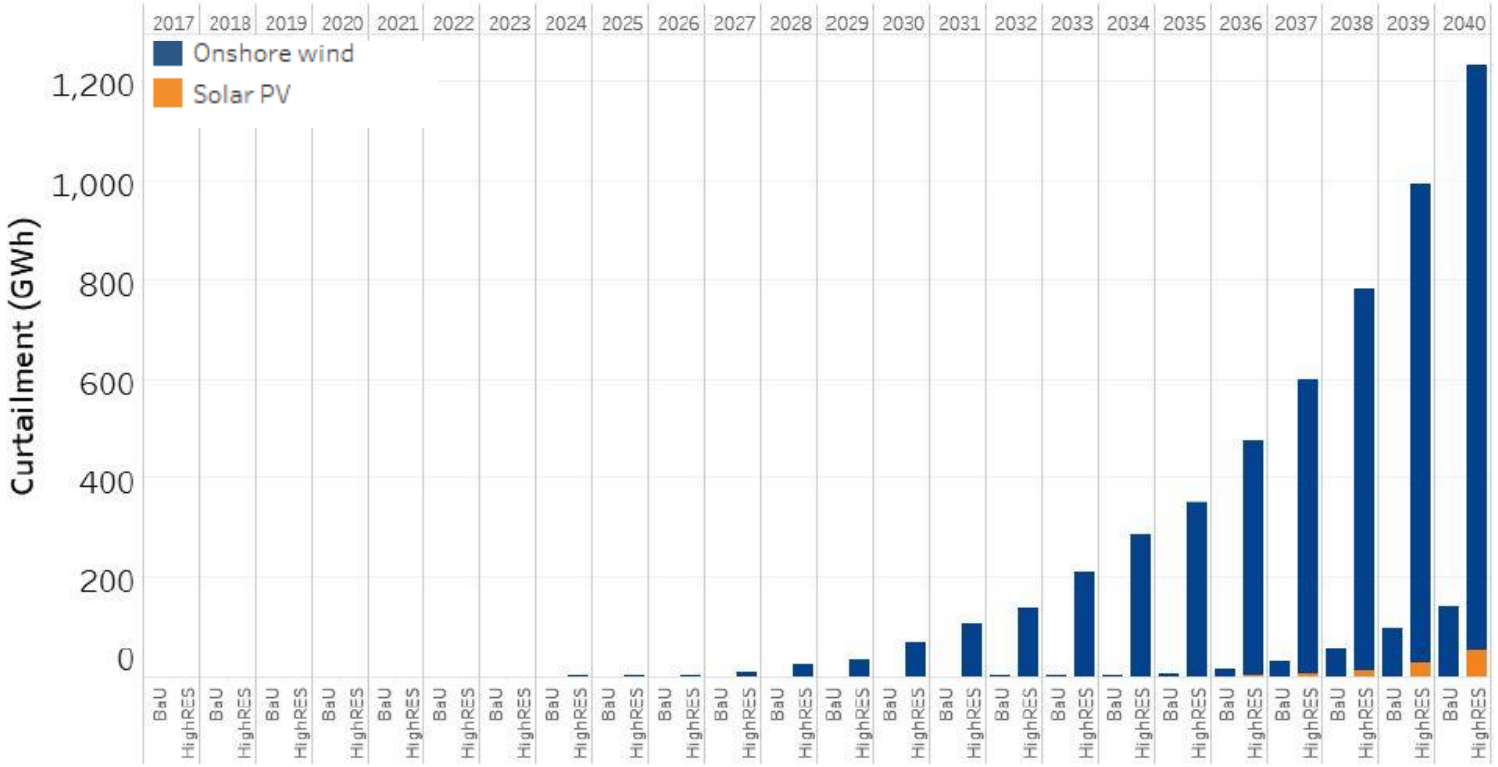
$$\text{Captured Price (€/MWh)} = \frac{\textbf{Yearly total revenues}}{\textbf{Yearly total generation}}$$

$$\text{Captured Rate (\%)} = \frac{\textbf{Captured Price}}{\textbf{Wholesale Price}}$$

Source: Pöyry Report to APREN

Model Results

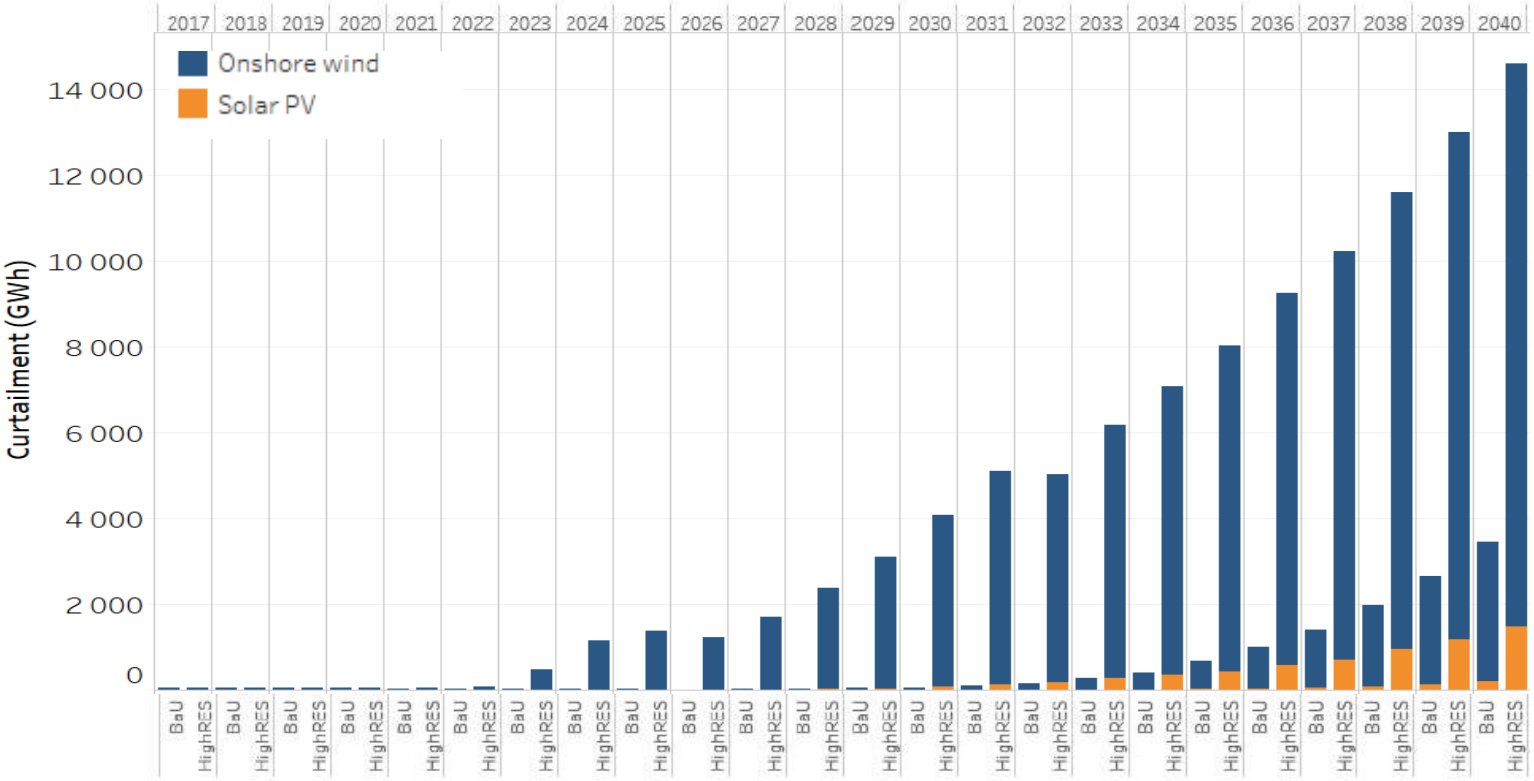
PT - Curtailments by technology [GWh]



Source: Pöyry Report to APREN

Model Results

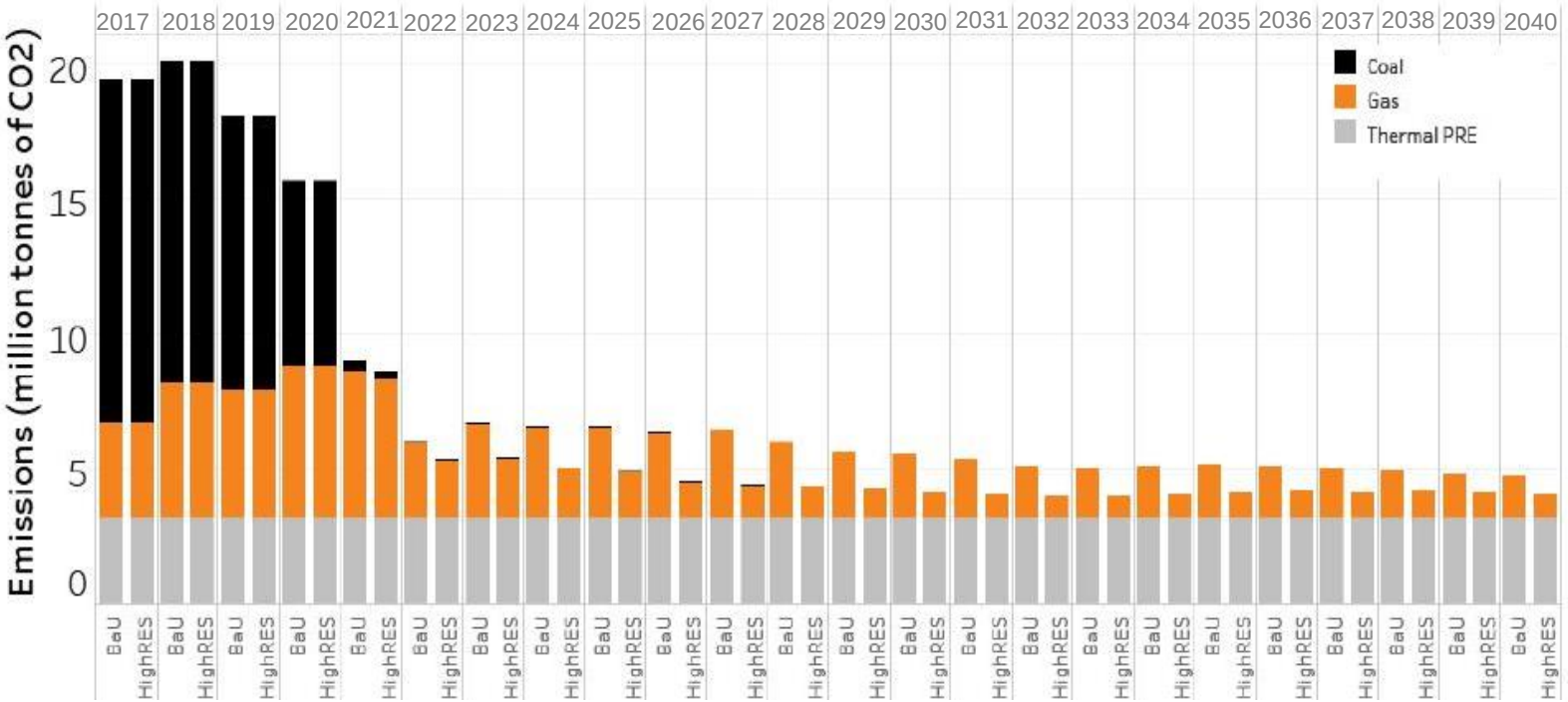
ES - Curtailments by technology [GWh]



Source: Pöyry Report to APREN

Model Results

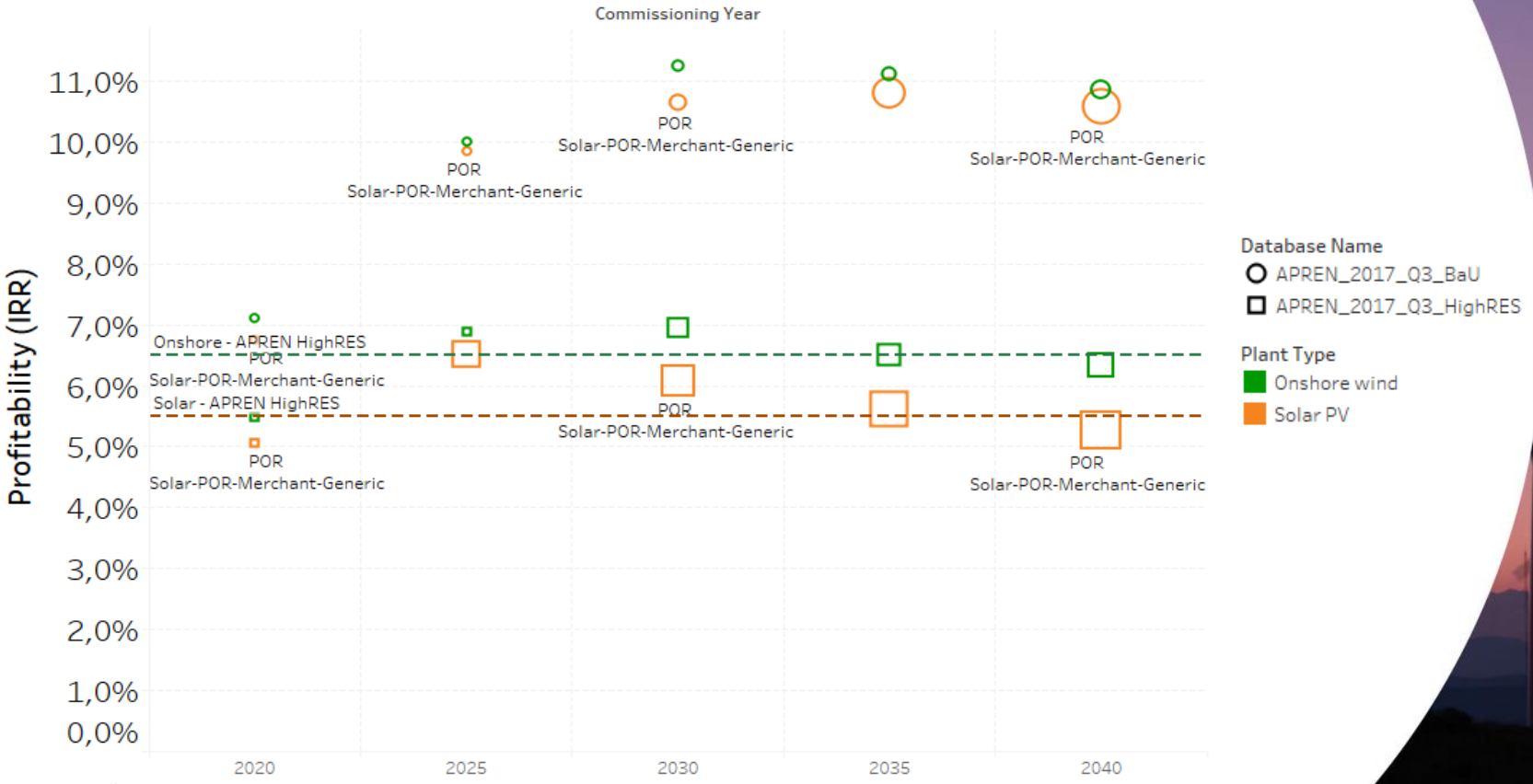
CO_2 emissions projections [million tones per year]



Source: Pöyry Report to APREN

Model Results

IRR Projections



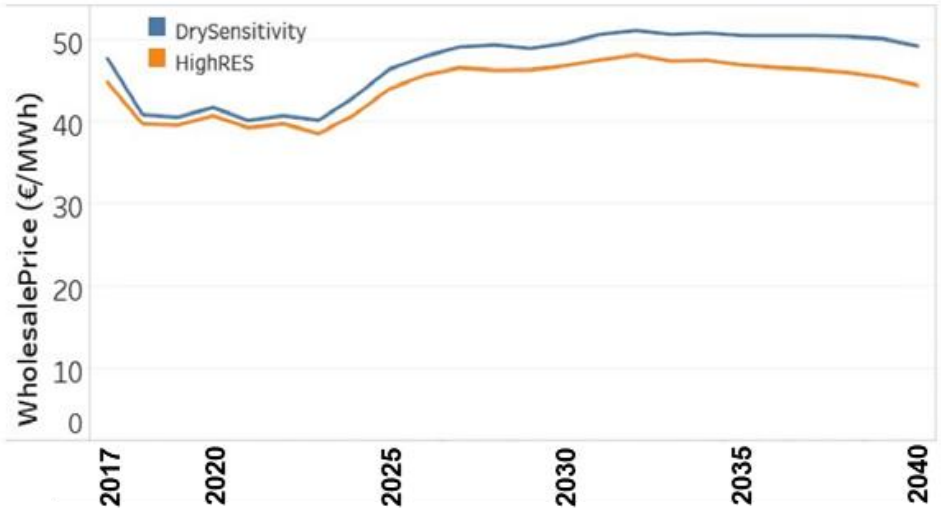
Source: Pöyry Report to APREN

Sensitivities over the HighRES Scenario

Sensitivities over the HighRES Scenario

Dry year

ASSUMPTION: HYDRO PATTERN OF 2012, WITH A HYDRO GENERATION OF 44% LOWER THAN THE AVERAGE FOR THE PERIOD 2008-2017



Results:

- **The system would be adequate** to face these dry conditions keeping a positive security margin
- As this sensitivity scenario has **higher wholesale prices**, **IRR would tend to increase**

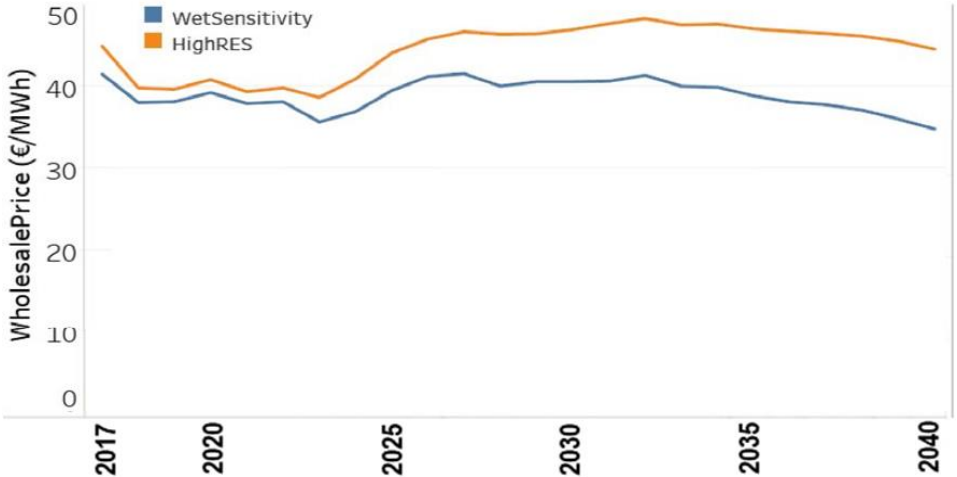
	Onshore Wind	Solar PV
$IRR_{HighRES,2040}$	6,5%	5,5%
$IRR_{Dry,2040}$	8,4%	7,2%

Source: Pöyry Report to APREN

Sensitivities over the HighRES Scenario

Wet year

ASSUMPTION: HYDRO PATTERN OF 2013, WITH A HYDRO GENERATION OF 27% HIGHER THAN THE AVERAGE FOR THE PERIOD 2008-2017



Results:

- The hydro resource availability growth will induce around **40% more curtailments** in 2040;
- As this sensitivity scenario has **lower wholesale prices**, **IRR would tend to decrease**

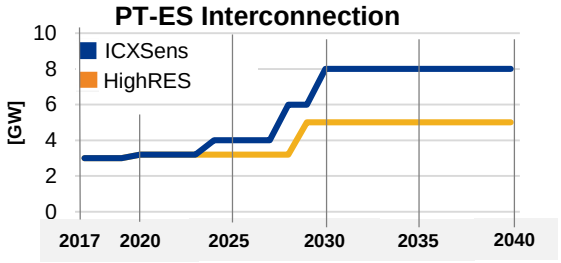
	Onshore Wind	Solar PV
$IRR_{HighRES,\ 2040}$	6,5%	5,5%
$IRR_{Wet,\ 2040}$	2,0%	2,9%

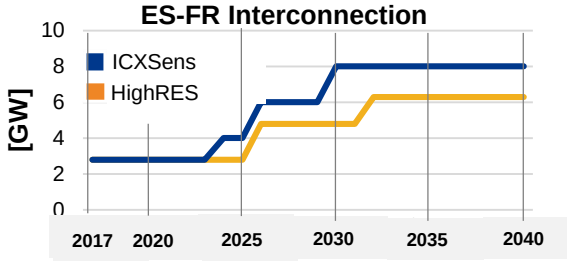
Source: Pöyry Report to APREN

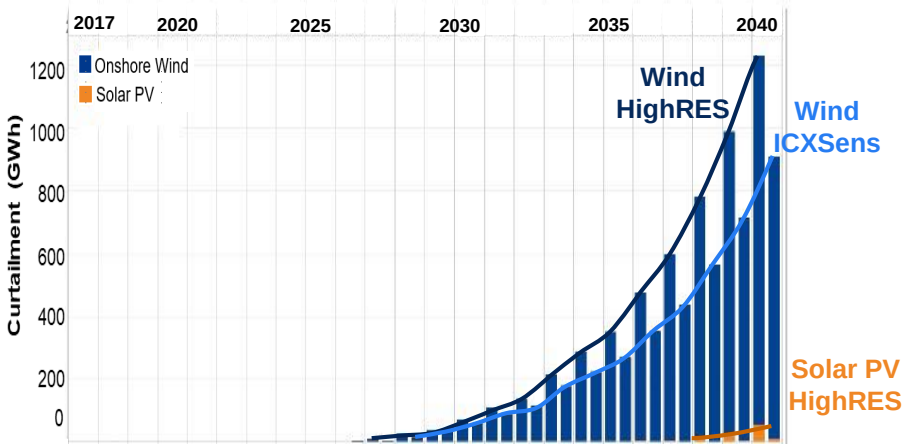
Sensitivities over the HighRES Scenario

Increased Interconnection (ICXSens)

ASSUMPTION ⇨







Results:

- This would **reduce curtailments** by 16% in 2030 and by 26% in 2040
- The difference in wholesale PV and Onshore Wind captured prices would not be significant

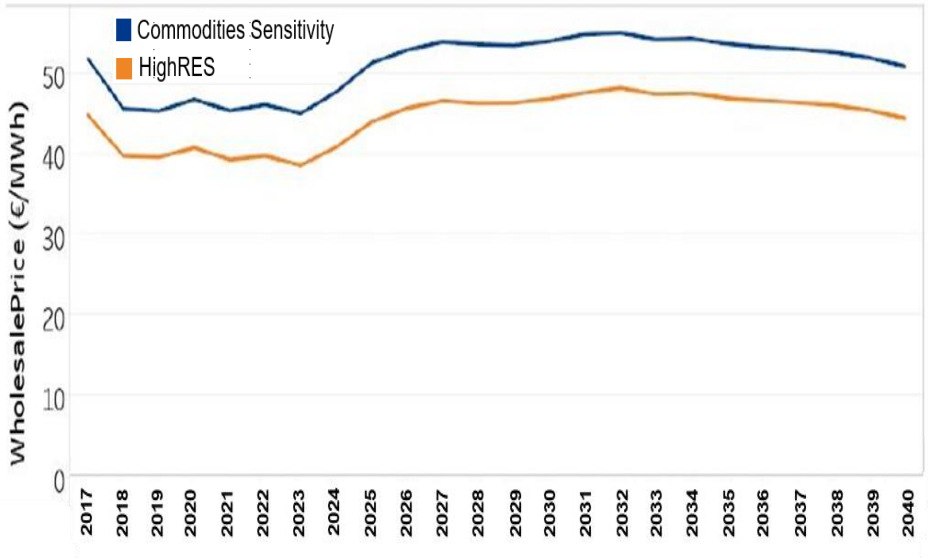
	Onshore Wind	Solar PV
$IRR_{HighRES,\ 2040}$	6,5%	5,5%
$IRR_{ICXSens\ 2040}$	7,1%	6,4%

Source: Pöyry Report to APREN

Sensitivities over the HighRES Scenario

Increased Commodity prices

ASSUMPTIONS: 20% INCREASE ON GAS, COAL AND CO_2 PRICE FROM 2017 ONWARDS



Results:

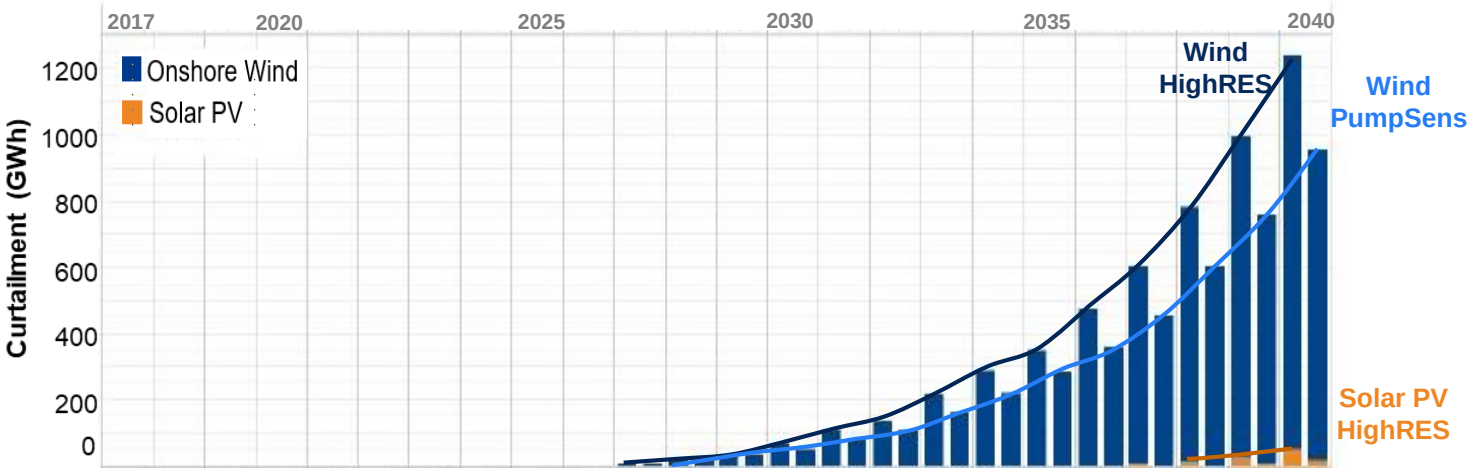
- This commodity price increase would lead to a **wholesale price growth of around 15%;**
- The results on **CO_2 emissions and curtailments** are not too different from the HighRES scenario

Source: Pöyry Report to APREN

Sensitivities over the HighRES Scenario

New pumped storage capacity in 2030 (PumpSens)

ASSUMPTION: INSTALLATION OF A PUMPED STORAGE PLANT OF 1000 MW IN 2030



Results:

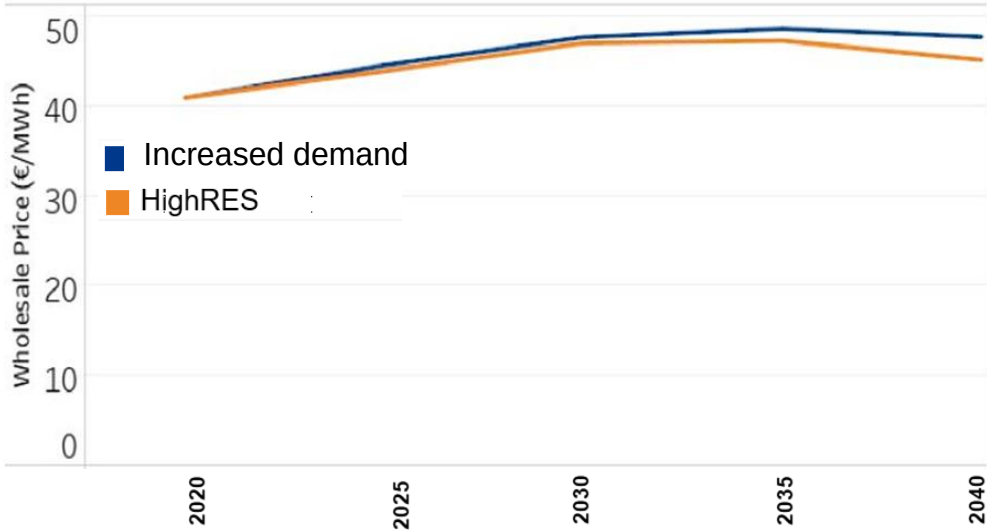
- **Wholesale price would be 0,2€/MWh higher**
- This would result in a **decrease in curtailed energy of 277 GWh** due to the new storage capacity introduced

Source: Pöyry Report to APREN

Sensitivities over the HighRES Scenario

Increased demand case

ASSUMPTIONS: USE OF A GREATER DEMAND GROWTH RATE IN THE DECADE 2030-2040 OF 1,6% PER YEAR REACHING 68TWh IN 2040 (AN ABSOLUTE 10% DEMAND INCREASE IN 2040)



Results:

- This sensitivity would result in **higher wholesale and captured prices**
- This would also result in a **decrease of approx. 35% (431 GWh) in curtailments for 2040**

	Onshore Wind	Solar PV
$IRR_{HighRES, 2040}$	6,5%	5,5%
$IRR_{Increased\ demand}$	8,2%	7,2%

Source: Pöyry Report to APREN

Sensitivities over the HighRES Scenario

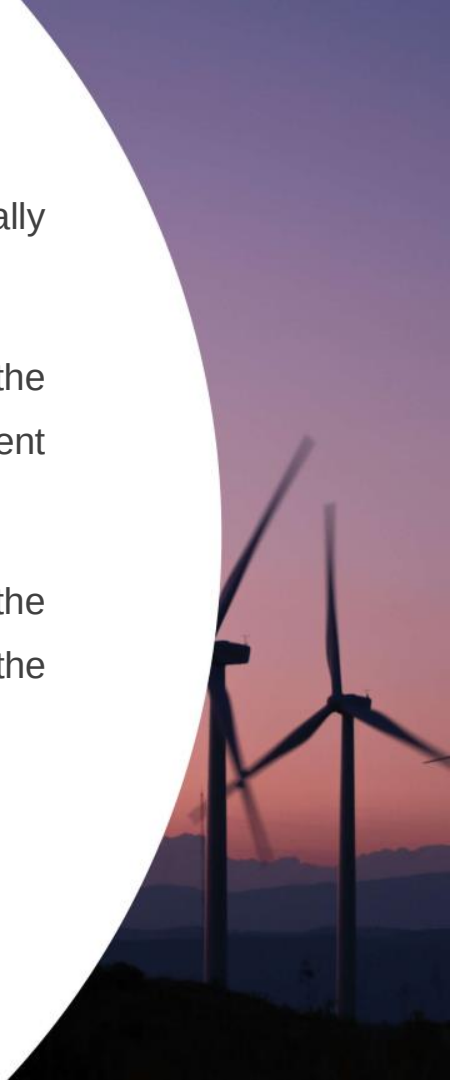
Summary of the applied sensitivities

Nº	Sensitivity	Description	CO2 emissions	Curtailments	Wholesale/ Captured Prices
1	Dry year	Using 2012 weather pattern	↑	↓	↑
2	Wet year	Using 2013 weather pattern	↓	↑	↓
3	Increased Interconnection	POR-SPA and SPA-FRA capacity	↓	↓	↑
4	Increased commodity prices	20% increase (gas, coal and CO_2)	↓	↓	↑
5	New pumped storage capacity in 2030	Installation of a 1000 MW plant	↓	↓	↑
6	Increased demand growth rate	Faster demand increase after 2030, reaching more 6TWh in 2040	↑	↓	↑

Source: Pöyry Report to APREN

Main results and messages (1/2)

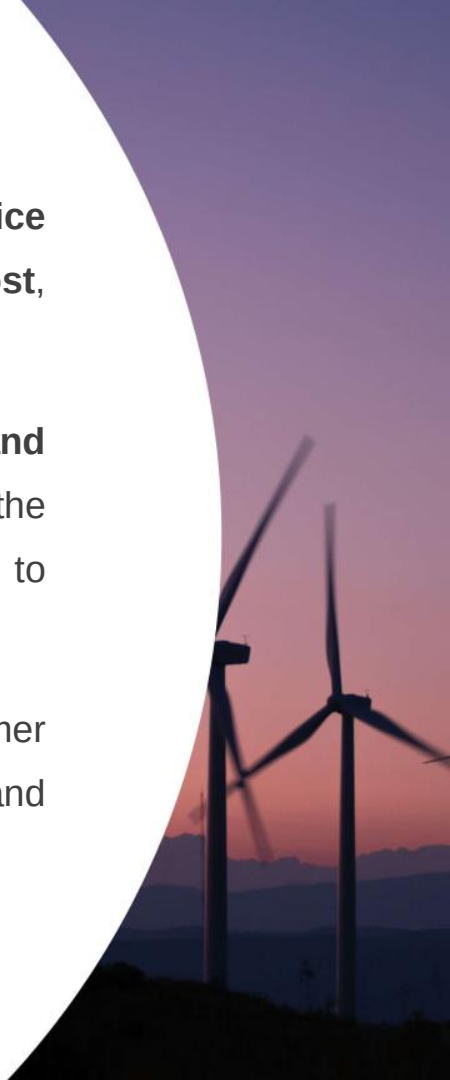
- ✓ The main investment difficulties for renewable technologies do not essentially result from technical or economic aspects, **but from Market design**;
- ✓ **Marginal markets are increasingly volatile,** thus failing to ensure the necessary predictability and stability to provide the appropriate investment signals, for both renewables and power/energy capacity reserve systems;
- ✓ **Nowadays renewables are already competitive** when compared with the marginal cost for fossil fuels and, even with a low CO_2 price, they will be the most cost-effective trajectory for the system's development;



Source: Pöyry Report to APREN

Main results and messages (2/2)

- ✓ Renewables do not need subsidies, **but competitive market and price stabilization mechanisms are necessary to foster a lower capital cost**, therefore reducing the system's overall expenditures;
- ✓ **It is necessary to create mechanisms for the regulation and encouragement of power plants** capable of providing firm capacity to the System services, mainly for technologies that provide flexibility and storage to the system;
- ✓ **Market aggregators must provide System services** (active consumer behavior, EV's smart charging, distributed storage), resulting in a smart demand side reaction to the resource availability and/or to the market price dynamics.



Source: Pöyry Report to APREN

Thank you!

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