Outlook on Power Market Adequacy
Central Western Europe

May 2019

For Discussion Purposes

Study performed for ENGIE

TRACTEBEL

ENGIE

Advisory and Advanced Analytics

Capacity Outlook: More than 90GW of today's reliable thermal capacity closed by 2030. Intermittent Wind and PV will double, increasing by more than 140GW.

Nuclear

Policy driven

*Nuclear phase-out in **DE** (end of 2022) and **BE** (2025)*

*Nuclear in France according to **RTE Ampere Scenario***

(63.1 GW today and 48.5 GW in 2030)

RES Development

Entso-E TYNDP 2018 : Decentralized Generation

Capacity installed in EU14 (modelling scope):

- ***PV** 108 (350) GW in 2018 (2030),*
- ***Wind Onshore** 133 (191) GW in 2018 (2030),*
- ***Wind Offshore** 16 (58) GW in 2018 (2030)*

Coal-based Generation

Policy driven

*Coal is phased-out in **FR** (end of 2021), **IT** (2025), **UK** (non-CCS, 2025) and **NL** (2029).*

Technical lifetime of 40y in other countries (economic extensions not allowed).

Gas-based Generation

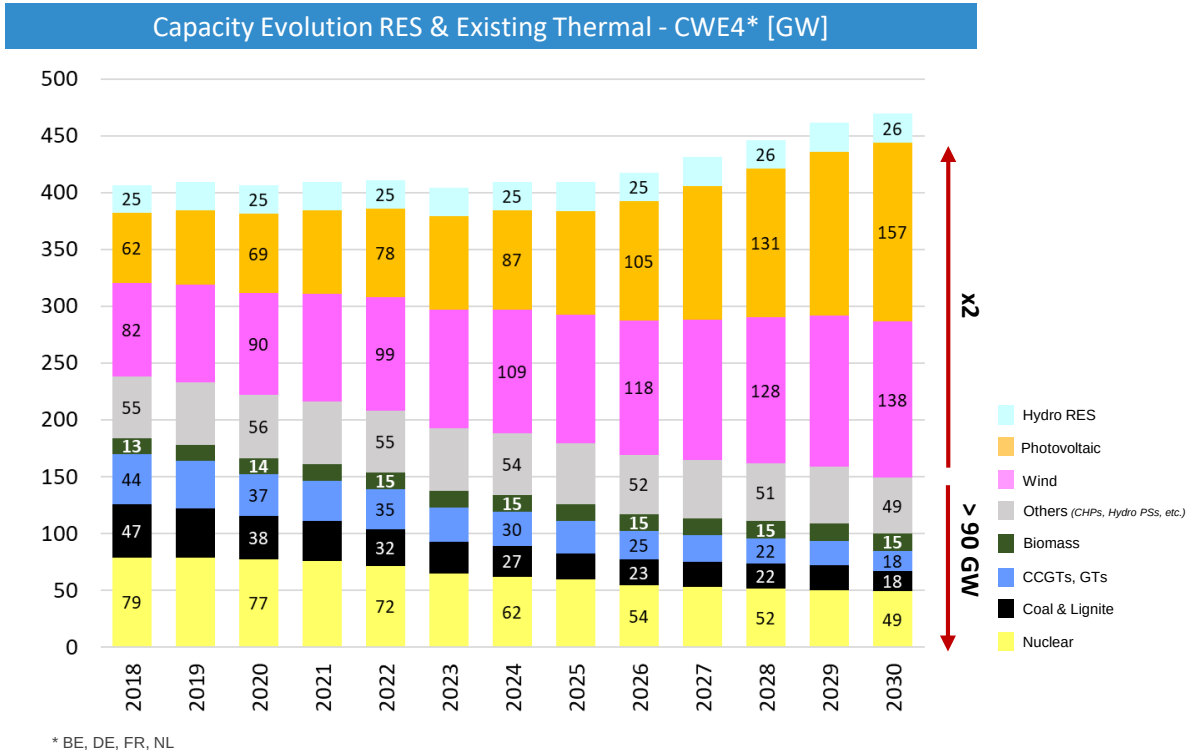
Technical lifetime

Operation of existing assets, based on technical lifetime: CCGT 20y, GT 20y . A sensitivity is foreseen with economic asset management: lifetime extension, reconversion, brownfield development)

Demand & Peaks

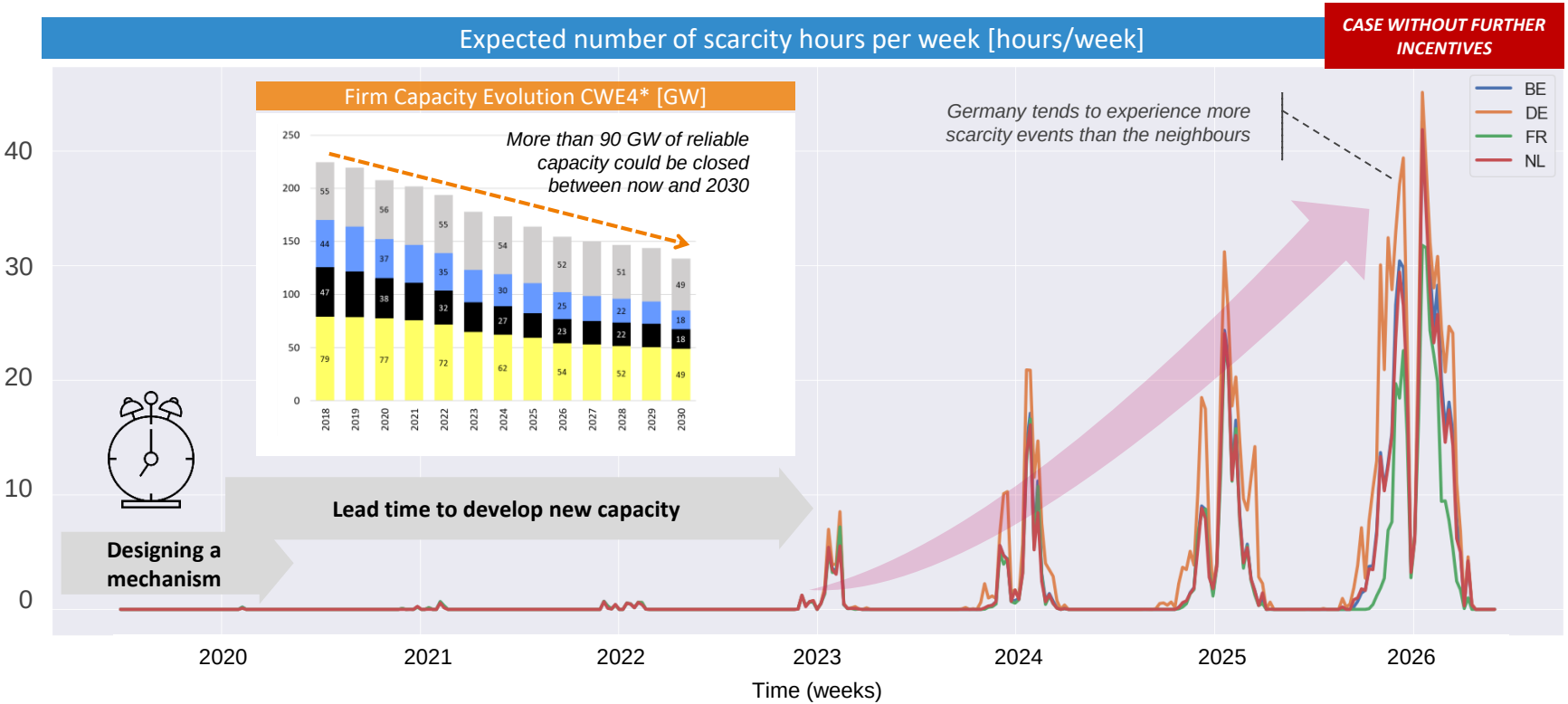
IEA WEO 2017 New Policies Scenario

CAGR 2018-30 : ~0.35% (both for annual and peak load)



* BE, DE, FR, NL

Without further incentives to keep existing or to build new reliable capacity, scarcity events tend to happen simultaneously across countries as of winter 2022-23.



Power markets are highly interconnected. There are net providers and net importers of capacity at peak.

CASE WITHOUT FURTHER INCENTIVES

1 Probabilistic Approach

Accounting for meteorological uncertainty (wind & PV generation, water availability, demand) & unforeseen thermal power unavailability

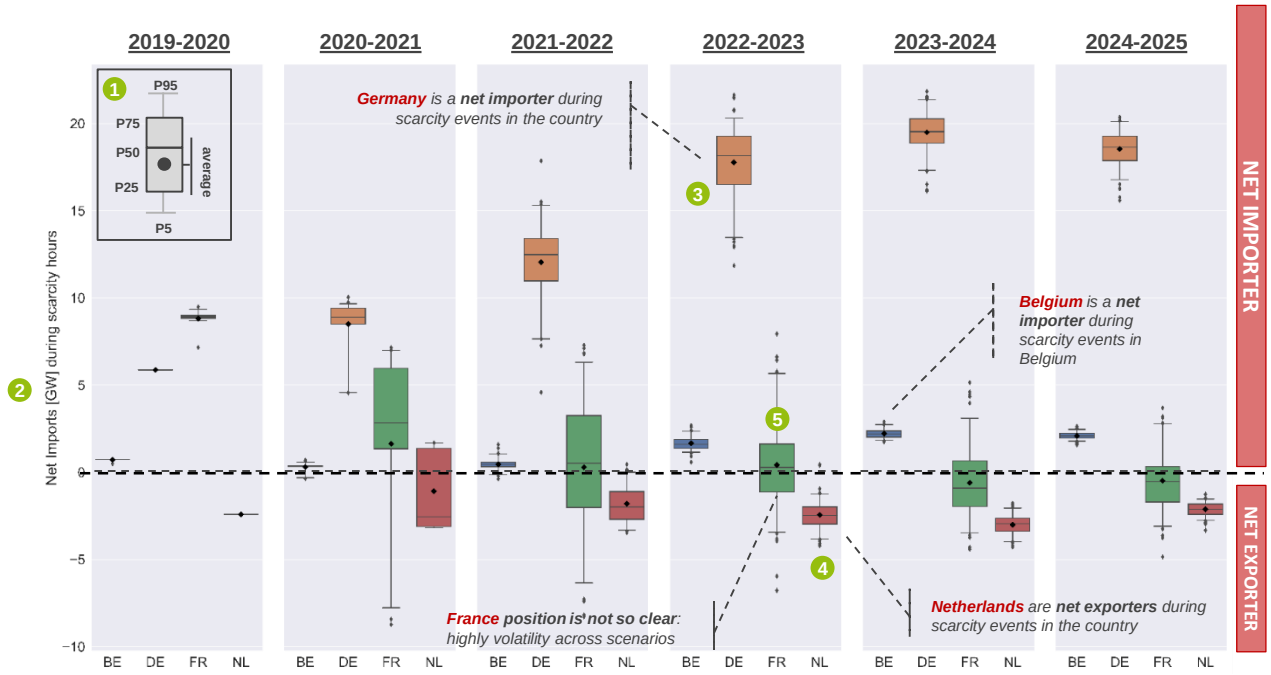
2 Balances during scarcity moments

3. **Germany and Belgium** are net importers of reliable capacity
4. **The Netherlands** are net providers of reliable capacity
5. **France** can be either net importer or exporter depending on the situation

Interconnections vs. Generation

We find that interconnection capacity is often not saturated. Hence, generation and not transmission capacity tends to be the scarce resource.

distribution of the exchange balance per country in scarcity moments [GW]



Simplified version for communication purposes in backup

CWE4 Adequacy Outlook - **Key Messages**

- **Outlook on power system adequacy in Central Western Europe (BE, DE, FR,NL): a regional issue**
  - significant baseload capacity is leaving, driven by implemented or announced nuclear and coal phase-out policies
  - more renewables are needed to meet climate objectives, but also creating flexibility and reliability challenges
- **National and regional adequacy studies do not give comfort, as they only provide a partial picture**
  - they contain little or no information on effective use of transmission capacity and availability of foreign generation capacity
  - the outlook especially on nuclear and coal capacity is highly uncertain and thus varying a lot across studies
  - relevant years are not always considered in their assessment
- **Our assessment strongly indicates that adequacy issues appear as of winter 2022/23**
  - in highly interconnected markets, adequacy is a regional concern: all countries considered face adequacy issues simultaneously
  - hence, it appears that generation rather than transmission is the scarce resource at peak
  - to allow cross-border capacity sharing, coordination between national authorities is thus essential
- **Measures to incentivize market based investment in generation capacity have thus to be taken immediately**
  - Ad hoc out of market solutions will not solve the issue on a sustainable basis
  - **We should seek a market based regional solution**

Appendix

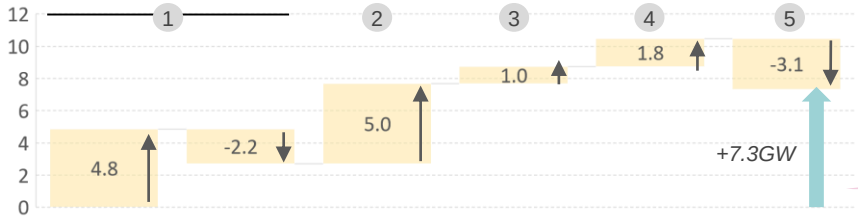
Recent Developments

Sensitivity Analysis: Recent information on coal (DE) and nuclear (FR) does not change the view that **adequacy issues appear as of Winter 2022-23**.

Recent Coal and Nuclear Developments

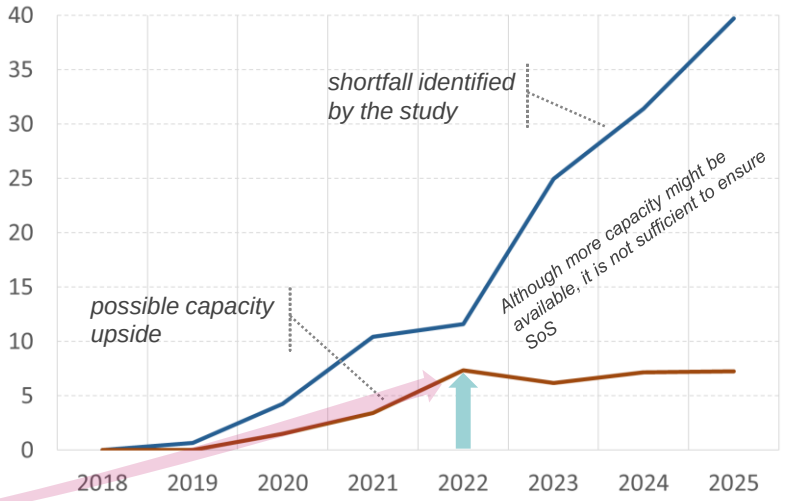
1. Proposal on 26/01 of the Coal Commission for phasing out coal and lignite in Germany: updated view for the year 2022.
2. Possible increase of the Climate Reserve (Lignite) in Germany, as a result of the proposed coal phase-out.
3. Possible reconversion of Coal CHP to Gas CHP based on existing CHP law, as a result of the coal phase-out.
4. Announcement on 18/01 of the French government regarding nuclear capacity (PPE). 50% target postponed to 2035.
5. Uncertain nuclear availability. Risk of lower availability driven by maintenance with extended lifetime. A 5% lower availability is considered here.

Zoom on 2022:



Capacity availability risk vs. Investment needs [GW]

Total at CWE4 level



Recent studies only provide a partial view on adequacy.

Studies under the Analysis Scope

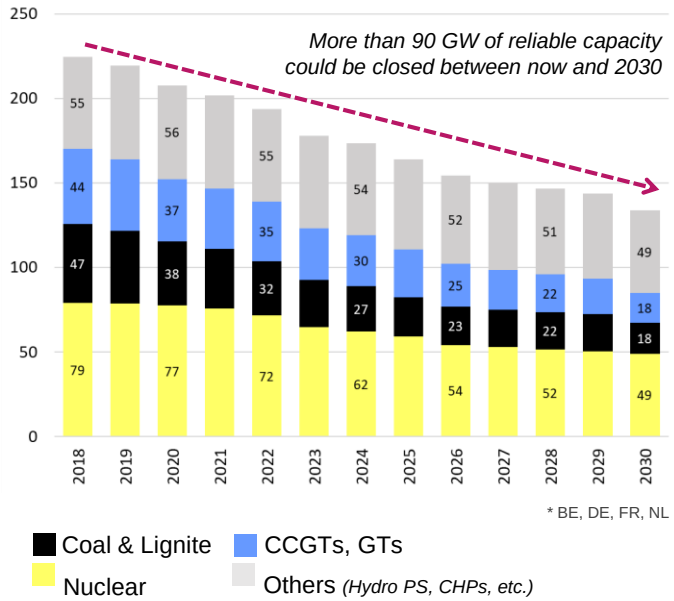
Year	Title and Institution
2015	*Security of supply in Germany and its neighboring countries*
2016	*Adequacy & Flexibility Study 2017-2027*
2017	*Medium Adequacy Forecast 2017*
	Electricity Scenario for Belgium towards 2050
2018	*2° Pentalateral Report*
	Bilan Prévisionnel 2017
	Medium Adequacy Forecast 2018

Key Insights

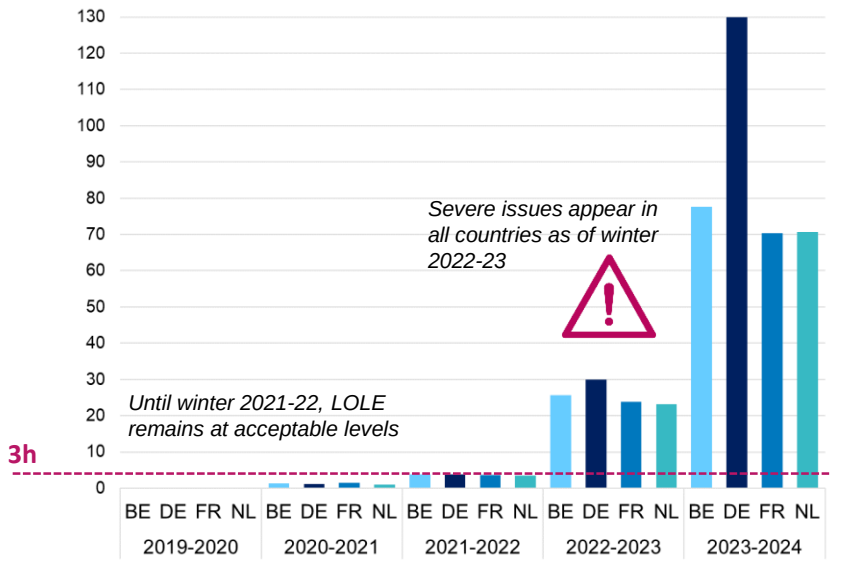
- No study assesses the adequacy of a country in isolation. Market interactions are in principle considered consistently, but there is **little or no information on effective use of transmission capacity** and availability of foreign generation capacity at peak.
- Studies are performed at different moments in time, explaining at least partially a **diverging view on available capacity**. In fact, the outlook especially on nuclear (FR) and coal (phase-outs) is highly uncertain.
- **Studies do not necessarily consider all relevant years.** Adequacy studies should consider all years between now and 2025, since important capacity reductions are foreseen/expected.

Without further incentives to keep existing or to build new reliable capacity, severe adequacy issues appear as of **winter 2022/23**.

Capacity Evolution Existing Thermal & RES - CWE4* [GW]



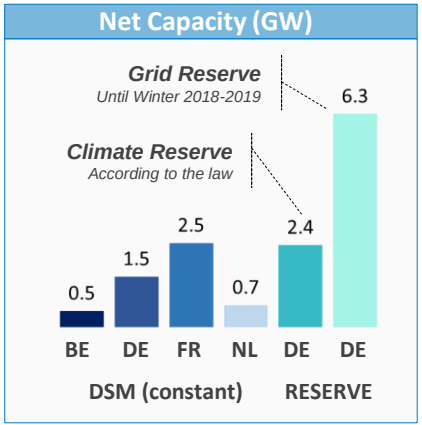
Expected scarcity hours during winter periods [hours/year]



Energy Not Served [GWh/y]

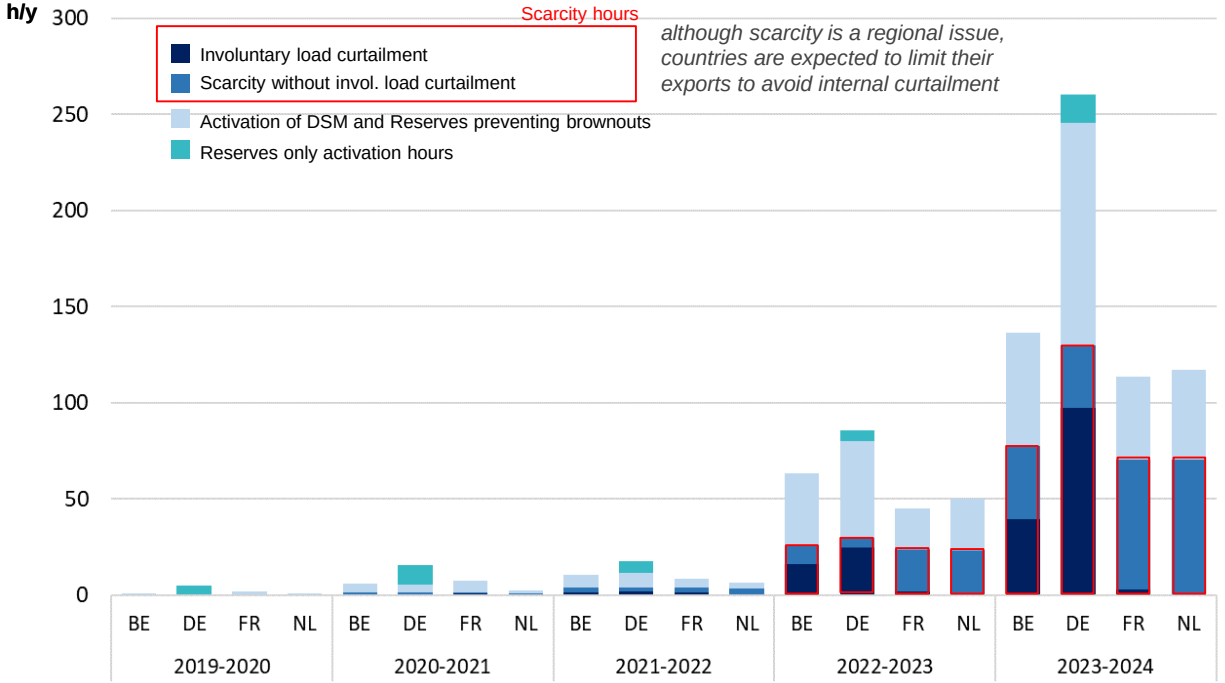
	19/20	20/21	21/22	22/23	23/24
BE	0	0	0.3	13	50
DE	0	0	1.1	94	342
FR	0.1	1.6	1.2	4.5	7
NL	0	0	0.3	0.3	0.3

Reserves and DSM contribution to System Adequacy



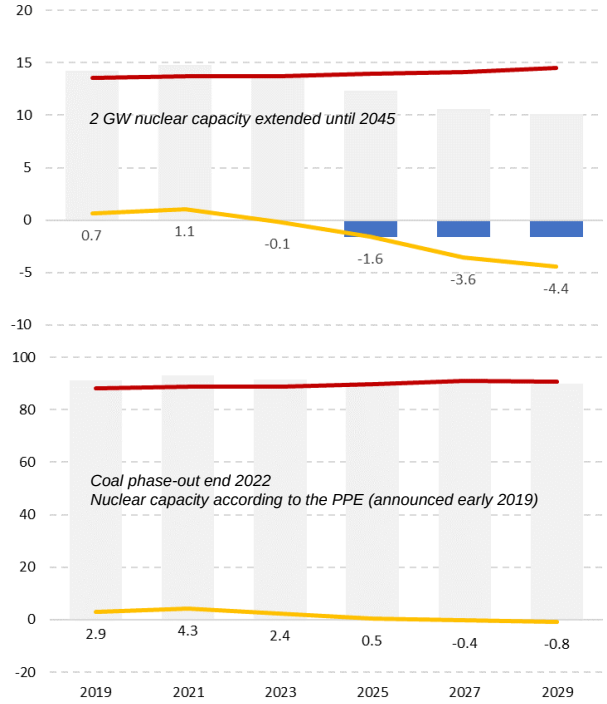
DSM potential available at peak based on *SEDC - Smart Energy Demand Coalition: « Explicit Demand Response in Europe - Mapping the Market 2017"*

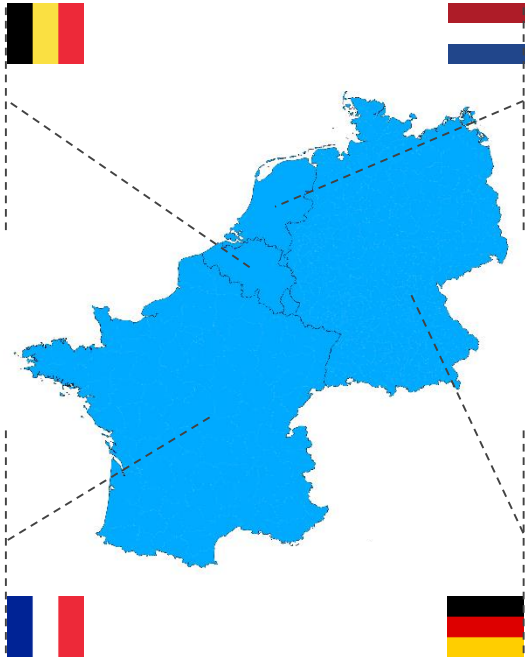
Reserve and DSM activation hours

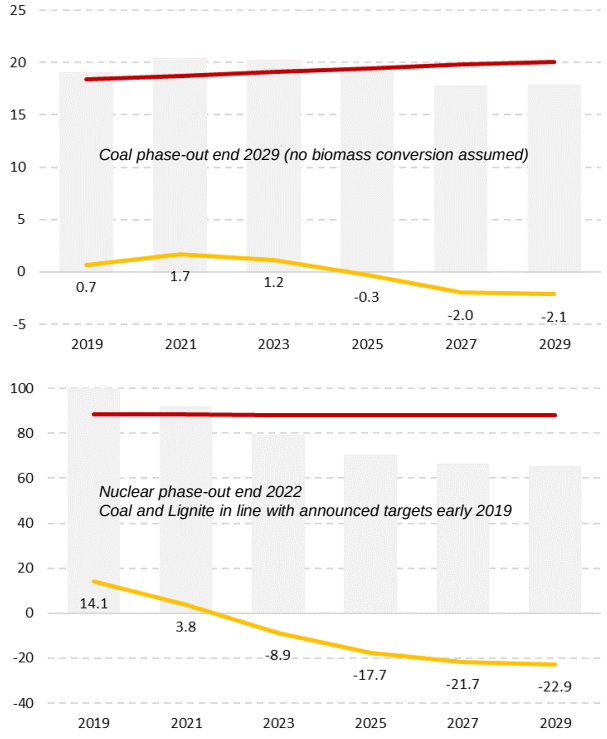


Overcapacity in CWE4 is quickly fading away

Strong need for new reliable capacity expected as of 2022-23





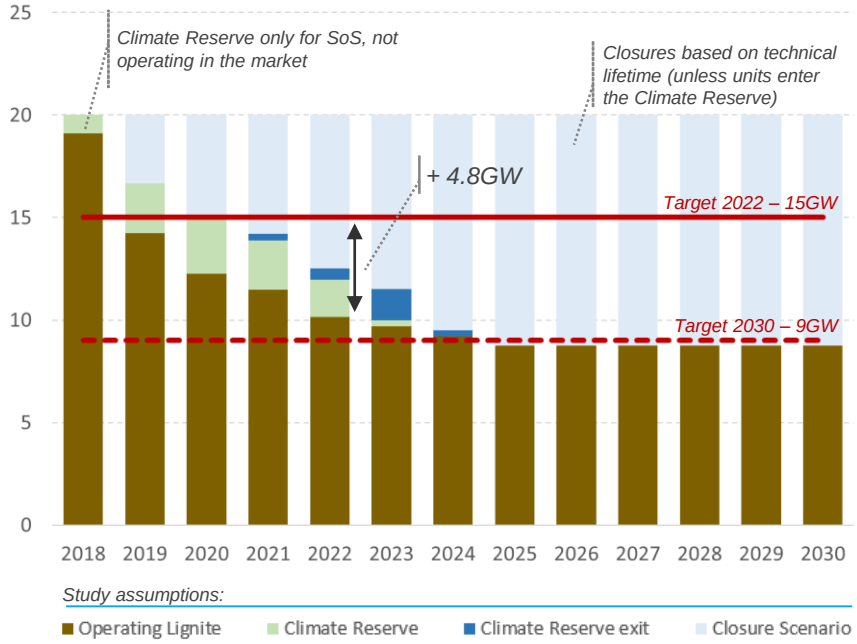


Total Reliable Capacity | Peak Load | Margin | Capacity needs projected by Elia **[GW at peak]**

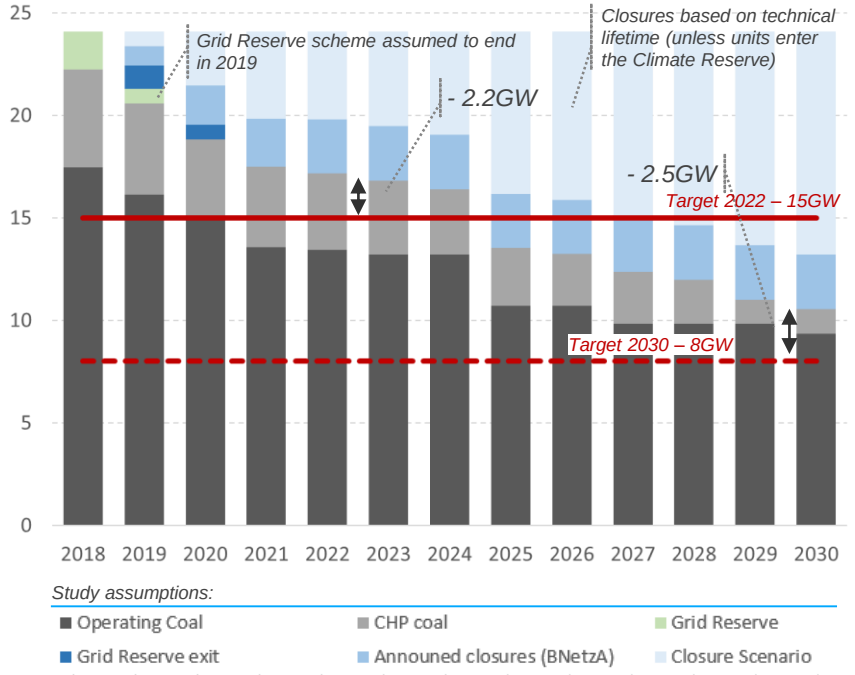
The German Coal Commission announced on 26/01/2019 targets for operating coal and lignite capacity by 2022&2030, with a complete phase-out by 2038 at the latest.

To what extend will current reserve schemes be extended to retain capacity leaving the market for SoS?

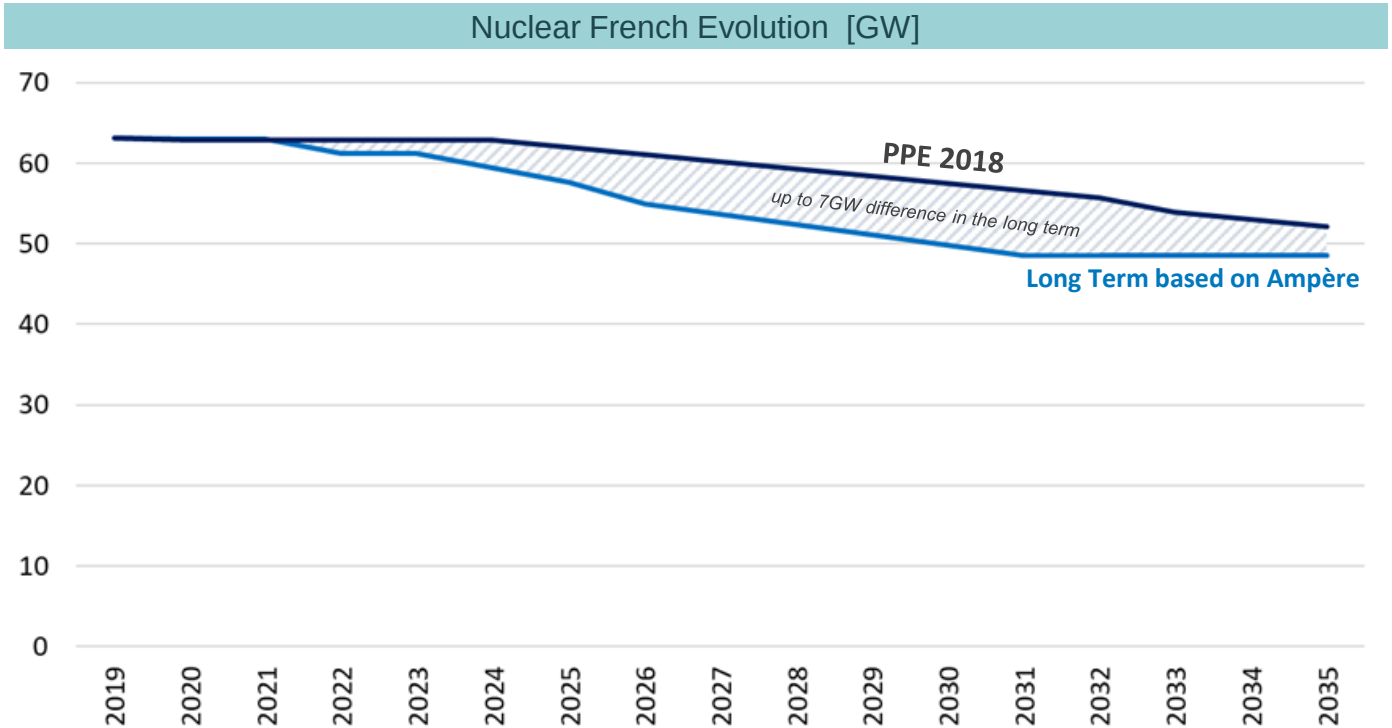
Lignite Capacity [GW]



Coal Capacity [GW]



The French Government published on 25/01/2019 new long term projections for nuclear capacity (PPE).

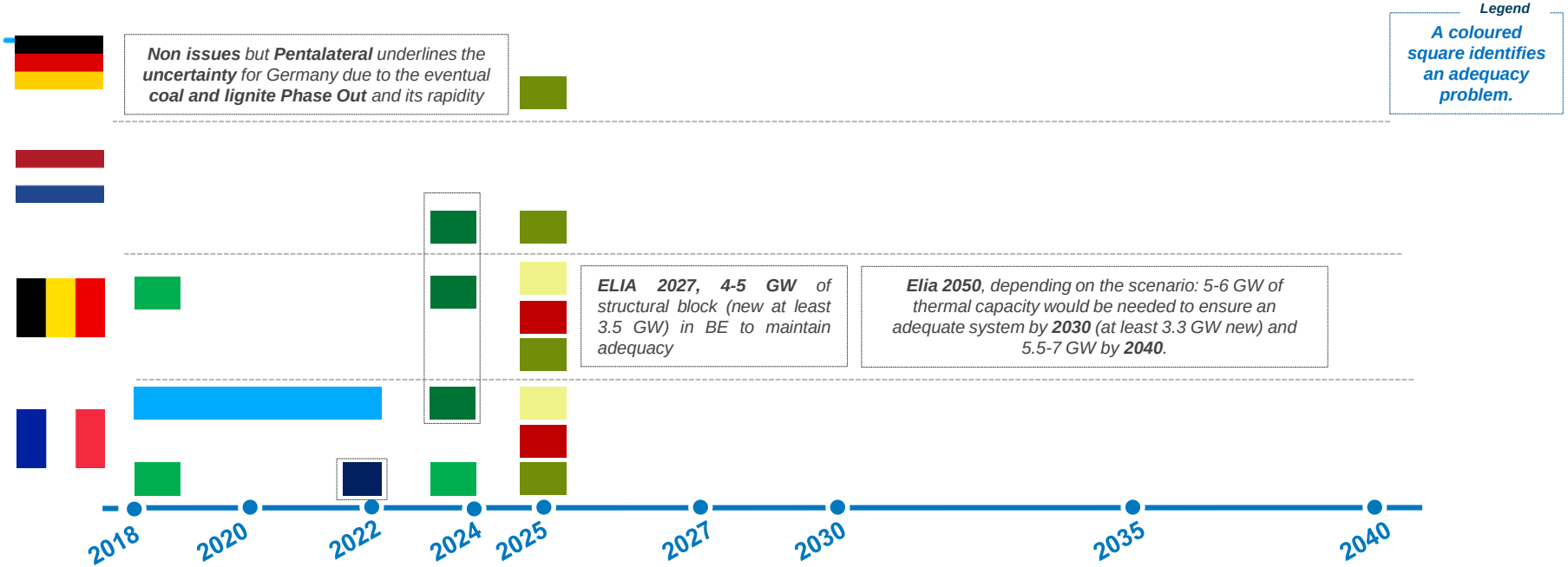


Ampère Scenario *aimed at reaching the target 50% Nuclear in the French production mix by 2030* ***(BP 2017).*** *The new PPE delays this target to 2035*

Agenda

- Recent studies on power system adequacy
- Study assumptions
- View on adequacy
- Detailed view on exchanges at scarcity
- Recent developments

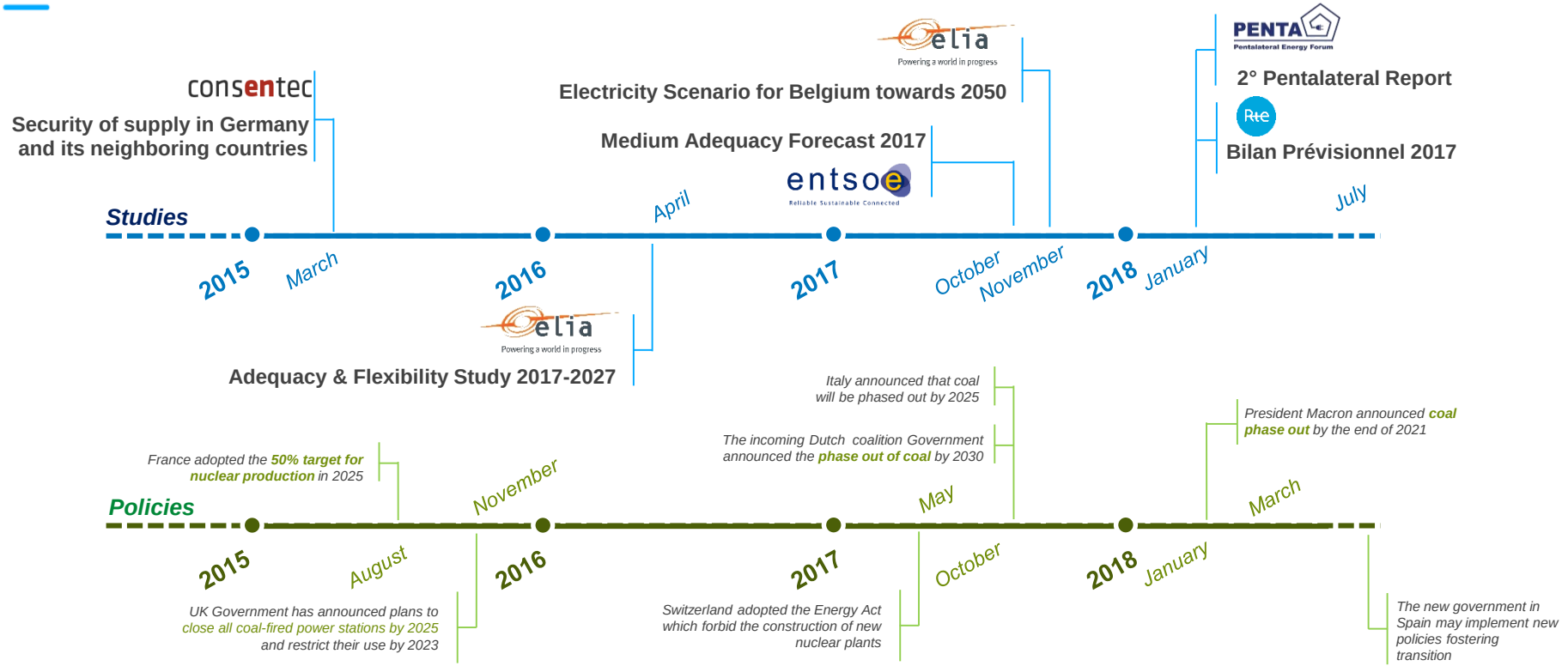
External studies provide a diverging view on adequacy.



- **Pentalateral Energy Forum,** Basecase + *LT Sensitivites: 1. Economical Decommissioning (-5.5 GW thermal), 2. Environmental Decommissioning (Coal Phased out)*
- **Consetec**
- **RTE**, 1. Coal phase out & 10y revision visits for 12m; 2. High Consumption + *3. Coal phase out & 40y old nuclear not extended*
- **MAF 2017** (only looks at years 2020 and 2025)
- **MAF2018,** Low Carbon Sensitivity (only looks at years 2020 and 2025)

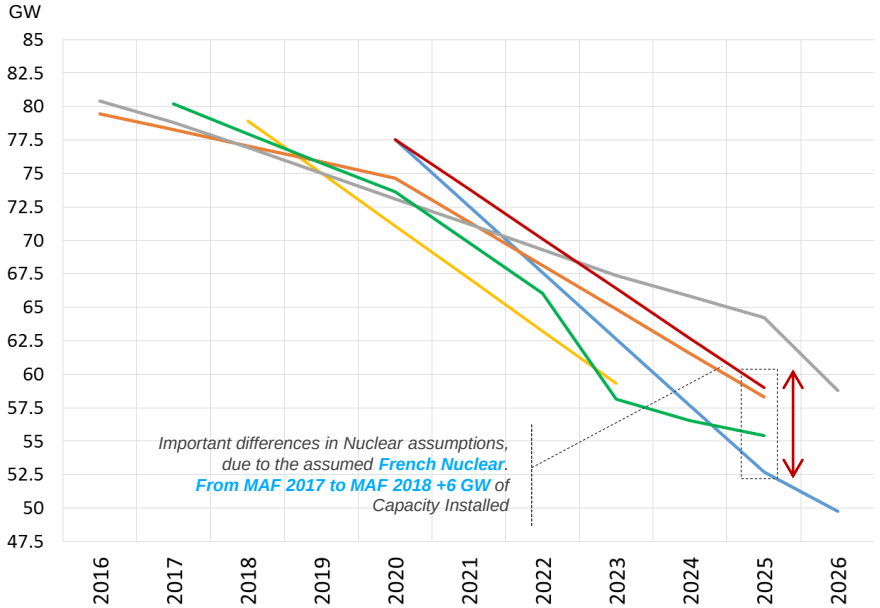
Studies considered

Possible differences in adequacy assessment can be driven by different timings

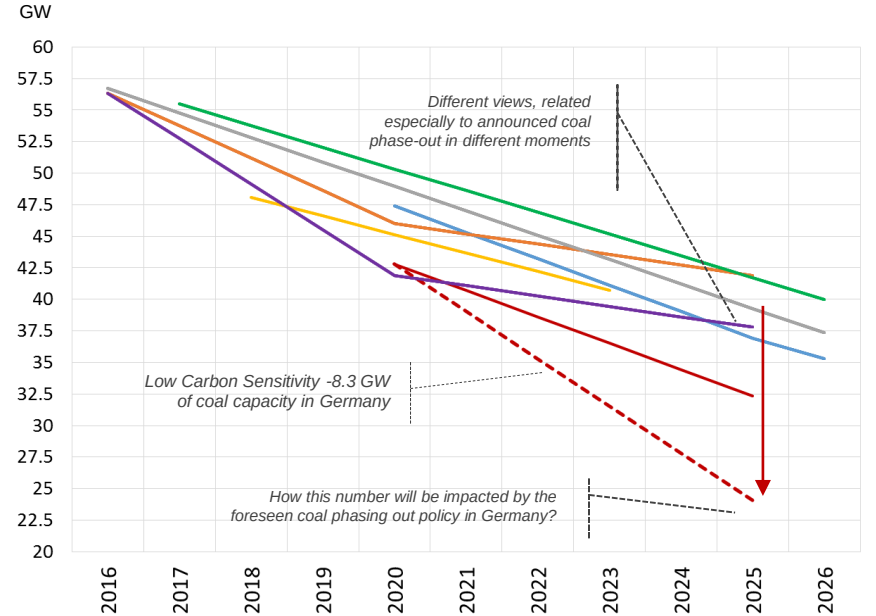


The view on future nuclear and coal capacity has changed significantly over time – and will continue to do so in the coming years.

Nuclear CWE4



Coal & Lignite CWE4



MAF 2018 | MAF 2017 | SO&AF 2015 | ELIA 2050 | Pentalateral | RTE BP2017 | ELIA2027

All studies consider interconnected systems, but there is little information on effective use of transmission capacity at peak.

	MAF 2018	MAF 2017	ELIA - 2017/2027	ELIA towards 2050	2° PLEF Report	RTE – BP 2017	CONSETEC 2015
Countries & Geo Scope	Europe + Turkey	Europe + Turkey	*Focus on Belgium, EU19*	*Focus on Belgium, EU22*	Focus on *Pentalateral* Countries, EU + Turkey	Focus on France Interconnected Countries)	France, Benelux, Italy, Germany, Switzerland, Austria, Czech Republic, Poland, Nordics
Current Installed Capacity in CWE4	Nuclear: 78 (59) GW Coal: 43 (33) GW in 2020 (2025)	Nuclear: 77 (53) [38] GW Coal: 47 (37) [29] GW in 2020 (2025) [2030]	Nuclear: 80 (76) [56] GW Coal: 56 (42) [38] GW in 2016 (2020) [2025] Data from **SO&AF 2015**, for **CWE4** updated with national reports	Nuclear: 80 (52) [30] GW Coal: 56 (30) [15] GW in 2016 (2030) [2040] In line w/ **MAF2017**, for FR: **BP2016**,	Nuclear: 78 (59) GW Coal: 48 (41) GW in 2018 (2023) In line w/ **MAF2017**, for FR: **BP2017**, (exception load data)	Nuclear: 80 (49) GW Coal: 55 (24) GW in 2017 (2035) In line w/ **MAF2017** and the **2° PLEF**	**SO&AF 2014**
Sensitivities Scenarios	**Low Carbon Sensitivity Scenario:** ~23 GW removed from the 2025 base case scenario	**Mothballing**: Capacity at risk of being not available for economic or policy reasons excluded	1) **GRID**: + 2GW or isolated 2) **High RES**: 1.5*BC growth 3) Coal Phase out 4) Low Capacity for neighbors	1) **Decentral**: prosumers and high electrification. 1bis) High EV and hybrid HP 2) **high RES**: achieving long term climate policies. 2bis): +30 GW in interconnection in EU	1) Decom. due to econ reasons 2) Decom. due to envi reasons 3) Reduced nuclear 4) Additional Flexibilities 5) Grid sensitivity	1) Coal Phase Out by 2022 2) No extension of nuc. park 3) 1) + nuc. extended 4) 1)+ no nuc. extended 4bis) High cons., low cons., PPE High; PPE High + DSM	
Model	ANTARES, Bid, GRARE, Plexos, PowrSym	ANTARES, Bid, GRARE, Plexos	ANTARES	ANTARES	ANTARES, PowrSym	ANTARES	Cross-Border Market Simulation Model
Meteorological Uncertainty	Climate conditions based on 34 historic years: **Climate Database Entso-e PECD**	Climate conditions based on 34 historic years: **Climate Database Entso-e PECD**	(40y) hrs wind prod timelines, PV schedules, daily temp. records, monthly column of hydro prod; availability parameters of thermal park	In line w/ **MAF2017**	In line w/ **MAF2017**	200 chronicles for Wind, PV and Temperatures (**Meteo France:** *ifferent from MAF*) and 6à chronicles for Hydro and Thermal	Weather year data 2010,2011,2012
Contribution of foreign capacity	*Data by TSOs are the max simultaneous import and export capacity per country*		*Max simultaneous import capacity of 6,5 GW.*	*Same as the Adequacy and Flexibility 2017-2027 ELIA study*		*From 2 to 15 GW of import capacity (at least 8GW in 50% of cases)*	
Interconnections	Development in line with **TSOs** projects Flow based Approach	Development in line with **TSOs** projects for 2020	4,5 (6.5) GW in 2017 (2027). Sensitivities: up to 8,5 GW 2027, isolated 2017-2027)	Based on the **TYNDP2016** + **Federal Development Plan**	**MAF2017** Flow Based Approach SR NTC LR	**TYNDP2016** Flow Based Approach	**SO&AF 2014**

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Modelling approach

Input
Technical and scenario-specific

Demand
- Yearly demand in line with the scenario framework
- Hourly profiles in line with historic data
- Fixed, not sensitive to prices
- Some DSM possible

Supply
- Current power plant list, including announcements on closures, mothballing and new capacity
- For each plant: net capacity, thermal efficiency
- Scenario-specific fuel and CO2 prices
- Policy driven capacity: RES development, coal and nuclear phase-out
- Existing Gas capacity (GTs and CCGTs based on technical lifetime

Asset Management
- No endogenous investment
- No endogenous management on existing assets

1

Market Representation
Competitive Demand – Supply interaction

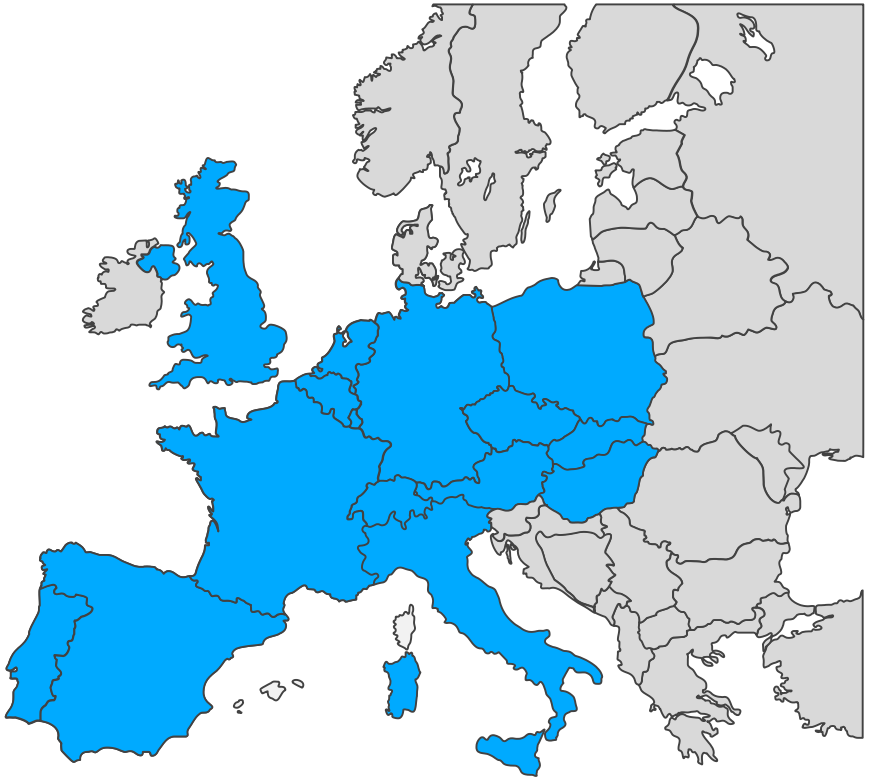
Short term stochastic dispatch model
- Short term dispatch according to merit order
- Accounting for uncertainty in water inflows (important for countries with substantial hydro) and different wind, PV and demand conditions, random thermal power plant outages
- Hourly granularity
- Coupling of 14 EU countries (NTC approach)

2

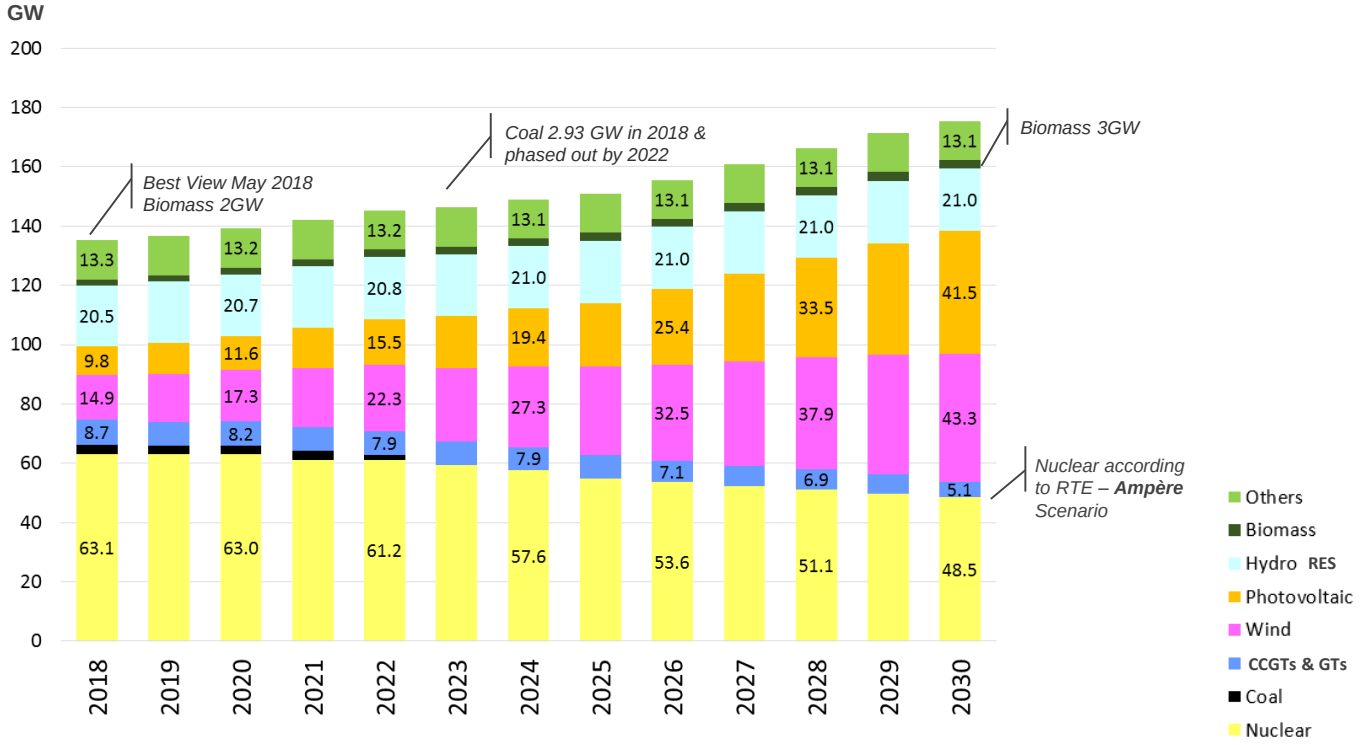
Output
Market outcome

- Hourly generation mix
- Hourly Cross-border flows
- Hourly power prices
- Scarcity events, prices reaching the cap

Geographical Scope: although focusing on Belgium, France, Germany and the Netherlands, the study considers the interaction of 14 countries.



Existing Thermal and RES Development



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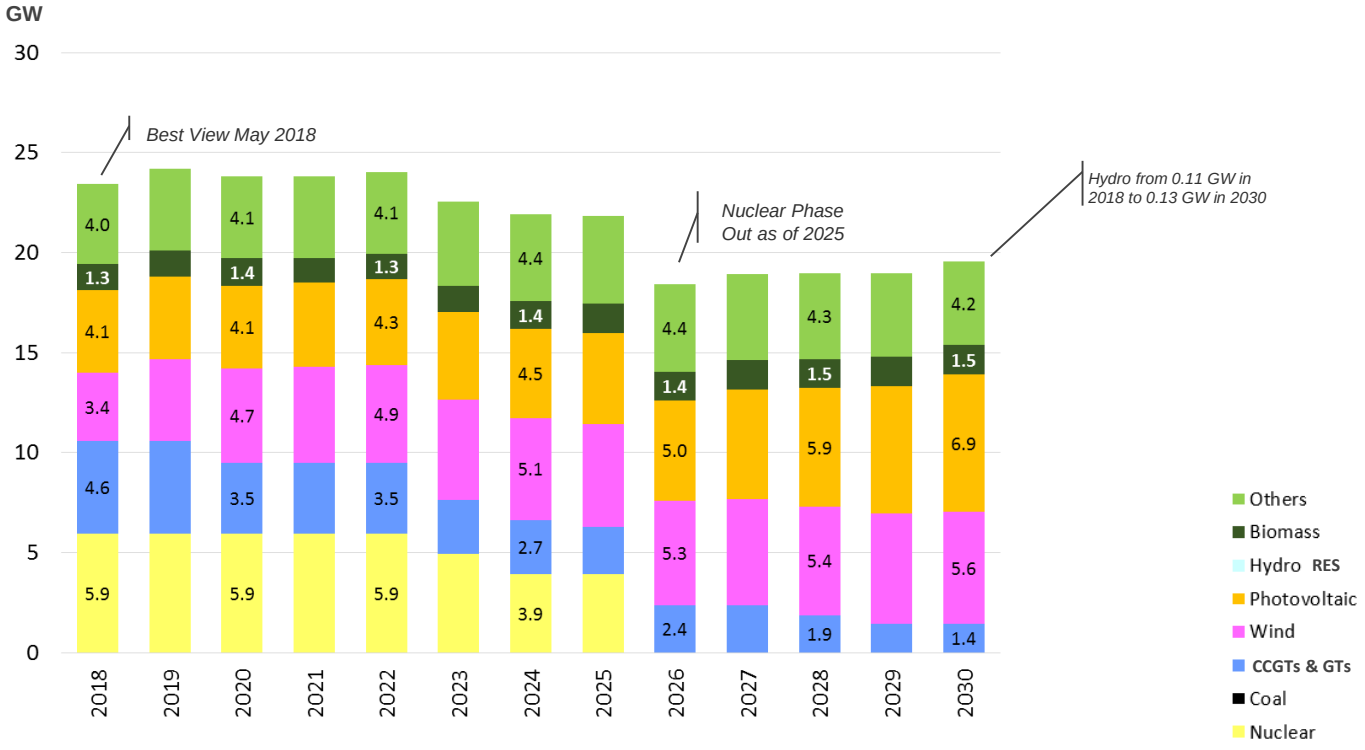
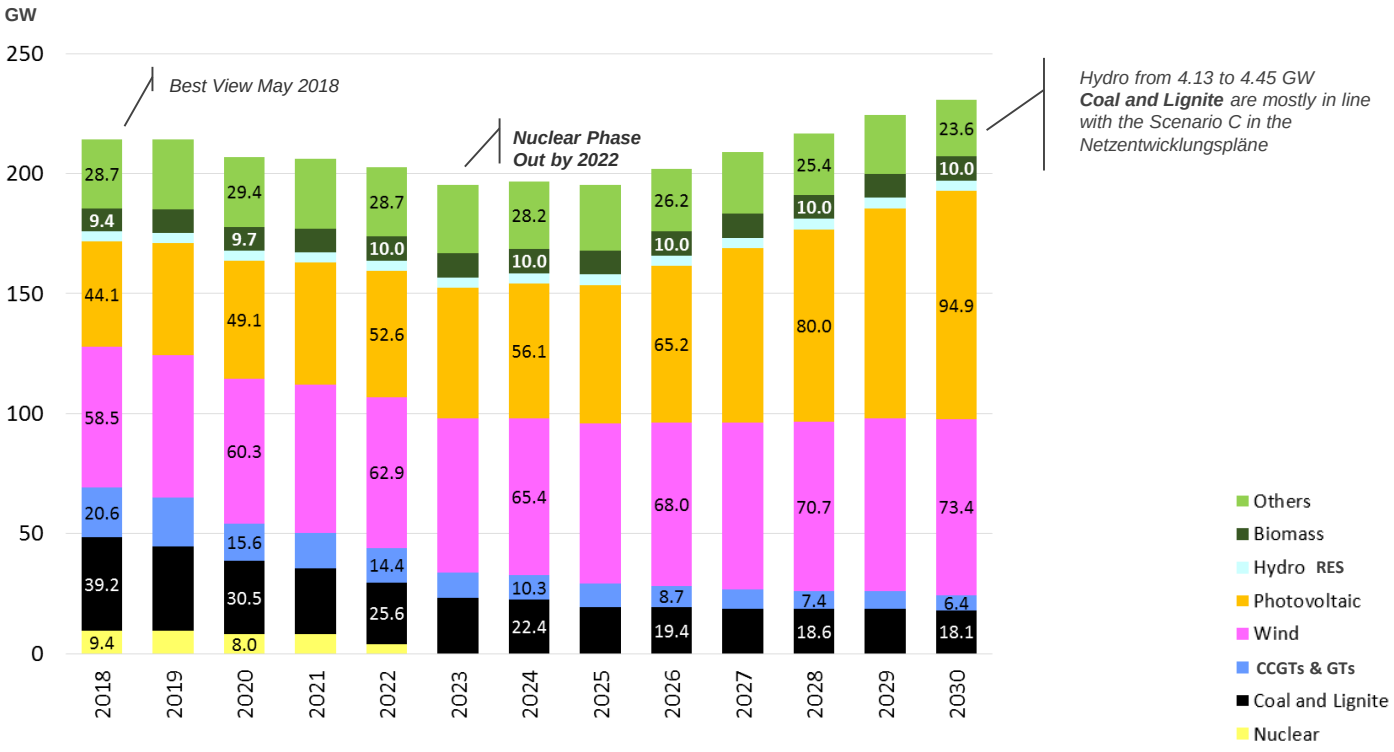
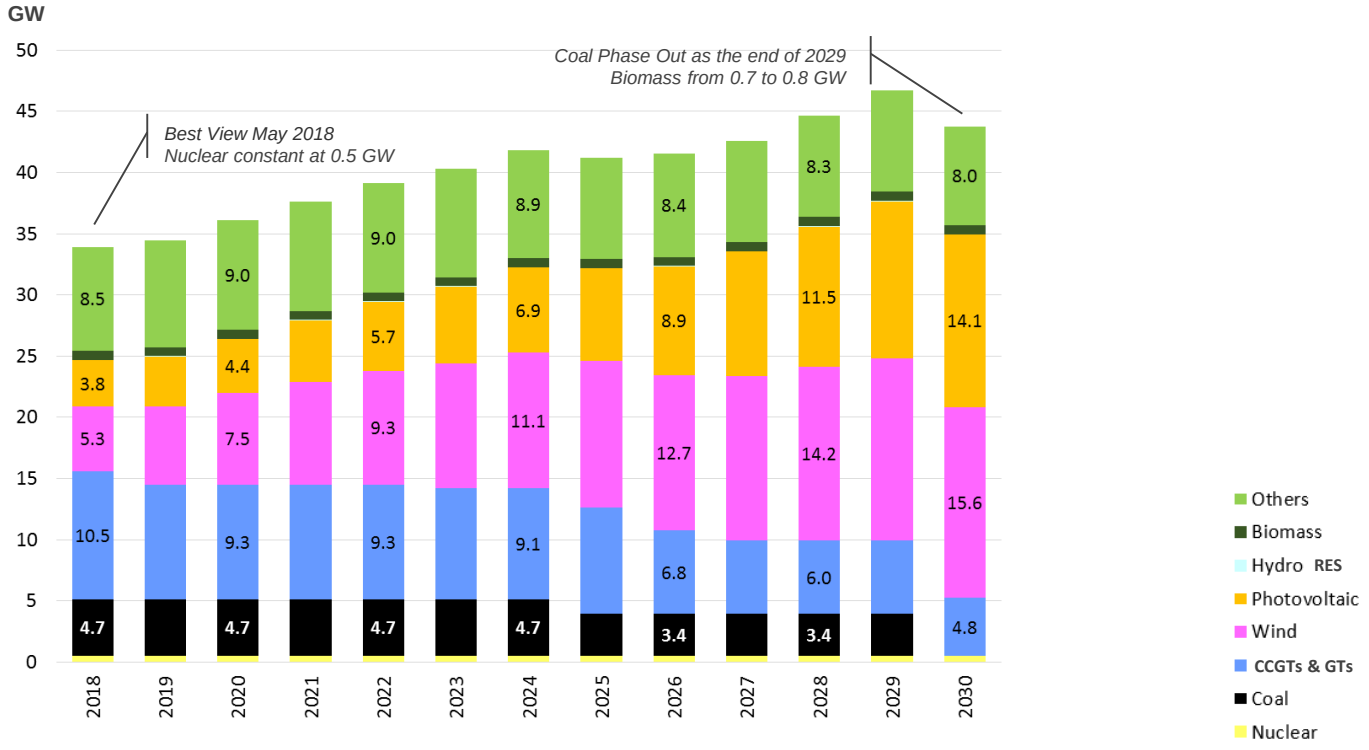


Existing Thermal and RES Development



Existing Thermal and RES Development



European power markets are getting increasingly interconnected.

France

Country	From FR in 2018 (2030)	To FR in 2018 (2030)
Belgium	3300 (4300)	1800 (2800)
Germany	3000 (4800)	3000 (4800)
Great Britain	2000 (5400)	2000 (5400)
Italy (North)	2500 (3453)	1020 (1900)
Spain	2800 (8000)	2800 (8000)
Switzerland	3200 (3700)	1400 (1500)
	~+13GW	~+12GW

Germany

Country	From DE in 2018 (2030)	To DE in 2018 (2030)
Austria	2100 (7500)	5000 (7500)
Belgium	0 (1000)	0 (1000)
Czech Republic	1000 (2000)	1600 (2600)
Denmark	2600 (2600)	2865 (2865)
France	3000 (4800)	3000 (4800)
Norway	0 (1400)	0 (1400)
Poland	1500 (3000)	1500 (3000)
Sweden	600 (600)	610 (610)
Switzerland	2000 (3286)	4000 (5500)
The Netherlands	4250 (5000)	4250 (5000)
	~+14GW	~+11GW

The Netherlands

Country	From NL in 2018 (2030)	To NL in 2018 (2030)
Belgium	2400 (3400)	1400 (3400)
Denmark	0 (700)	0 (700)
Germany	4250 (5000)	4250 (5000)
Great Britain	1000 (1000)	1000 (1000)
Norway	700 (1400)	700 (1400)
	~+3GW	~+4GW

Belgium

Country	From BE in 2018 (2030)	To BE in 2018 (2030)
France	1800 (2800)	3300 (4300)
Germany	0 (1000)	0 (1000)
Great Britain	0 (1000)	0 (1000)
The Netherlands	1400 (3400)	2400 (3400)
	~+5GW	~+4GW

Average net transfer capacity [MW]

Agenda

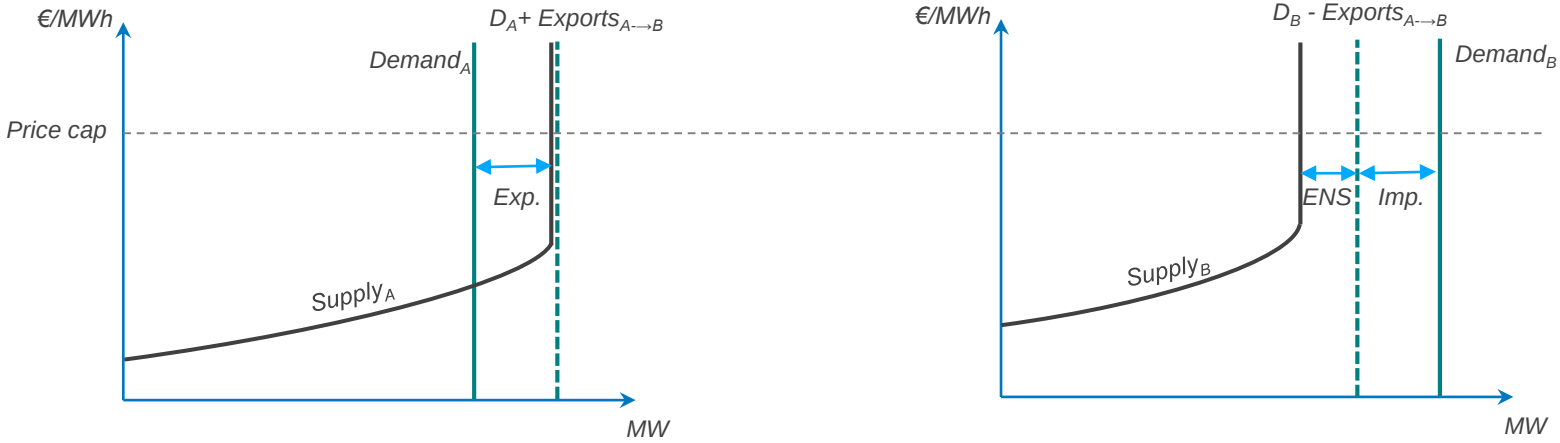
- Recent studies on power system adequacy
- Study assumptions
- View on adequacy
- Detailed view on exchanges at scarcity
- Recent developments

Definition of scarcity moments: there are net providers and net importers in highly interconnected markets.

Country A: Net provider of capacity

Country B: Net importer of capacity

Example where transmission capacity is not constraining

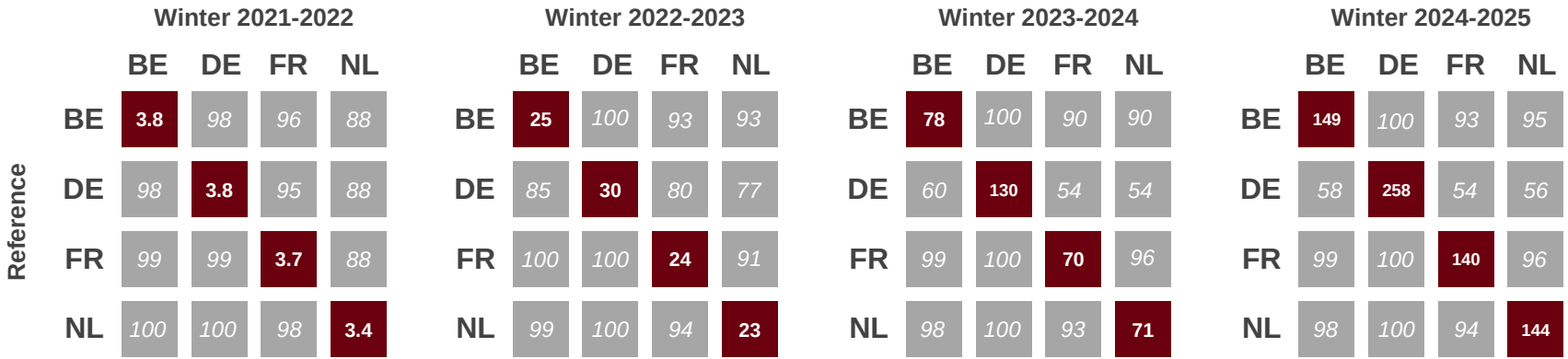


Country A has excess capacity. It exports to country B until it would have to curtail load as well.

Country B has not enough reliable capacity to meet peak load. It imports from country A. Some load has to be curtailed.

All countries tend to experience scarcity simultaneously. Germany experiences more scarcity and decouples from the other countries

CASE WITHOUT FURTHER INCENTIVES



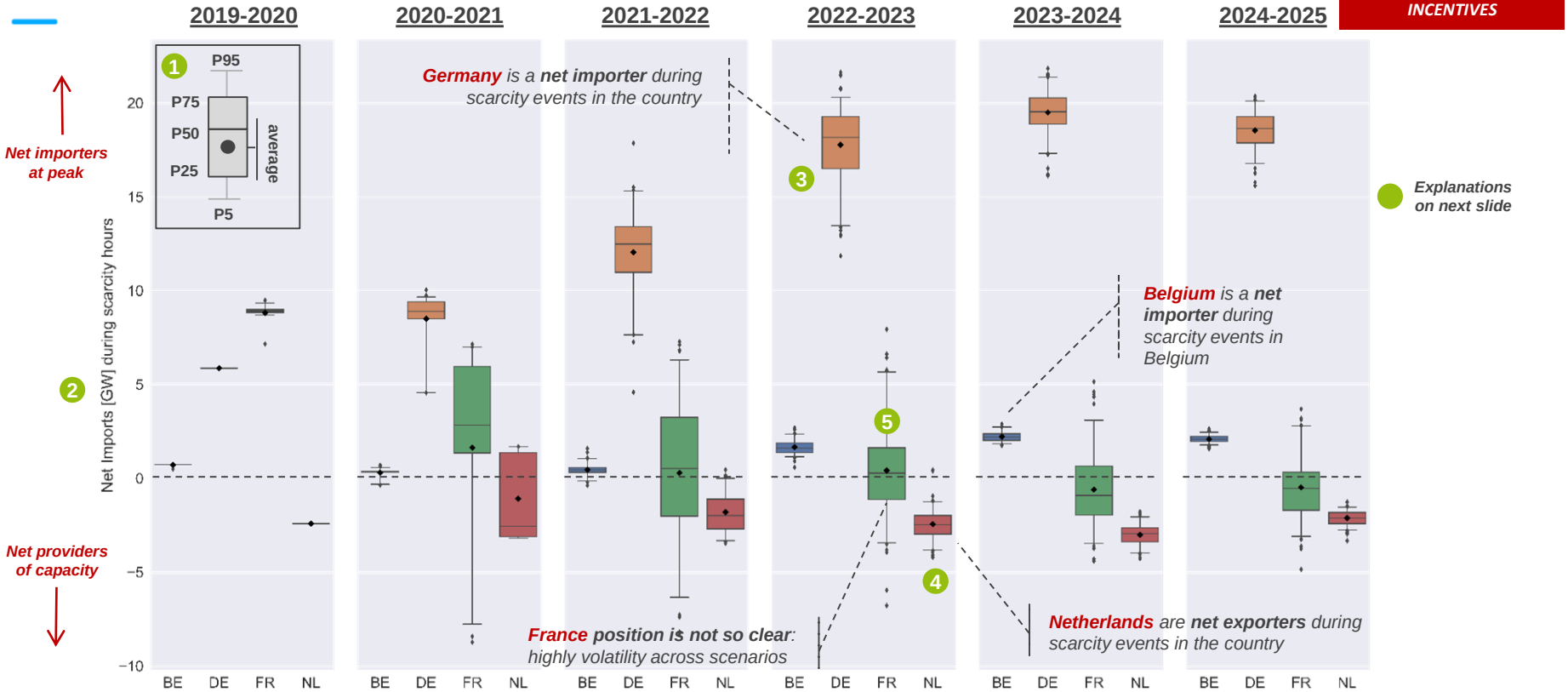
Legend

LOLE (hours)

% of the time at scarcity that another country experiences scarcity too

Exchange balances in scarcity moments: exchange of capacity is high. There are net providers and net importers of capacity.

CASE WITHOUT FURTHER INCENTIVES



Exchange balances in scarcity moments
Explanatory notes

1. The state of the system can be very different for a given installed generation capacity. Because of meteorological conditions, wind and PV generation, water availability for hydro plants as well as power demand levels vary. Also, thermal power generation plants can be unavailable for unforeseen reasons. Studying adequacy issues requires thus a probabilistic approach.

2. We consider the distribution of the net exchange balance during system stress, i.e. when the tight demand/supply balance is tight, leading to power prices reaching the cap. Until winter 2021-22, only a few hours are concerned.

3. Whatever the conditions, Germany is always a net importer in system stress. It imports more than it exports. Main reasons are the nuclear phase-out by end of 2022 and coal closures. Belgium is also a net importer in almost all situations.

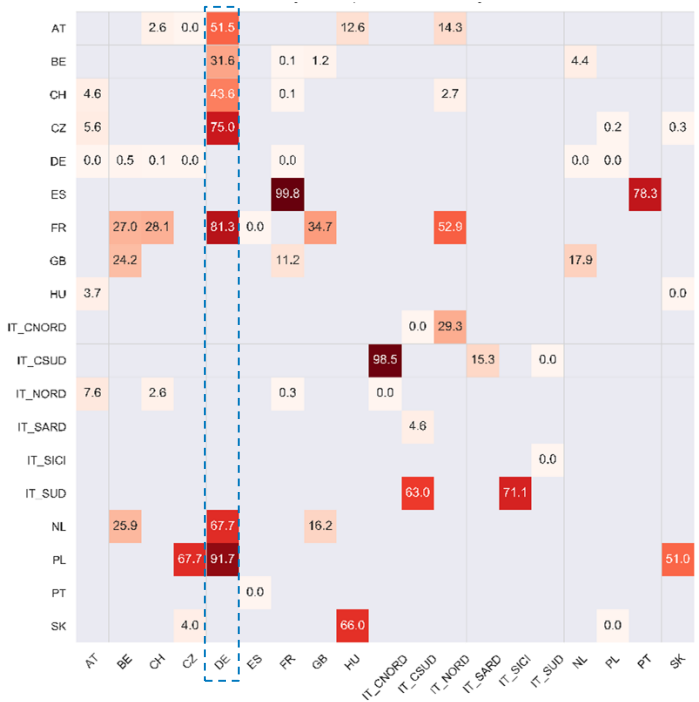
4. The Netherlands are relatively abundant in generation capacity. They are net providers of capacity to the neighboring countries in system stress. Generation capacity is shared up to the moment where demand would have to be curtailed in the Netherlands too.

5. France is in an intermediate position. It can benefit from excess capacity in Spain (not shown on the graph), but capacity is also leaking to Belgium and Germany.

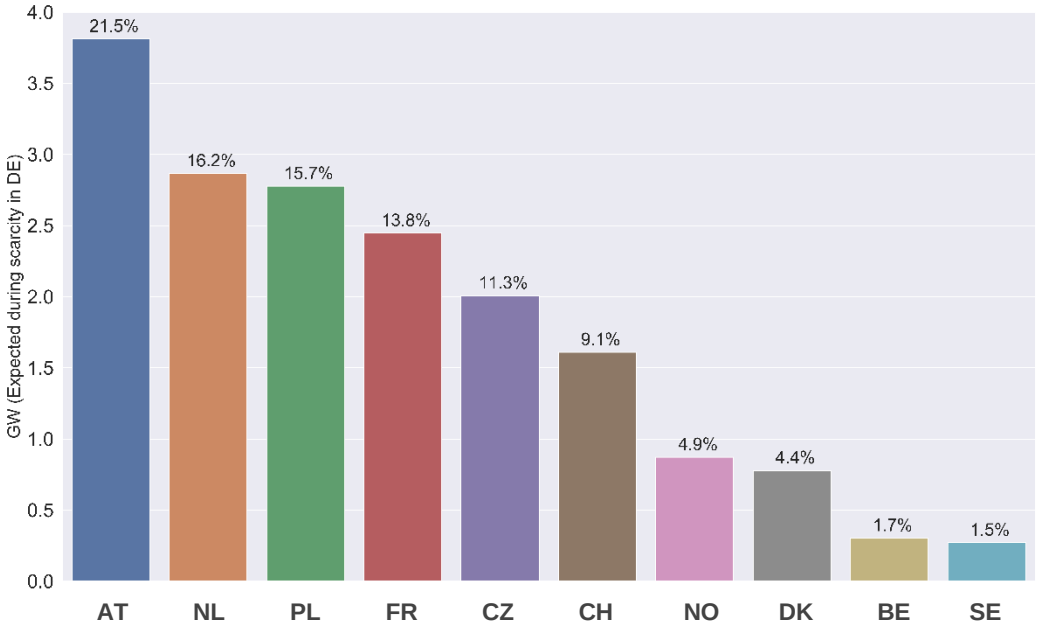
In general, we find that interconnection capacity is often not saturated. See slides in appendix. Hence, generation and not transmission capacity turns out to be the scarce resource.

Countries' balances reflect an interconnected network

Interconnection usage in DE Scarcity Hours
Winter 2022-2023



DE expected imports balance during scarcity hours



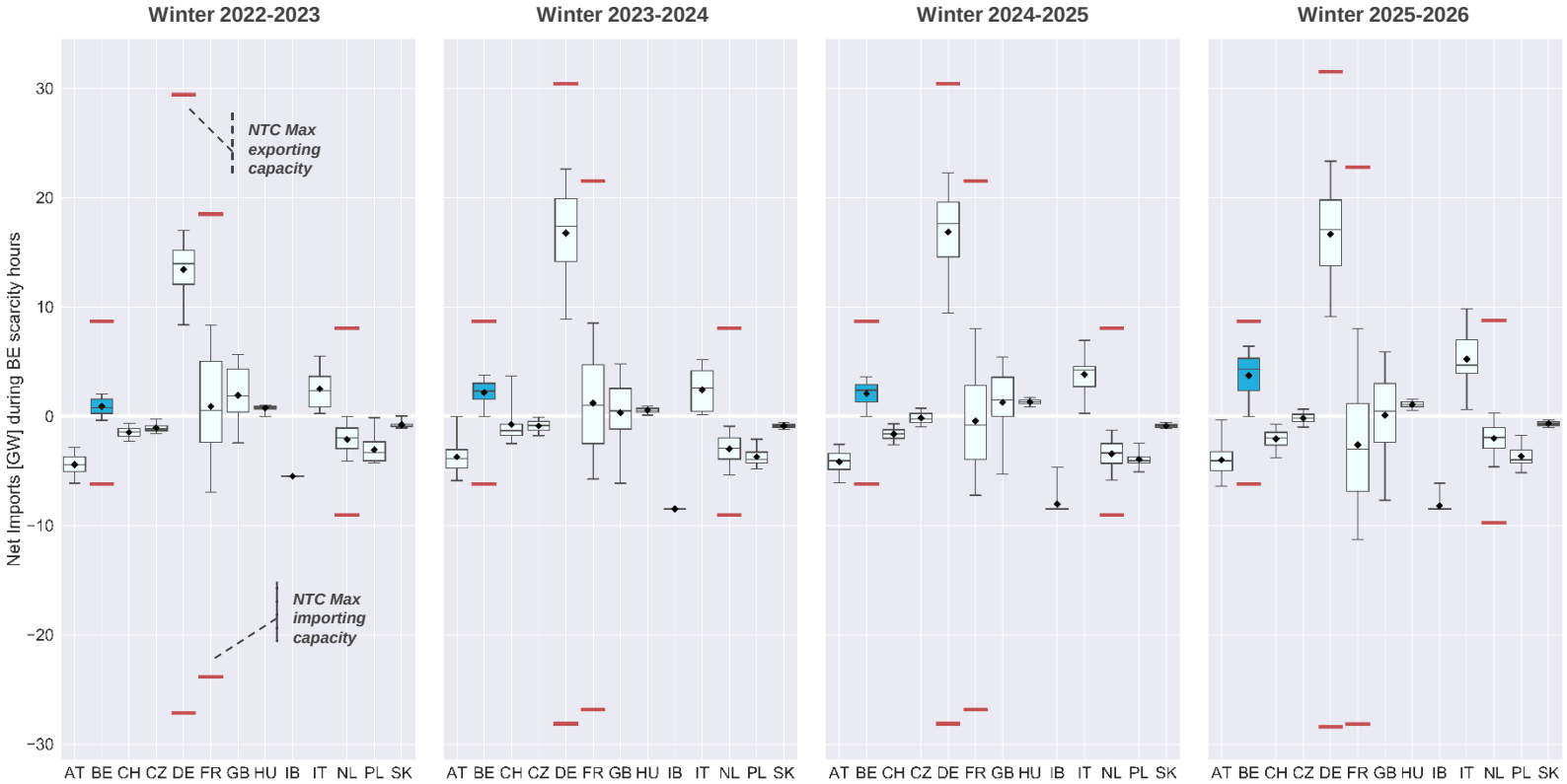
INTERNAL

Agenda

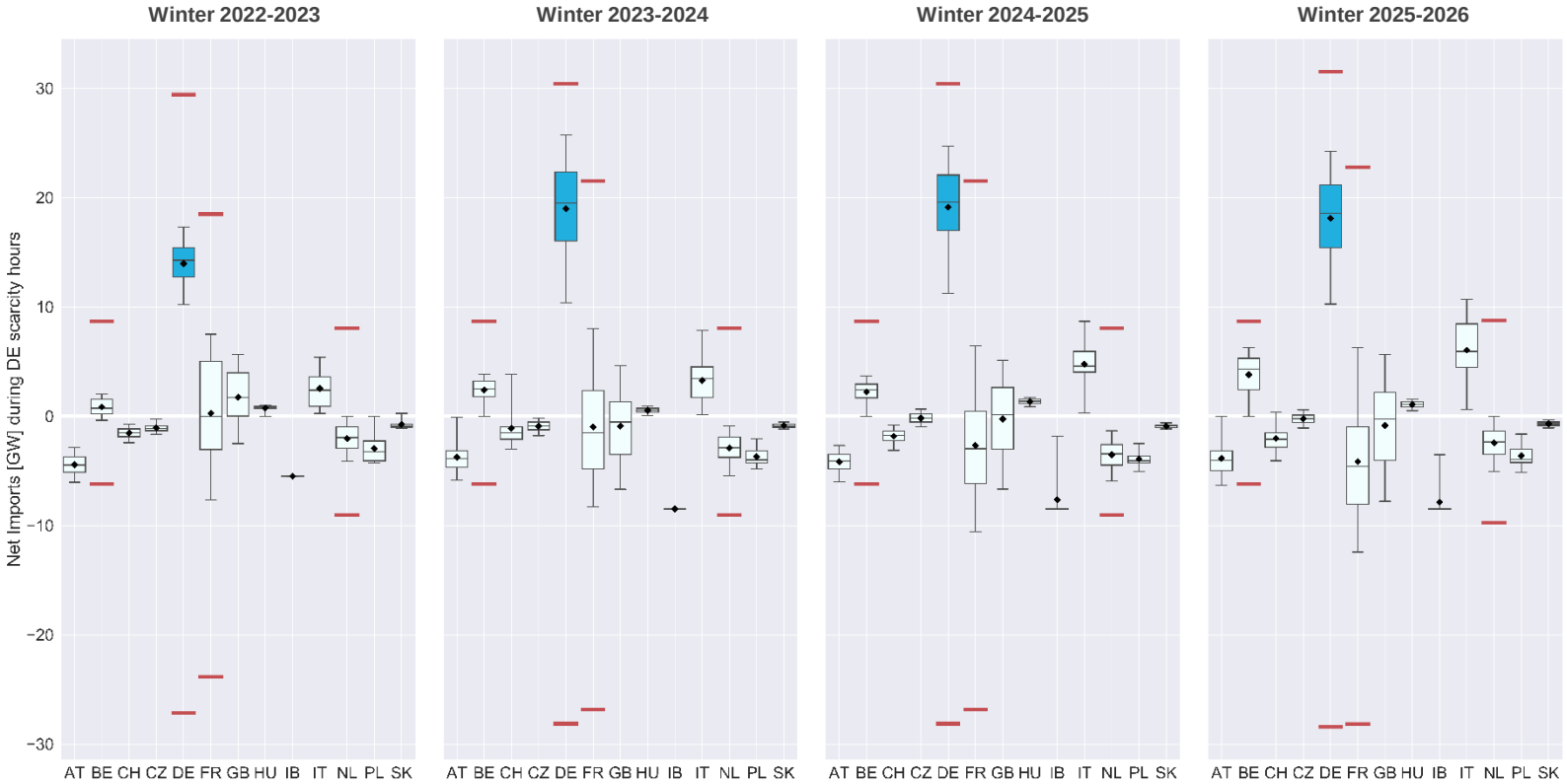
- Recent studies on power system adequacy
- Study assumptions
- View on adequacy
- Detailed view on exchanges at scarcity
- Recent developments

Results for the case if no investment would happen

Exchange balances during **scarcity events in Belgium**

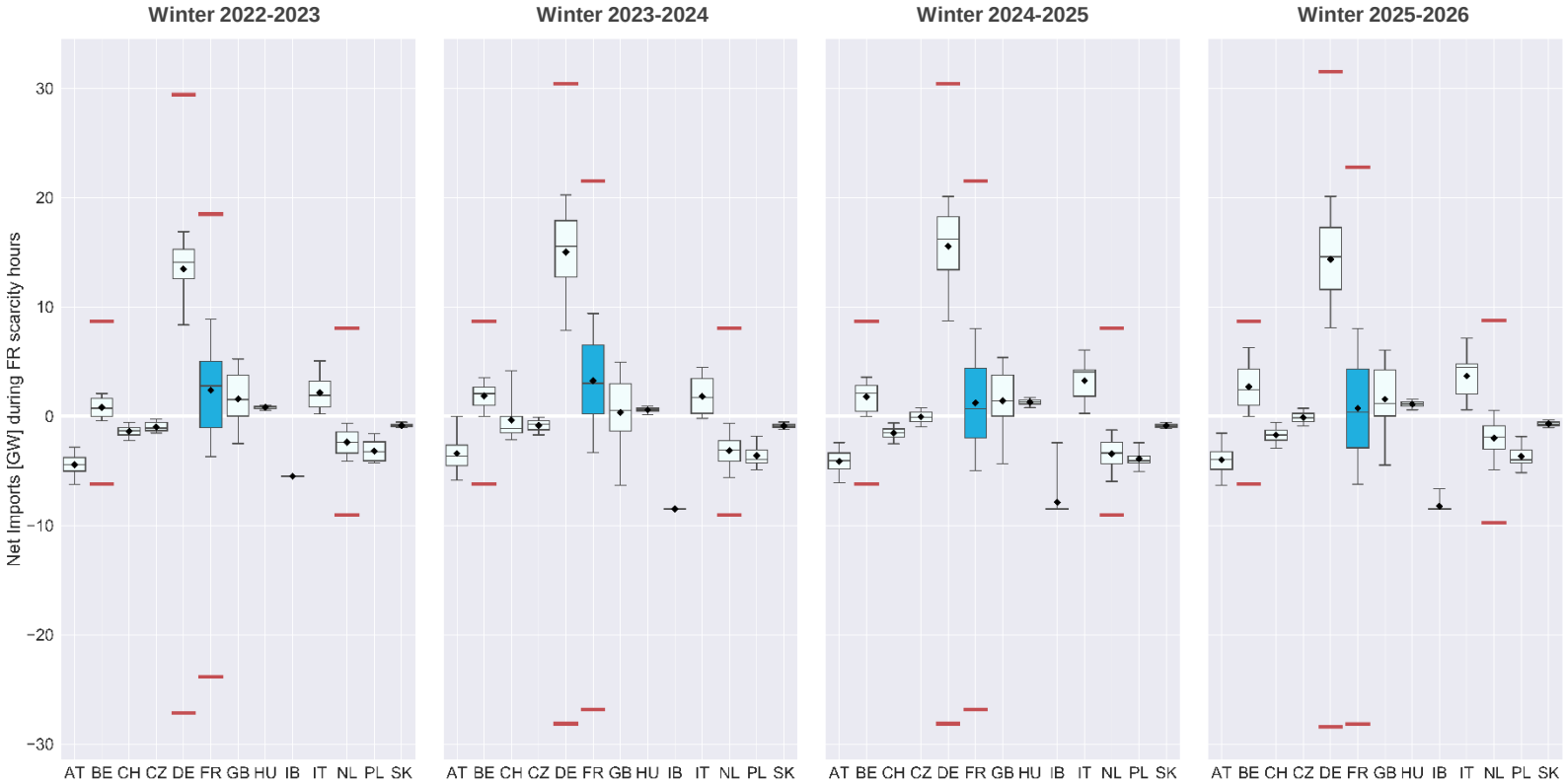


Exchange balances during **scarcity events in Germany**

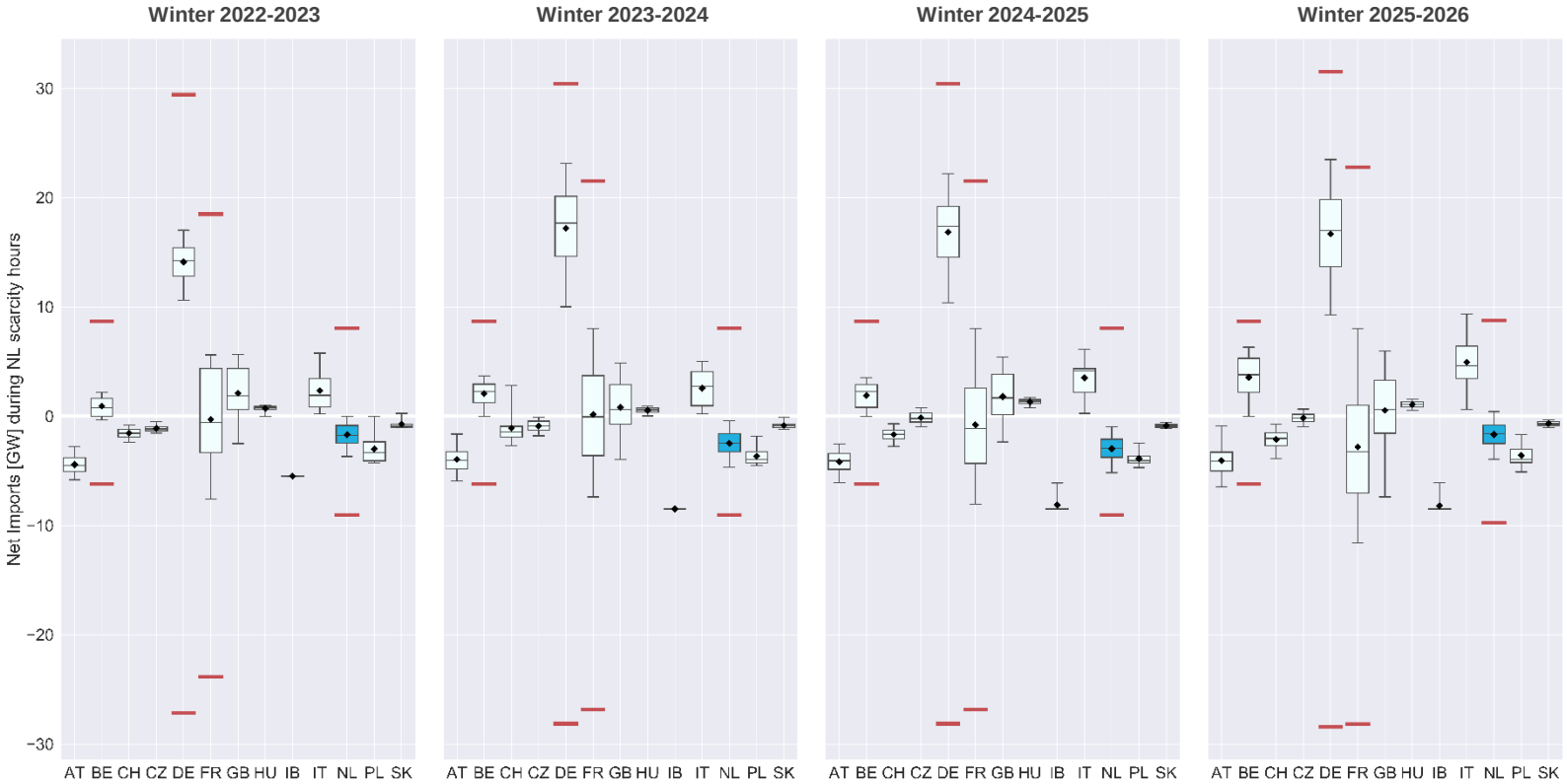


Results for the case if no investment would happen

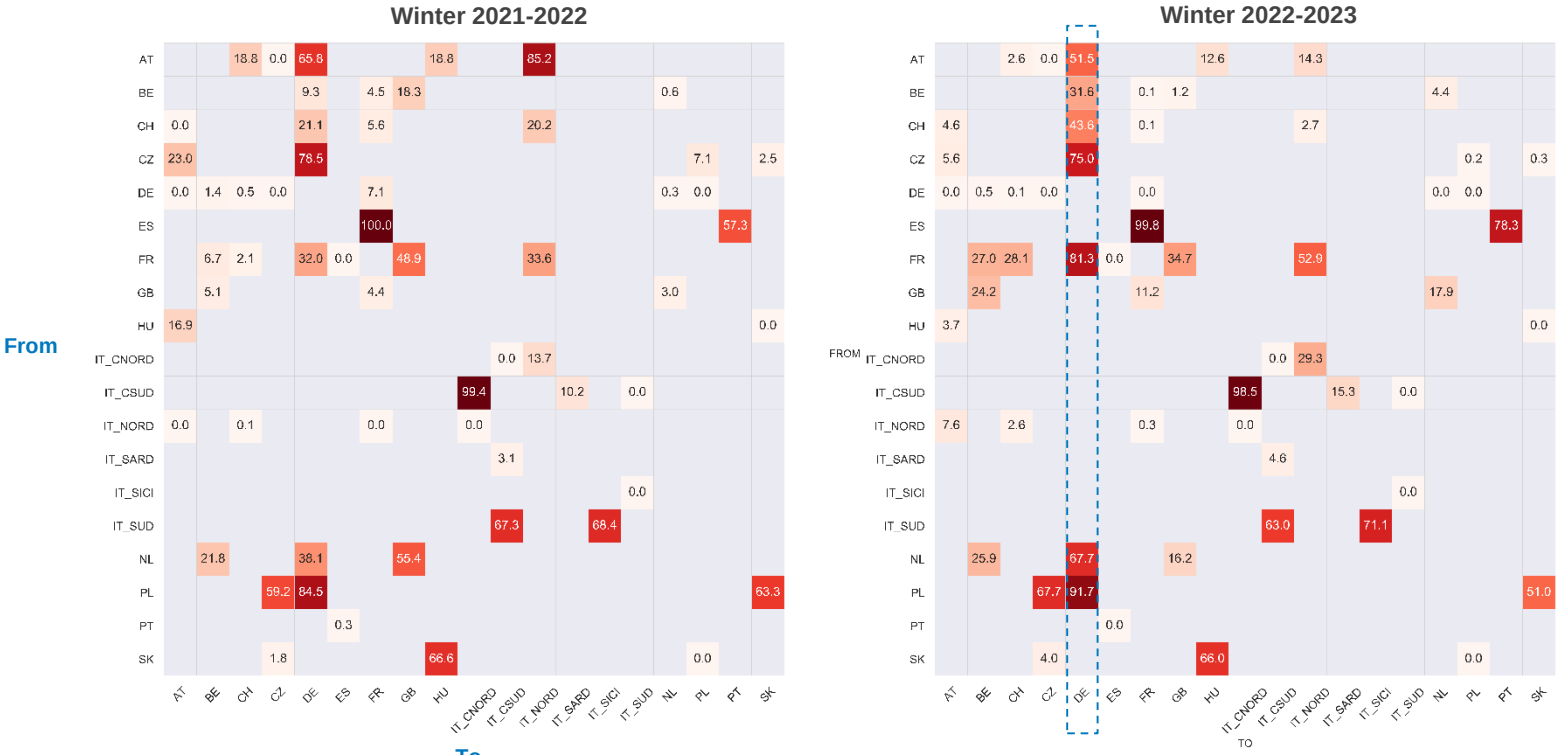
Exchange balances during **scarcity events in France**



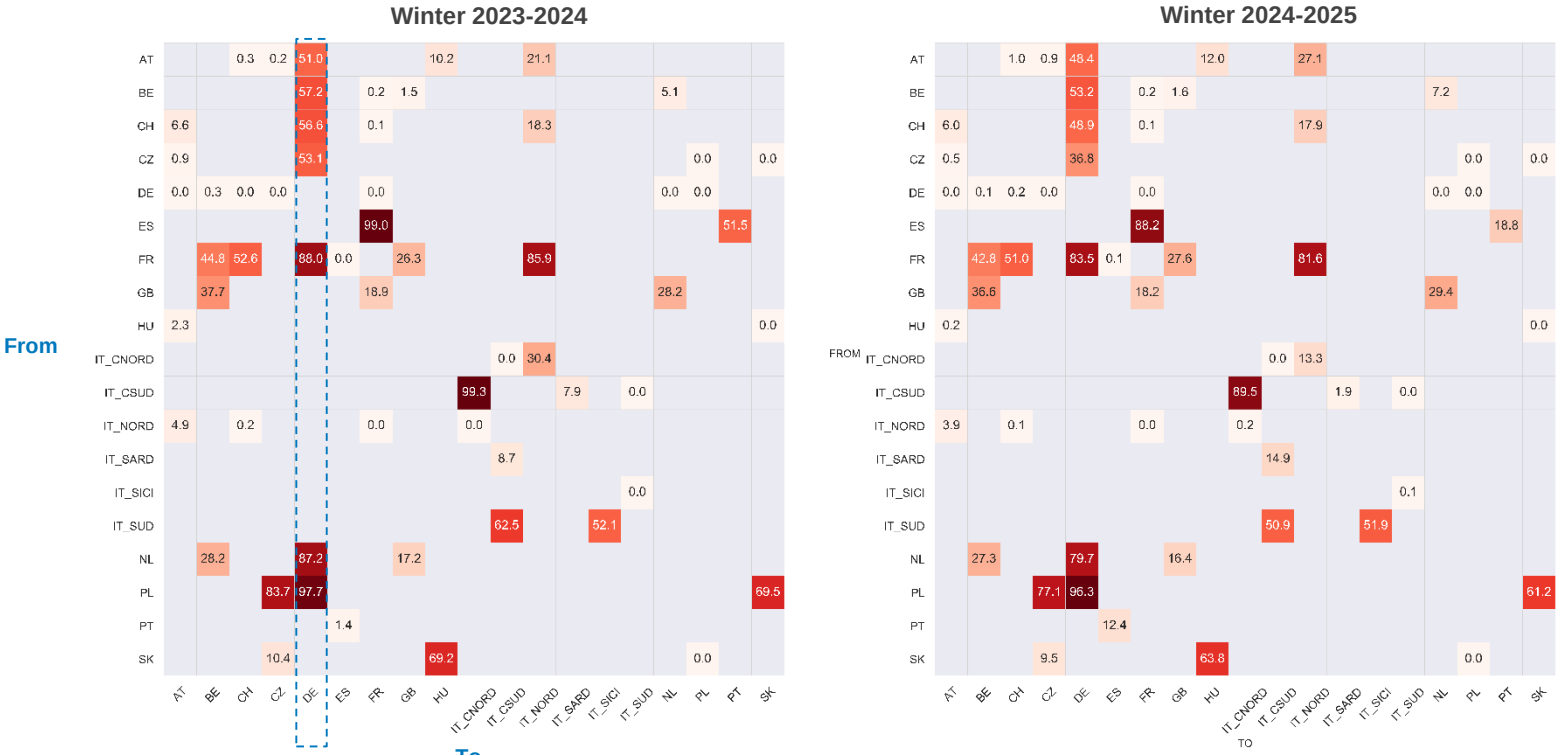
Exchange balances during **scarcity events in the Netherlands**



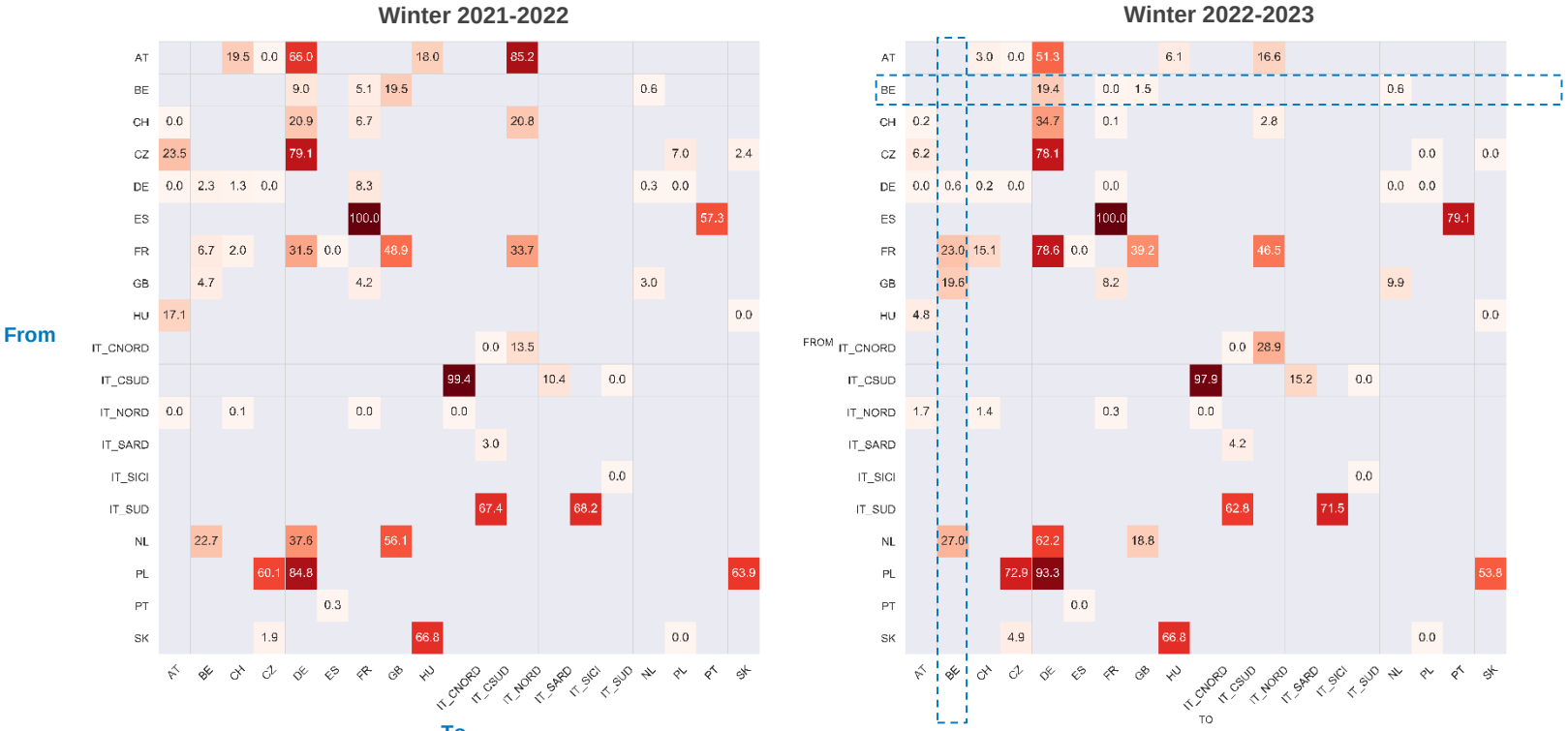
Average interconnection usage **during Scarcity Hours in Germany**



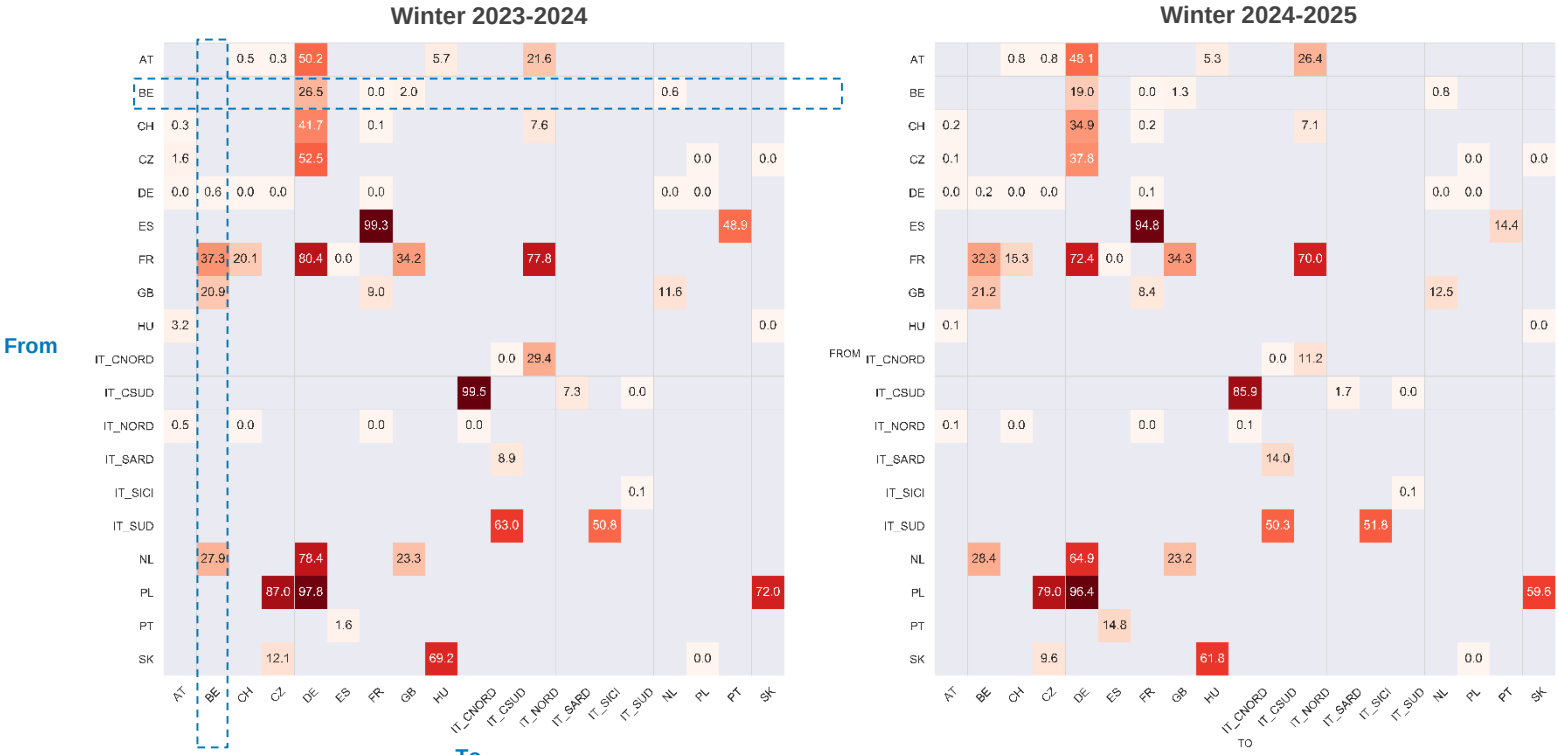
Average interconnection usage **during Scarcity Hours in Germany**



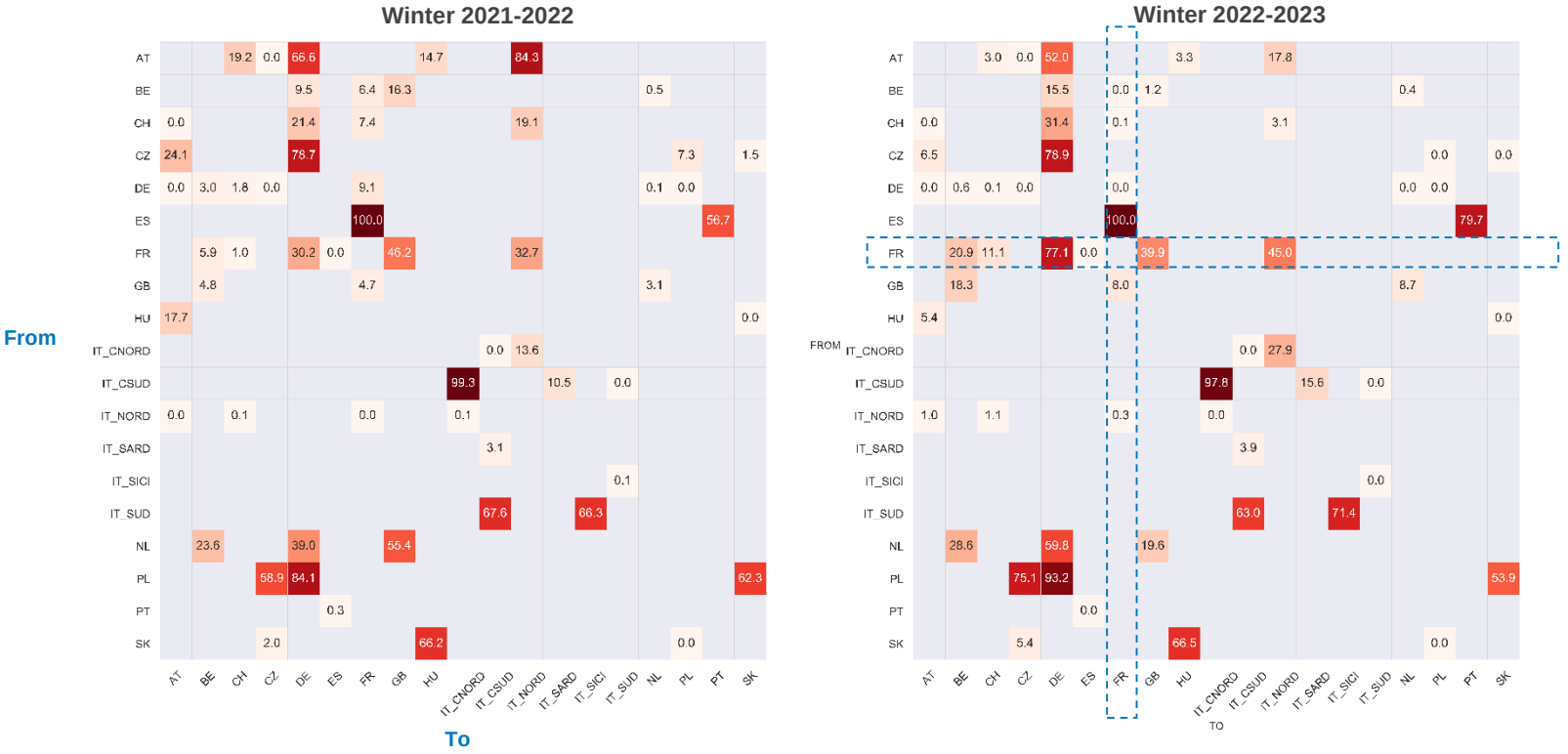
Average interconnection usage **during Scarcity Hours in Belgium**



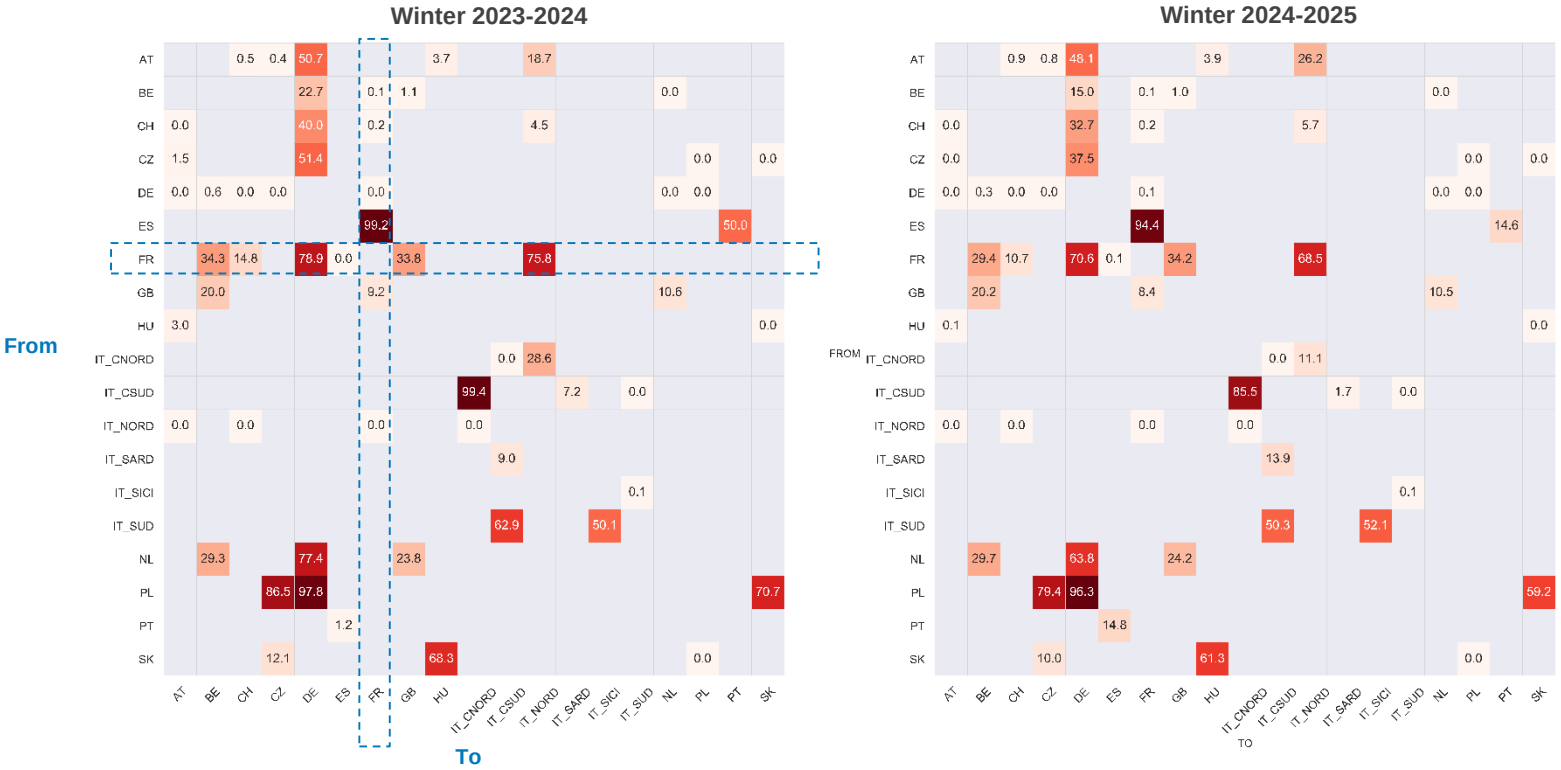
Average interconnection usage **during Scarcity Hours in Belgium**



Average interconnection usage **during Scarcity Hours in France**

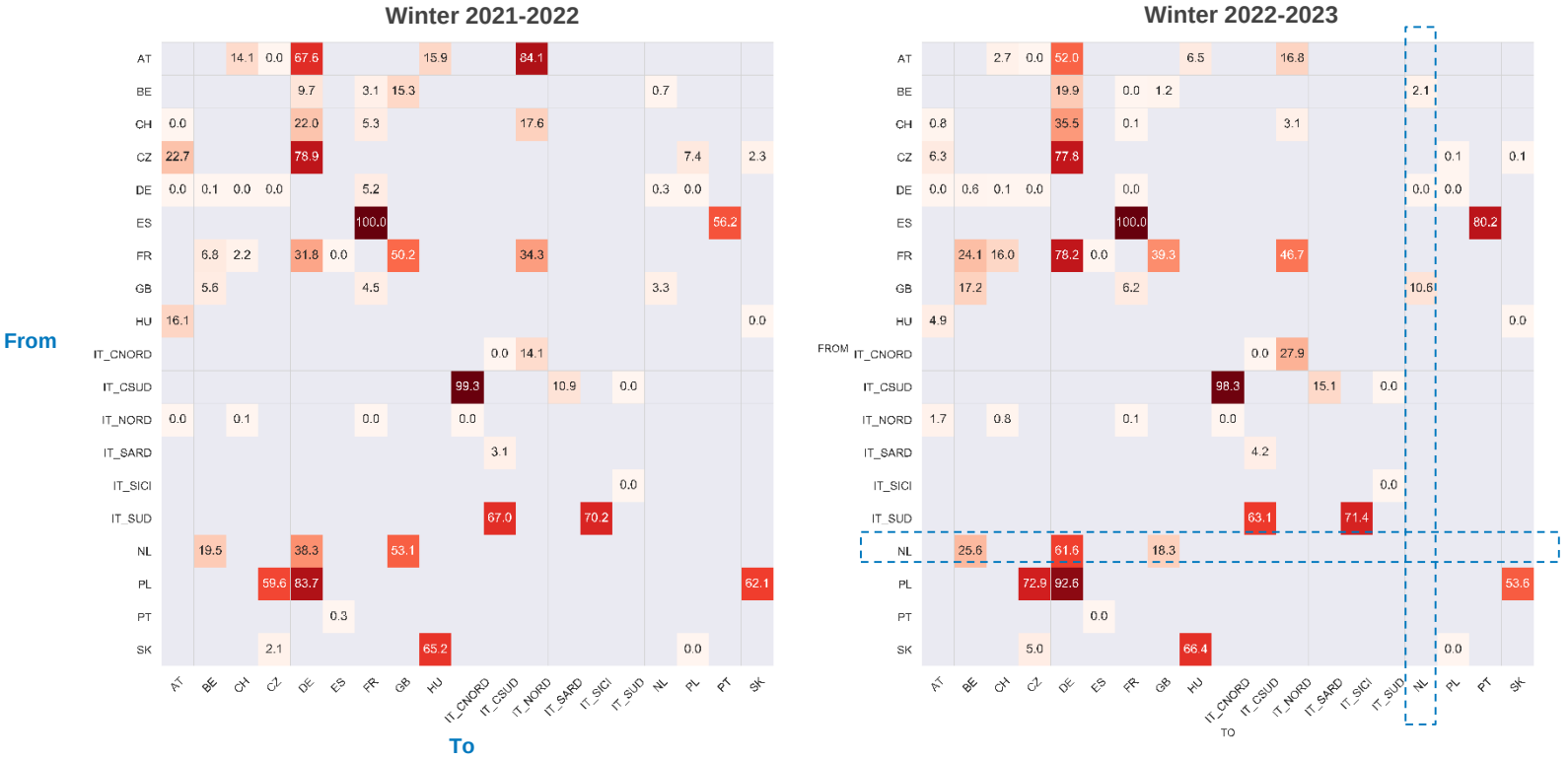


Average interconnection usage **during Scarcity Hours in France**

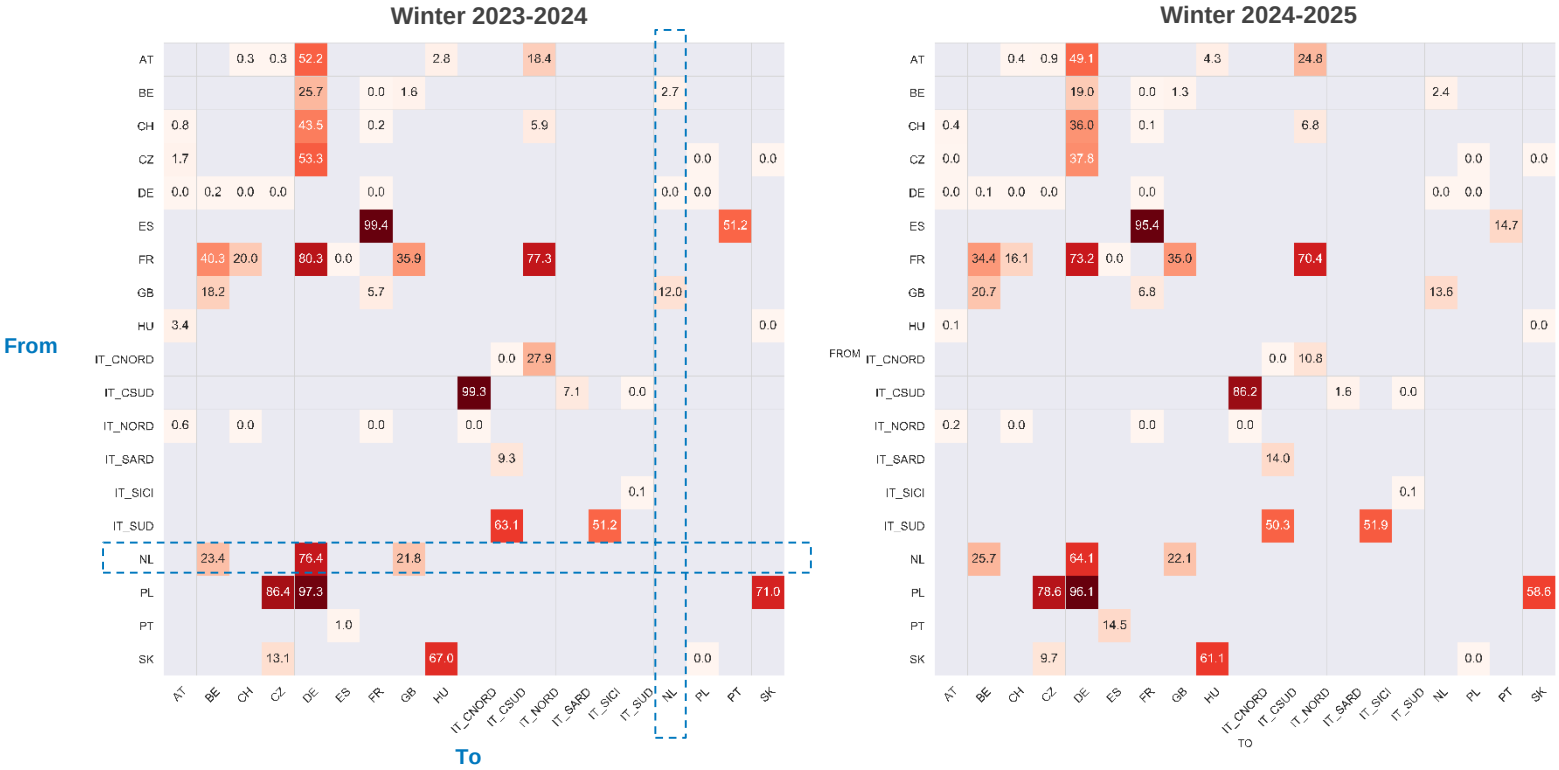


Results for the case if no investment would happen

Average interconnection usage **during Scarcity Hours in NL**



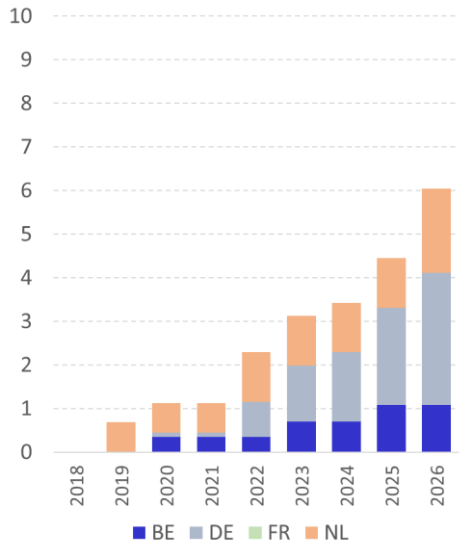
Average interconnection usage **during Scarcity Hours in NL**



“Low-Cost” capacity development potential CWE4

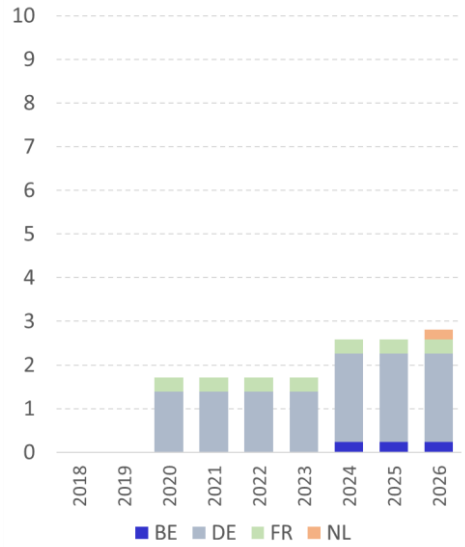
CCGT lifetime extensions [GW]

After a lifetime of 20 years, CCGTs can be extended with 10 years.



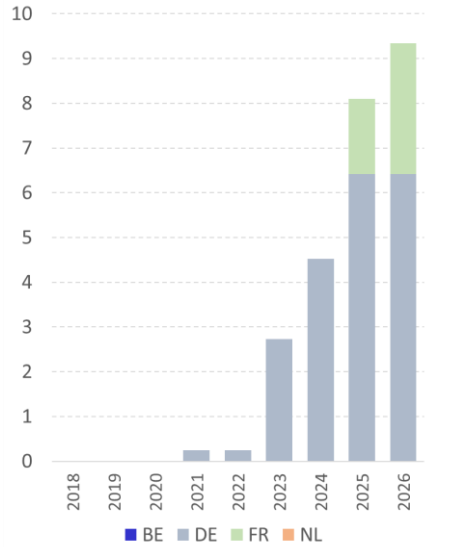
Reconversion CCGT to GT [GW]

Instead of closing a CCGT, one keeps the GT as a cheap provider of peak capacity.



Brownfield CCGT [GW]

As a cheaper alternative to greenfield development, new CCGTs could be build on existing sites of closed coal or CCGT plants.



The potential is based on an economic assessment where future expected margins (inframarginal and scarcity rents) cover at least the necessary CAPEX. Scarcity rent can be captured through price spikes in an energy-only market (EOM) environment or via capacity payments in CRM. However, from a risk perspective, it is questionable whether more CAPEX intensive decisions (Brownfield CCGT > CCGT LT extension > GT reconversion) will happen in EOM without long term contracts.

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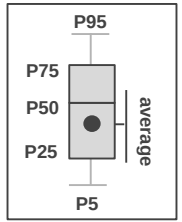
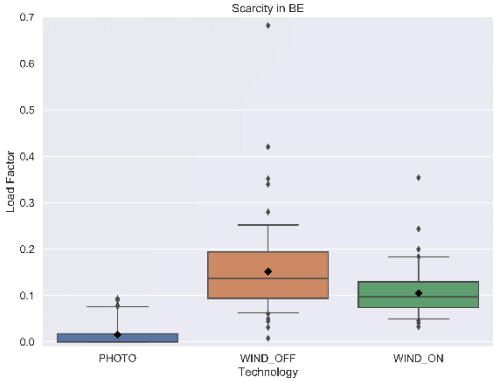
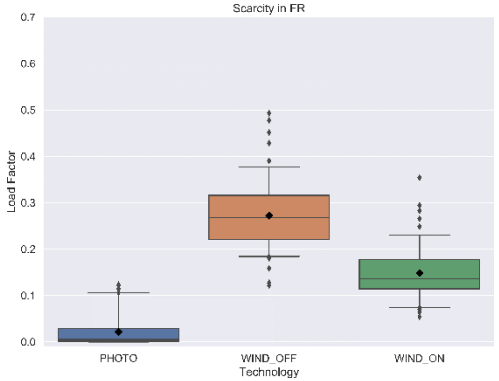
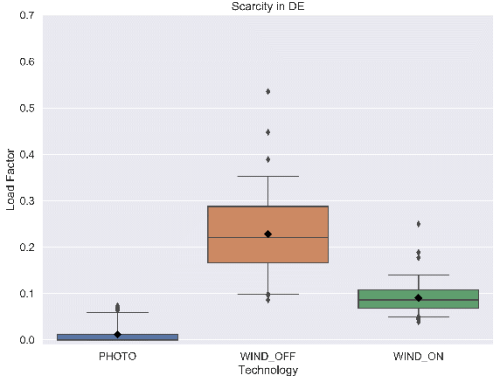
Contribution of renewables in scarcity moments*

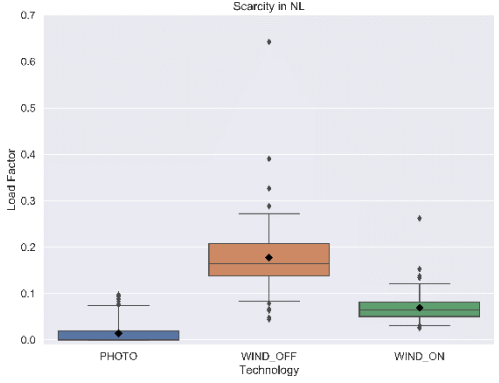
PV close to 0% while wind onshore rather 10% (more in FR, less in NL)











** availability (load factor) during scarcity moments in Winter 2022-23 period. The distribution covers meteorological uncertainty, based on historical conditions (2008-2016)*

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