

An assessment of balancing resources in the Italian power system

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Increasing generation from Non-Programmable Renewable Energy Sources (NPRES)



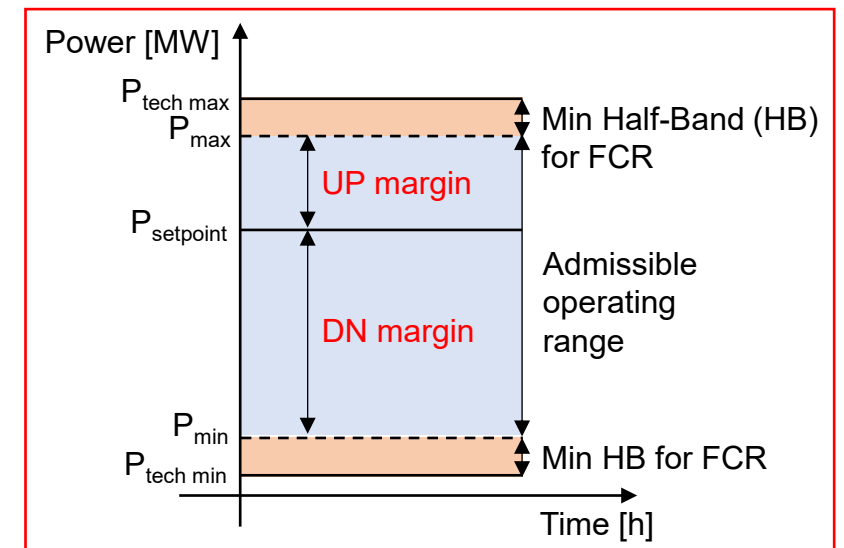
- high **variability** and **uncertainty**
- connection on both **transmission** and **distribution** systems
→ increasing **reverse power flows** and **congestions**
- **connection via inverter technologies**
→ **reduction** of power system **mechanical inertia** and **short-circuit power**
→ faster and wider **frequency** and **voltage variations**

Transmission System Operators (TSOs) may need increasing resources to regulate grid frequency (and voltage)
→ How many resources are still available? Are they enough?



- **Traditional resources for frequency regulation:**
 - from **relevant** (≥ 10 MW, connected to the transmission system) and **programmable Generation Units (GUs)**, e.g. **large thermoelectric GUs** and **hydroelectric GUs** except Run-Of-River (ROR) ones.
- Resources for **automatic Frequency Restoration Reserve (aFRR)**, for **manual Frequency Restoration Reserve (mFRR)** and **Replacement Reserve (RR)**:
 - normally collected and deployed by the TSO (Terna) on the **Ancillary Service Market (ASM)**.
- Resources for **Frequency Containment Reserve (FCR)**:
 - from **relevant programmable GUs** (i.e. the ones traditionally eligible for participation in the ASM) on a **mandatory basis** with a devoted **optional remuneration mechanism outside the ASM**.

Objective: assessment, from public data, of the overall upward (UP) and downward (DN) margins [MW] (which can be exploited for aFRR, mFRR and RR) available historically to the Italian TSO in each hour of the year, for 2015-2022.



Italian spot electricity market

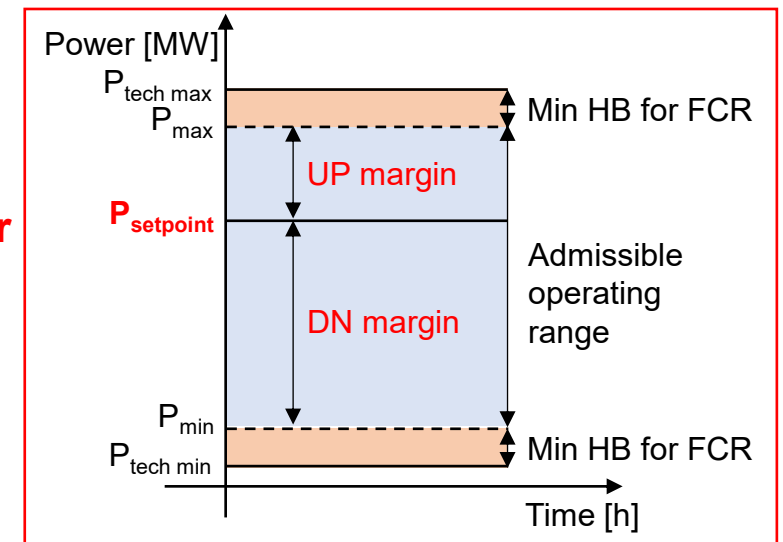
Market	Purpose	Participation	Price scheme
Day-Ahead Market (DAM)	Meet demand	voluntary	marginal price
Intraday Market (IM) + Cross-Border IntraDay (XBID)	UP/DN changes in the quantities negotiated on the DAM		
<i>Ex ante</i> Ancillary Service Market (<i>ex ante</i> ASM)	Meet TSO's demand for balancing services for power system control <ul style="list-style-type: none"> • aFRR, mFRR, RR, • congestion management Corresponding energy products : <ul style="list-style-type: none"> • Secondary Power Reserve (UP and DN): SR • Non-Secondary Power Reserve: "steps" (UP and DN): GRs • Minimum Power/Shutdown to zero (UP/DN): MS plus manoeuvre products: Start-Up (UP) and Reconfiguration (UP)	mandatory for GUs fully compliant with Grid Code requirements (including being relevant GUs)	pay as bid
<i>Ex post</i> ASM or Balancing Market (BM)			

Time

- Daily submission of **hourly upward (UP) and downward (DN) bids**
- **Bid = (energy quantity, unit price) [MWh, €/MWh]**
- **Assumption: mRR and RR associated to GR services and to the MS service**

In each hour, P_{setpoint} computed here as the algebraic sum of power variations associated to UP and DN bids on the "market chain":

DAM → IM → XBID → ex ante ASM → BM



Estimate energy source, technology, installed net generation capacity, technical min and max power for each GU

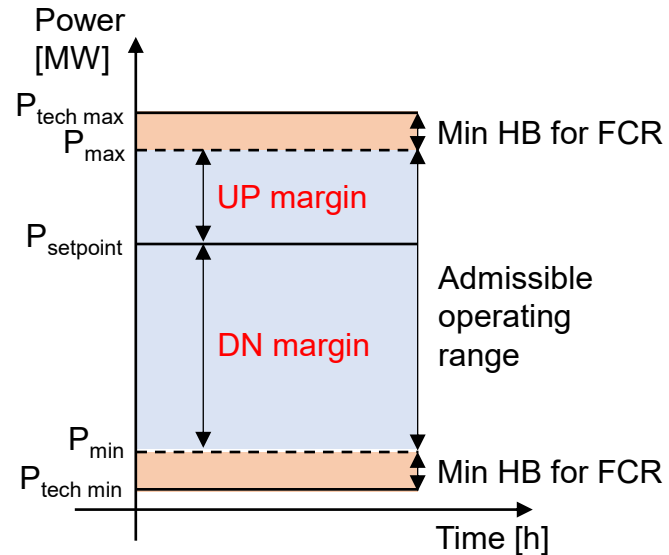
Estimate GUs enabled to supply FCR and their minimum Half-Band (HB) required for FCR from Italian Grid Code requirements

Evaluate the online/offline status and power setpoint, for each GU in each hour, from the Italian electricity market outcomes

Assess the current UP and DN margin, for each GU online in each hour

Derive the overall UP and DN margin, e.g. per "source & technology" class and market zone or at the national level, in each hour

GUs showing up on the ENTSO-E Transparency Platform and on the Italian wholesale electricity market



a. MF: Multi-Fuel. MF 2: natural gas, diesel oil; MF 2a: natural gas, process steam; MF 2b: natural gas/fuel oil; MF 3: natural gas, diesel oil, coal; MF 3a: natural gas, syngas, fuel oil; MF 3b: natural gas, diesel oil, syngas
 b. CCGT: Combined Cycle Gas Turbine; CHP: Combined Heat and Power; IGCC: Integrated Gasification Combined Cycle; GT: Gas Turbine; PSH: Pumped Storage Hydropower; ROR: Run Of River; RPW: Repowered; ST: Steam Turbine

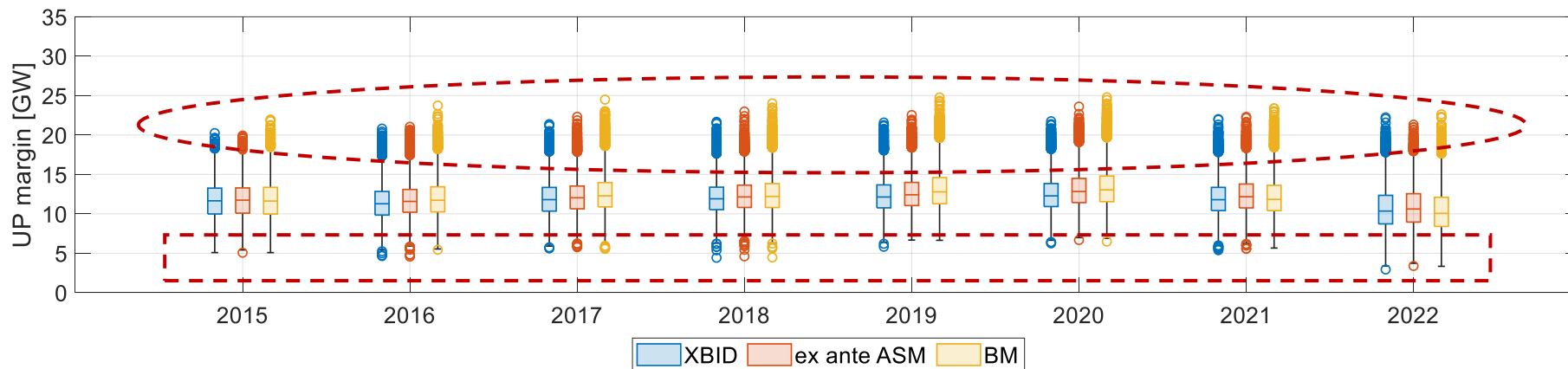
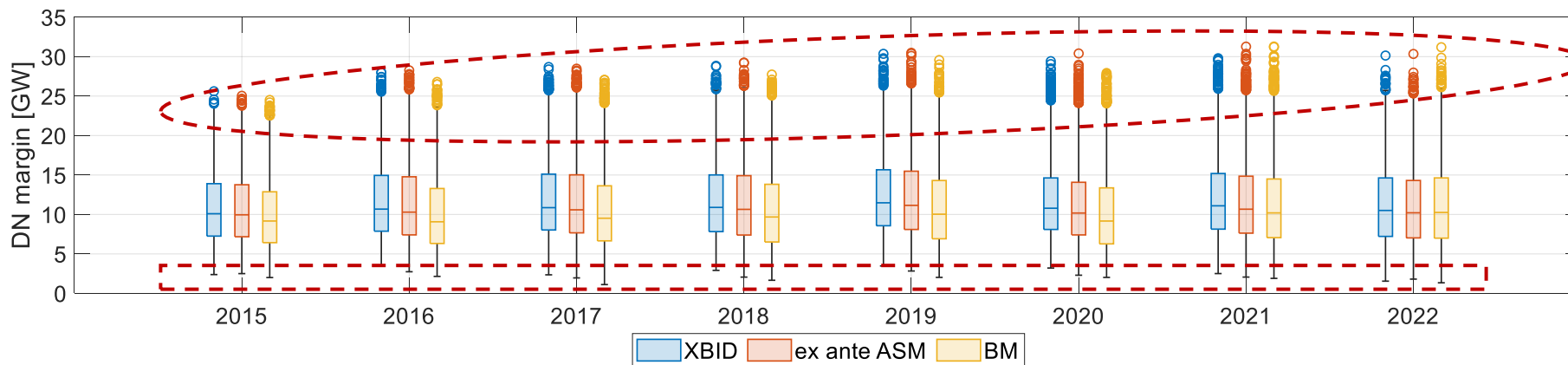
Energy source ^a	Technology ^b	H [s]	FCR Y/N
Coal	ST	3.9	Y
Fuel oil	ST	4.3	Y
Natural gas	ST	4.2	Y
Syngas	ST	4.2	N
Waste	ST	3.8	N
Biomass	ST	3.3	N
Geothermal	ST	3.5	N
MF 2a	ST	4.2	N
MF 2b	ST	4.3	Y
MF 3a	ST	4.3	Y
Natural gas	CCGT	4.2	Y
Syngas	CCGT	4.2	N
Hydrogen	CCGT	4.2	N
Natural gas	CHP CCGT	4.2	Y
Syngas	CHP CCGT	4.2	Y
Syngas/natural gas	CHP CCGT	4.2	Y
Natural gas	RPW CCGT	4.2	Y
MF 2	RPW CCGT	4.3	Y
MF 3	RPW CCGT	4.1	Y
Natural gas	GT	4.2	Y
Diesel oil	GT	4.3	Y
MF 2	GT	4.3	Y
MF 3b	GT	4.2	Y
Natural gas	CHP GT	4.2	Y
Syngas	IGCC	4.2	Y
Natural gas	Engine	3.8	N
Syngas	Engine	3.8	N
Diesel oil	Engine	3.8	N
Natural gas	CHP engine	3.8	N
Diesel oil	CHP engine	3.8	N
Water	ROR	2.7	N
Water	Pondage	2.7	Y
Water	Reservoir	3.7	Y
Water	PSH	3.5	N
Sun	PV	0	N
Wind	Onshore	0	N
Wind	Offshore	0	N
Natural gas	CHP GT + CHP engine	4	N
Syngas	GT, ST	4.2	N

in 2015-2022



Results for all Italy – boxplots

Downward (top) and upward (bottom) margins of the eligible GUs analyzed in years from 2015 to 2022, downstream of the energy market (XBID), the ex ante ASM and the BM

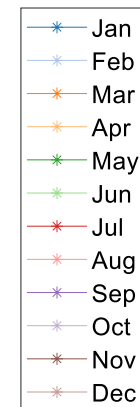
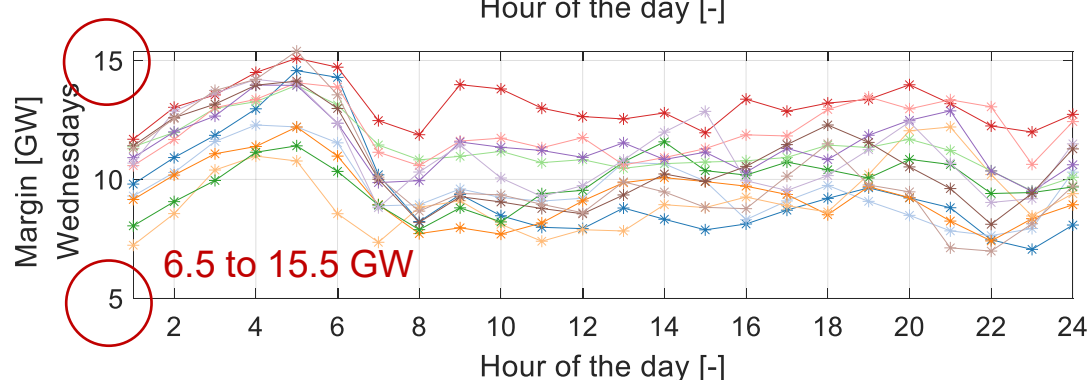
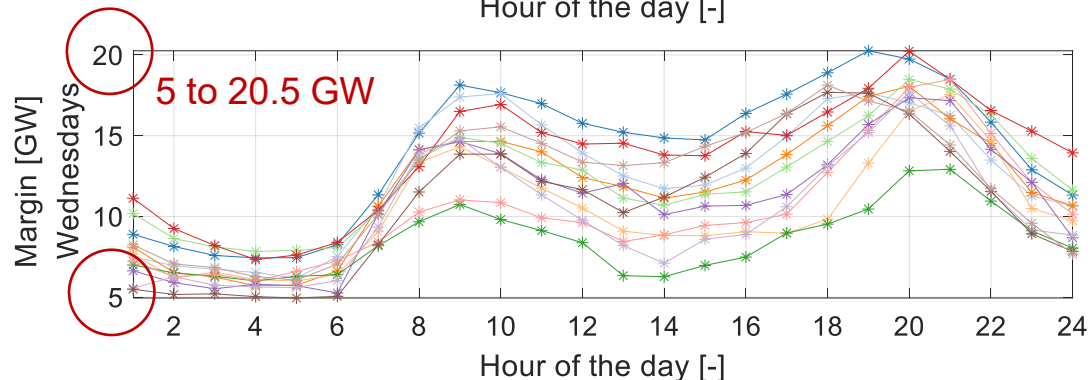
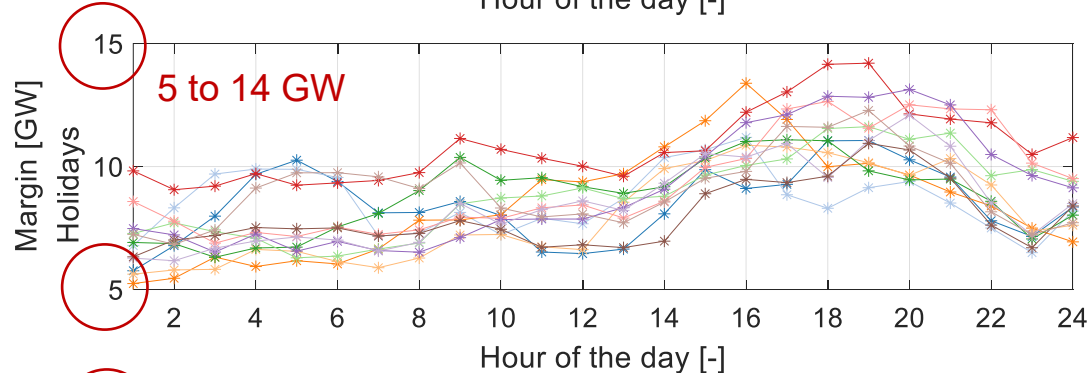
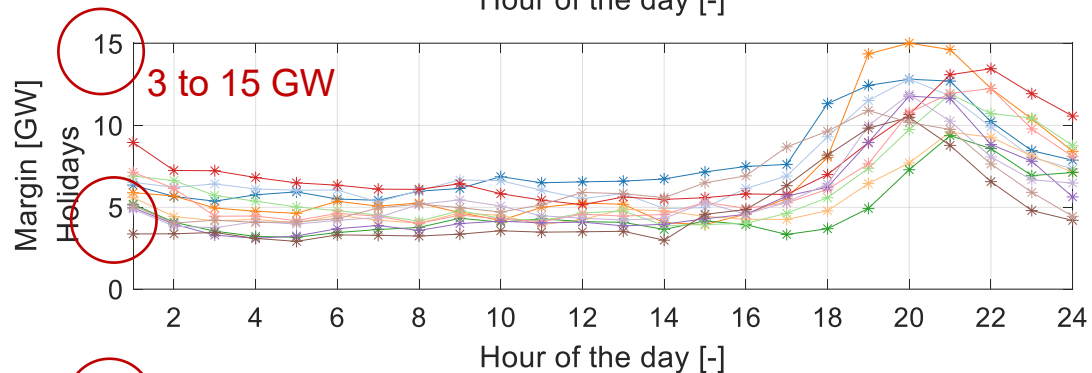
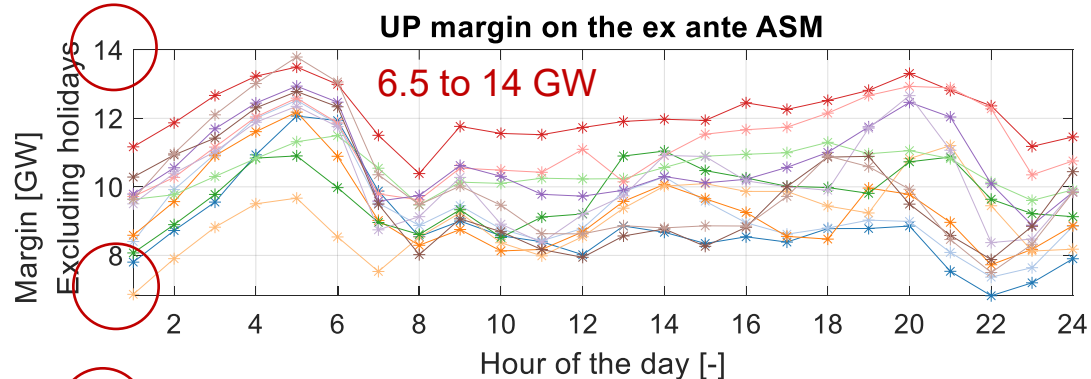
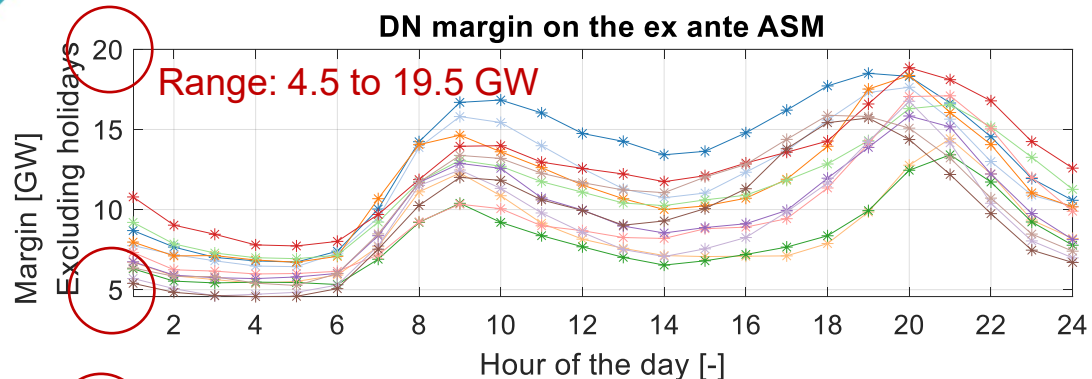


Margin	DN	UP
min	2-4 GW	3-6 GW
max	25-31 GW	20-25 GW
median	9-12 GW	10-13 GW
25 th perc.	6-9 GW	8-11 GW
75 th perc.	13-16 GW	12-15 GW



Mean per hour of the day and month for NCC(*)

Mean downward (left) and upward (right) margins of the eligible GUs analyzed in 2022, downstream of the ex ante ASM



(*) NCC (National Control Center) control area: aggregate of market zones covering the continental part of Italy: CNOR, CSUD, NORD, SUD and CALA, and also SIC1 when connected synchronously to the peninsula (neglected here)



Results for NCC – Possibly critical hours

Hours with margins below a threshold, here 3.5 GW, in 2022

DN margin after the ex ante ASM: 376 “violation” hours in 2022

	Sun		Mon		Tue		Wed		Thu		Fri		Sat		Tot	Tot
	D	H	D	H	D	H	D	D	H	H	D	H	D	H	D	H
Jan	2	3	1	2	1	5	1	1	1	4	0	0	1	11	7	26
Feb	1	9	1	1	0	0	0	0	0	0	0	0	1	1	3	11
Mar	1	2	0	0	0	0	0	0	0	0	0	0	1	1	2	3
Apr	3	26	3	14	0	0	1	4	0	0	3	3	4	8	14	55
May	5	36	2	3	0	0	0	0	1	1	0	0	3	10	11	50
Jun	3	11	1	1	0	0	0	0	1	1	0	0	1	7	6	20
Jul	1	3	0	0	0	0	0	0	0	0	0	0	1	5	2	8
Aug	3	11	2	4	0	0	0	0	0	0	0	0	1	6	6	21
Sep	4	24	1	4	0	0	0	0	0	0	1	1	0	0	6	29
Oct	4	19	1	2	1	5	0	0	0	0	1	2	4	12	11	40
Nov	4	40	1	1	2	6	2	4	1	5	3	3	4	14	17	73
Dec	3	14	2	5	1	2	0	0	1	1	2	3	3	15	12	40
Year	34	198	15	37	5	18	4	9	5	12	10	12	24	90	97	376

D = number of days
H = number of hours

around the maximum of the average values reported by Terna for 2020-2021 for the total FRR and RR requirement (average values aggregated by hour of the day and month for January, April, July and October)

Possibly critical hours for DN margin:

- similar results also after XBID and BM;
- overall, the critical hours of the day (from 1 to 24) most often cover the range from 1 or 2 to 18 from April to June, from 2 to 16 or 17 from August to December.

Possibly critical hours for UP margin:

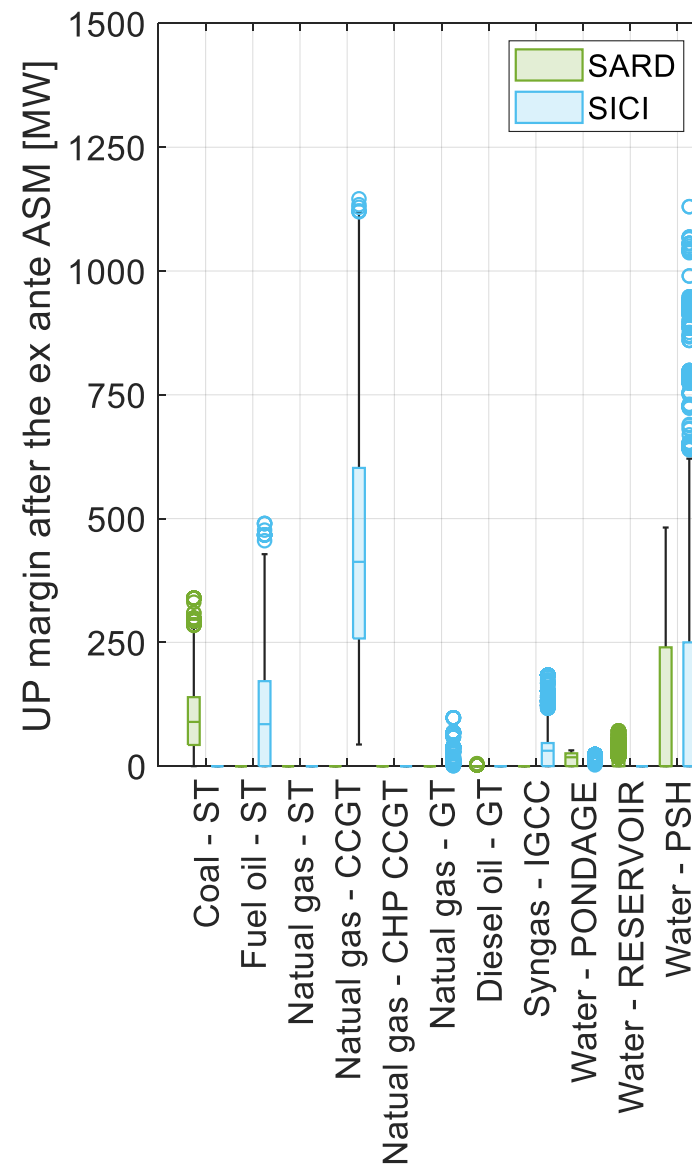
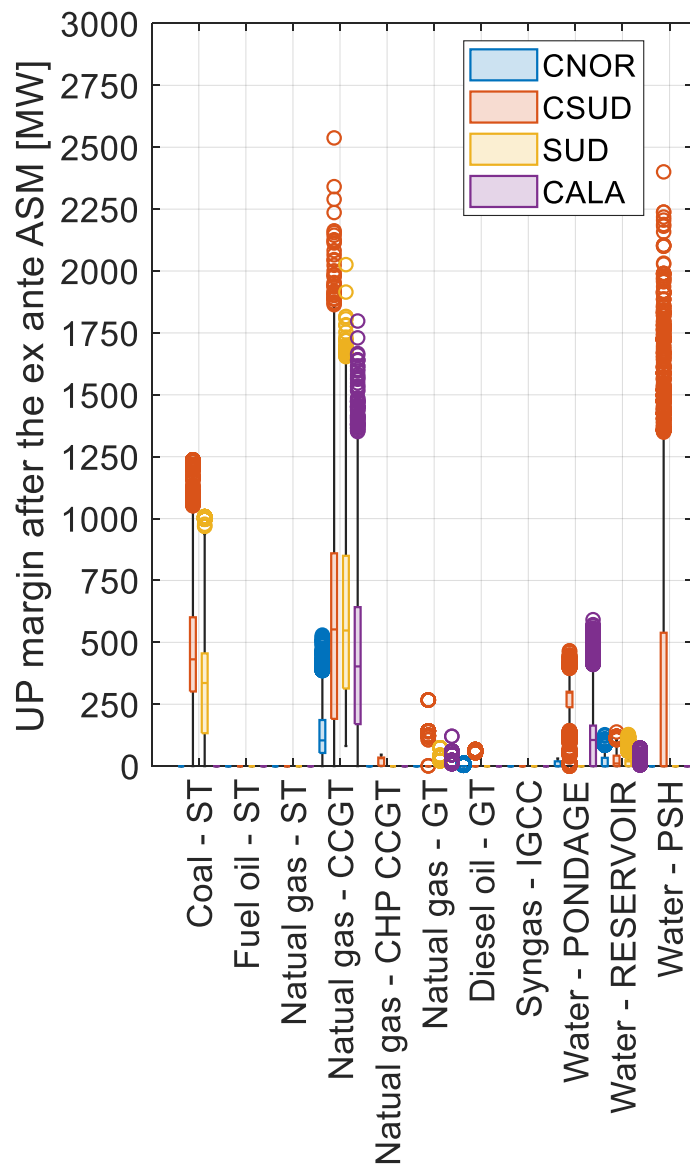
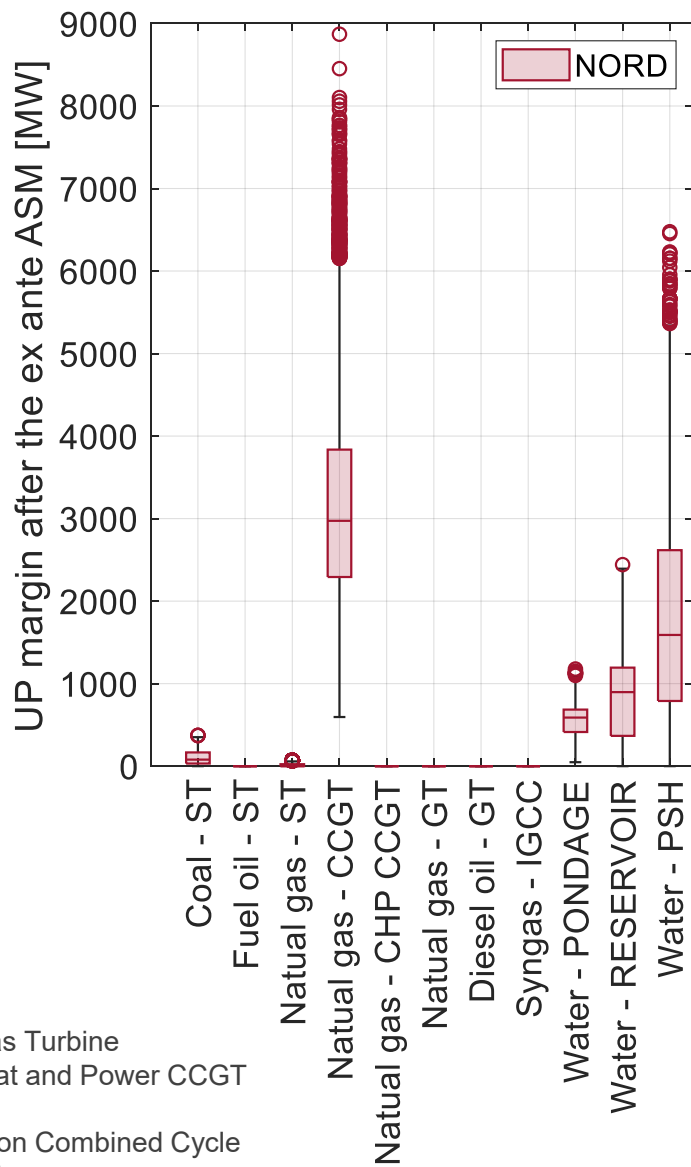
- 4 hours after the ex ante ASM (all on Saturdays)
- 8 hours (7 on Saturdays, 1 on a Sunday) after XBID
- 6 hours after the BM (3 on Saturdays, 3 on Sundays);
- overall, a Saturday in January, a Saturday and a Sunday in April, a Saturday in March, one in November, and a Sunday in August
- hours in the first half of the day, between 1 and 11, mainly in the first quarter of the day (up to about 6 or 7).

NCC (National Control Center) control area: aggregate of market zones covering the continental part of Italy: CNOR, CSUD, NORD, SUD and CALA, and SIC1 when connected synchronously to the peninsula (neglected here)



Zonal results per energy source & tech in 2022

UP margin,
ex ante ASM

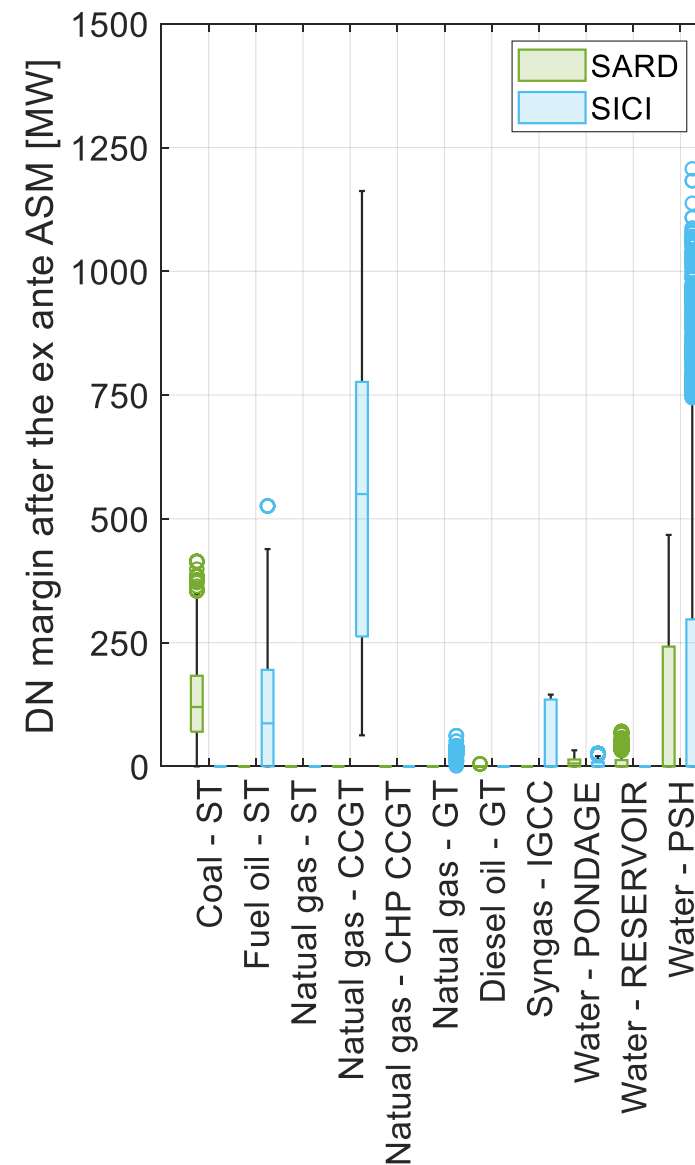
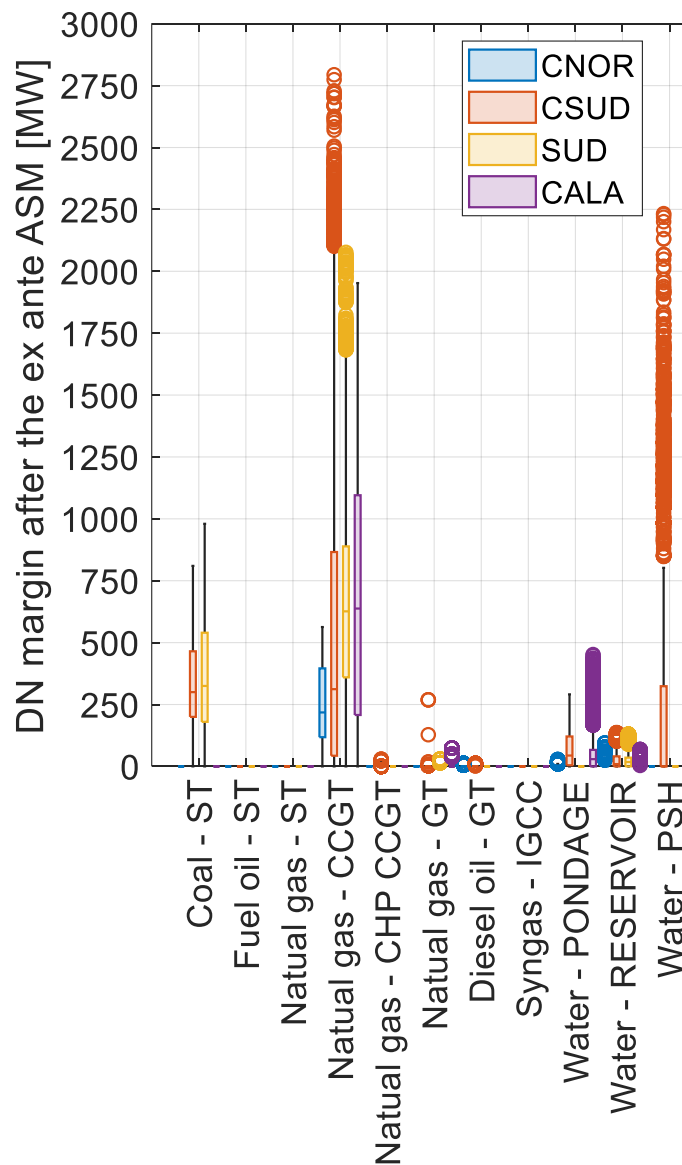
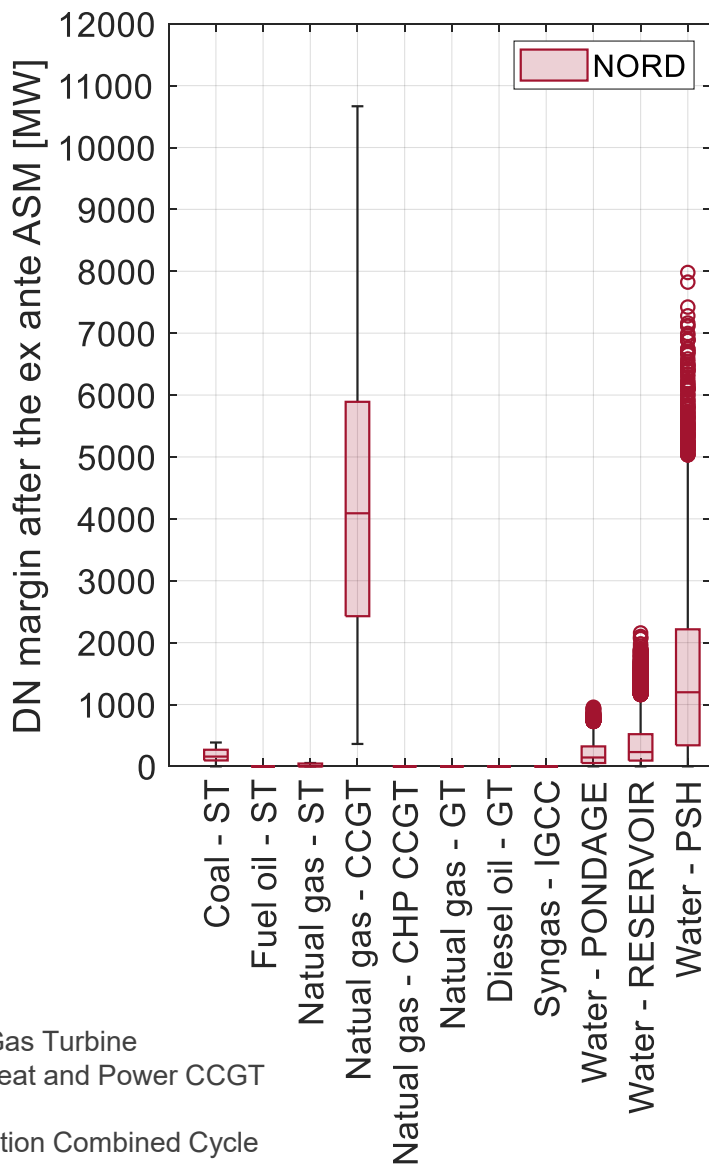


ST: Steam Turbine
CCGT: Combined-cycle Gas Turbine
CHP CCGT: Combined Heat and Power CCGT
GT: Gas Turbine
IGCC: Integrated Gasification Combined Cycle
PSH: Pumped Storage Hydropower



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DN margin,
ex ante ASM



ST: Steam Turbine
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- Estimate of the **hourly upward and downward margins** available for **aFRR, mFRR and RR** in the **Italian power system** in 2015-2022, from eligible Generation Units (GUs).
 - Focus on **2022** after the **ex ante ASM**:
 - **especially on Sundays and Saturdays**, when few conventional GUs are online (low residual load to be met), **downward margins could become too small: for a 3.5 GW threshold, e.g., 4.3% critical hours**;
 - **most significant contributions to the median values of the margins**:
 - **UP: natural gas CCGTs, PSH and reservoir GUs in the NORD zone** (3.0 GW, 1.6 GW and 0.9 GW respectively); **natural gas CCGTs in the other zones except for SARD and CNOR, pondage GUs in NORD and CSUD, and coal-fired STs in CSUD and SUD** (each between 0.3 GW and 0.6 GW);
 - **DN: natural gas CCGTs and PSH GUs in the NORD zone** (4.1 GW and 1.2 GW respectively); **natural gas CCGTs in the other zones except for SARD, coal-fired STs in CSUD and SUD, reservoir GUs in NORD** (each between 0.2 GW and 0.6 GW).
 - **Recent evolution of the Italian regulatory framework: 2025: new Integrated Text for Electrical Dispatching (“Testo Integrato del Dispacciamento Elettrico” - TIDE)**
 - ongoing changes to the Italian Grid Code
 - **more technologies and energy sources (e.g., NPRES GUs and, more generally, inverter-based technologies) involved in ancillary service supply**
 - **new classification of ancillary services and new remuneration mechanisms**
 - increasing participation in **European platforms** for the exchange of FCR, aFRR, mFRR, RR.
- ➡ For each ancillary service, analyse the evolution of**
- **requirements/needs**
 - **(all) available flexible resources**



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– sustainable energy security, ready for the future –

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**Thank you very much
for your attention!**

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