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IEA Wind
Task 25
Spring 2021 meeting

Assessing the operational flexibility provided by energy storage systems. The Spanish system in 2030

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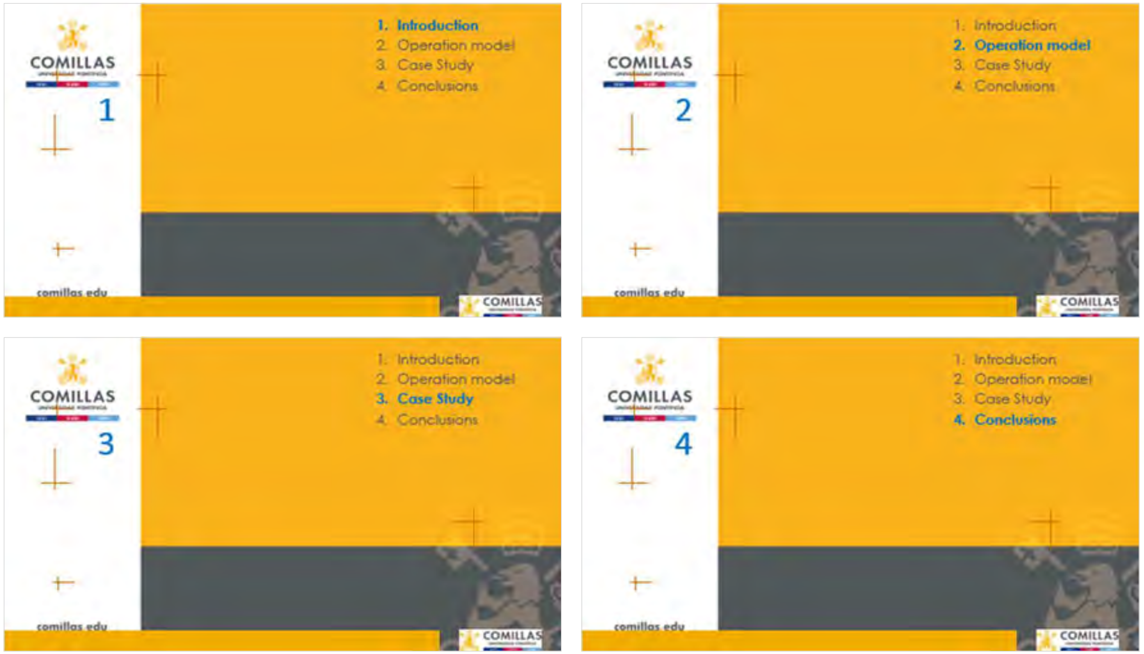
Content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Operational flexibility

- Ability of the system to withstand to the uncertainty and variability in generation and electricity demand, while maintaining the desired reliability at an affordable cost
- Measures:
  - Capacity factors
  - Contribution of each dispatchable technology to the variation of the (net) demand at different time horizons (monthly, weekly, daily)
  - Contributions to the system ramps
  - Contributions to the peak (net) demand hours

Key question: which flexibility is provided by any type of ESS

Pumped-storage hydro (PSH) or batteries operate shifting energy between different timeframes

Comparison between pumped-storage hydro and batteries → a detailed system operation modeling

- Hourly operation
- Thermal units: operational constraints
- Hydro power plants: operation guide curves, maximum functional ramps, minimum and maximum weekly power
- Energy production and operating reserve provision
- Unit-based modelling of energy storage units

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open TEPES

https://opentepes.readthedocs.io/en/latest/

Open Generation and Transmission Operation and Expansion Planning Model with RES and ESS (openTEPES)

- Chronological model with flexible duration of the time step (e.g., bi-hour, 3-hour, 4-hour time step)
- Efficient mathematical implementation:
  - Tight and compact formulation of some UC constraints
  - Scaling variables and constraints around 1

open source

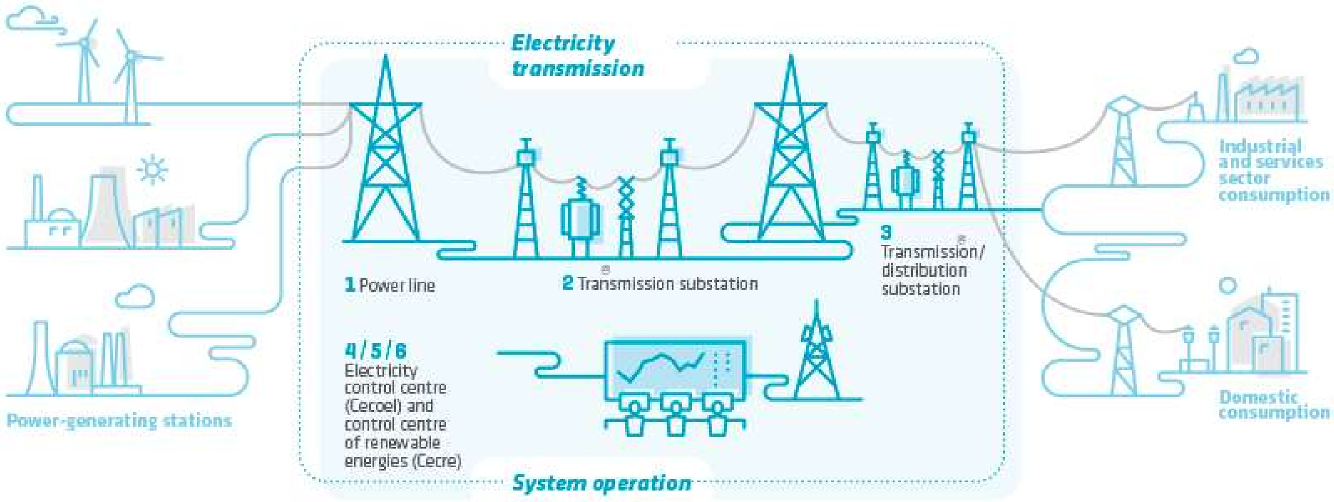
PYTHON

PYOMO

GitHub

Main features

- Generation and transmission operation and expansion planning
- Network constrained unit commitment (NCUC)
- DC power flow (DCPF) with losses and line switching



Demand and operating reserves

- Balance of generation and demand [GW]
- Upward and downward operating reserves [GW] provided by controllable generators (CCGT, storage hydro) and ESS (pumped-storage hydro, batteries), including activation of these reserves [GWh]
- Operating reserve activation: proportion (e.g., 25-30 %) of the power provided as operating reserves which is asked to be deployed as energy

Thermal subsystem

- Minimum and maximum output of the second block of a committed unit [p.u.]
- Total output of a committed unit [GW]
- Logical relation between commitment, startup and shutdown status [p.u.]
- Maximum ramp up and ramp down for the second block [p.u.]
- Minimum up time and down time [h]

Hydro and energy storage systems

- Power plants: hydro, open-loop pumped-storage hydro (PSH) aggregated in management units, closed-loop PSH treated individually, and system battery storage
- ESS energy inventory (only for load levels multiple of 24, or 168 h depending on the ESS type) [GWh]
- Total charge of an ESS unit [GW]
- Minimum and maximum charge of an ESS [p.u.]
- Incompatibility between charge and discharge of an ESS [p.u.]
- Minimum and maximum weekly variable generation [GW]
- Operation guide curves [GWh]

Variable renewable energy sources (VRES)

- Power plants: solar PV, solar thermal, onshore wind, biomass, and cogeneration
- Minimum and maximum hourly variable generation [GW]

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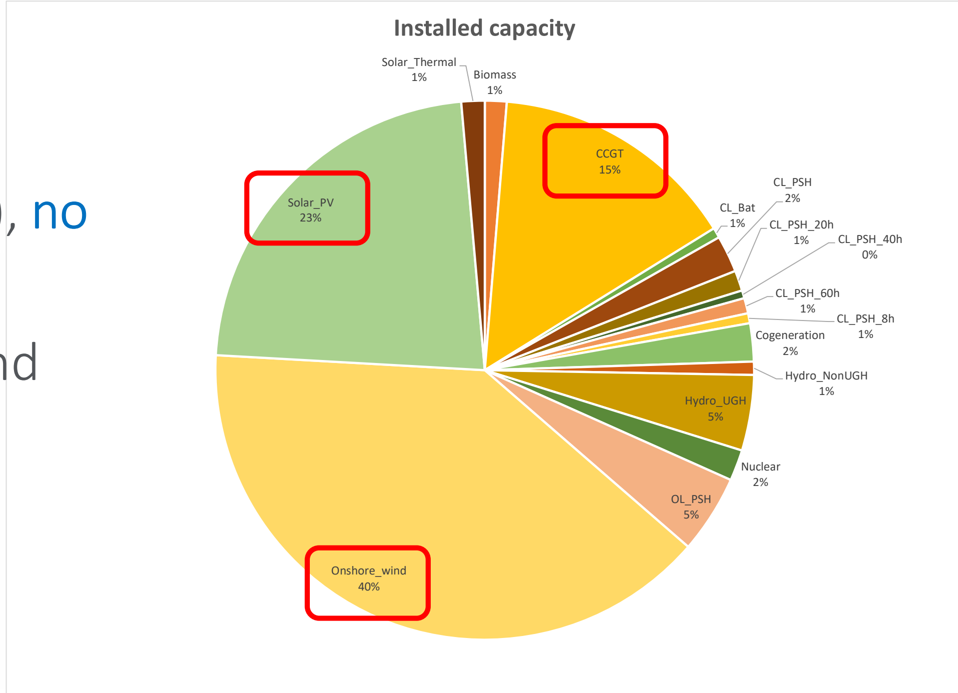
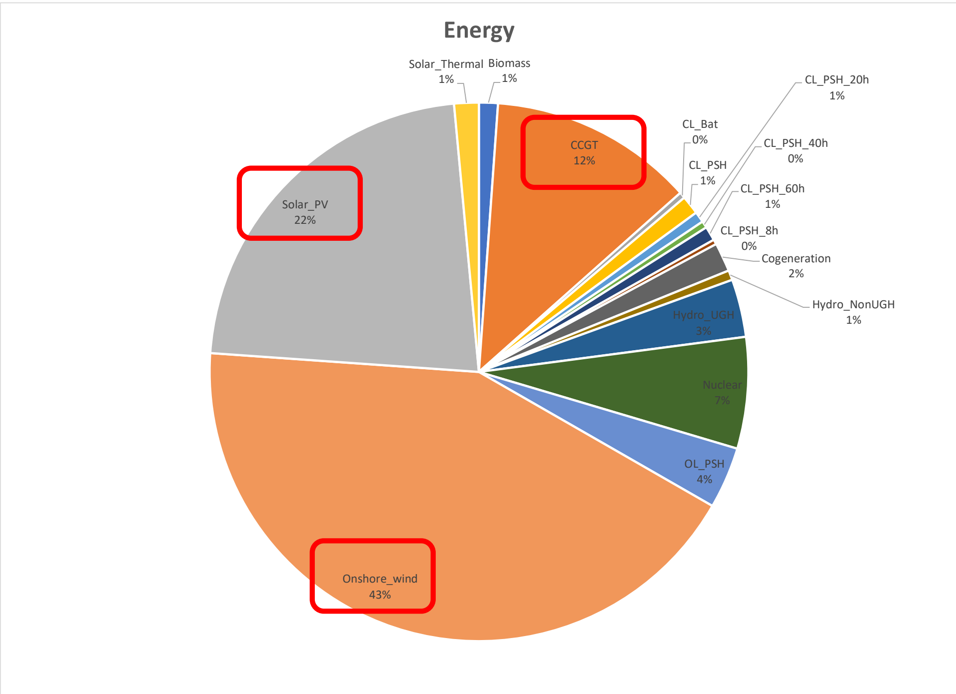
Case study: Spain 2030

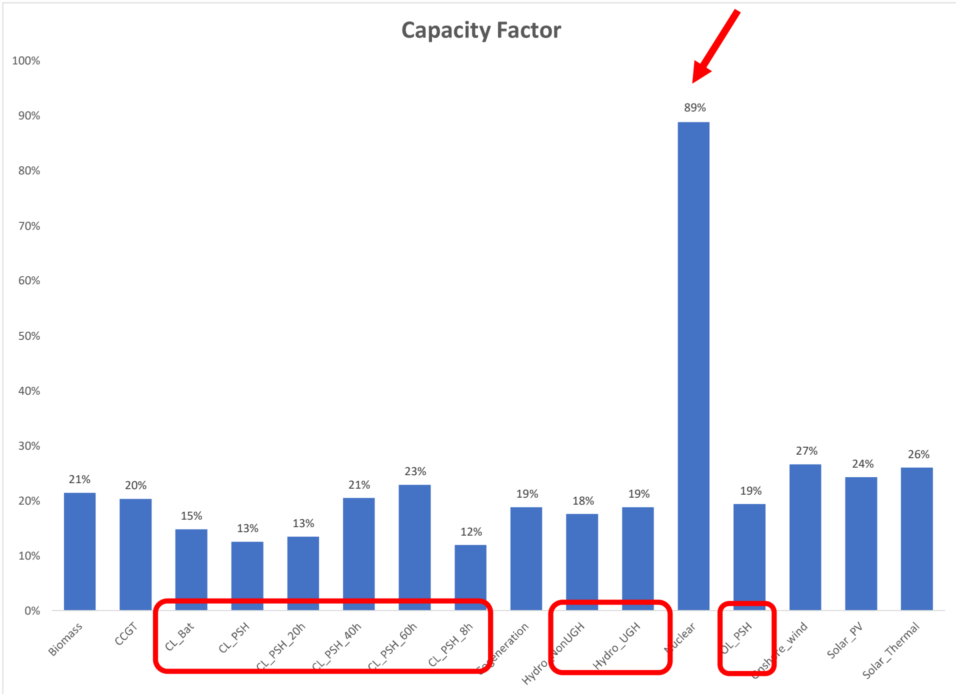
- 10-year Integrated National Energy and Climate Plan (NECP)
- Installed capacity: 165,000 MW
- Half of the nuclear units phased out (3,050 MW), no coal units, existing CCGT (24,560 MW)
- Significant investments on solar (39,800 MW) and onshore wind (65,200 MW)
- Existing (5,600 MW) and additional pumped-storage hydro (5,300 MW) of different sizes
- Batteries forced to be installed (1,000 MW)



System operation

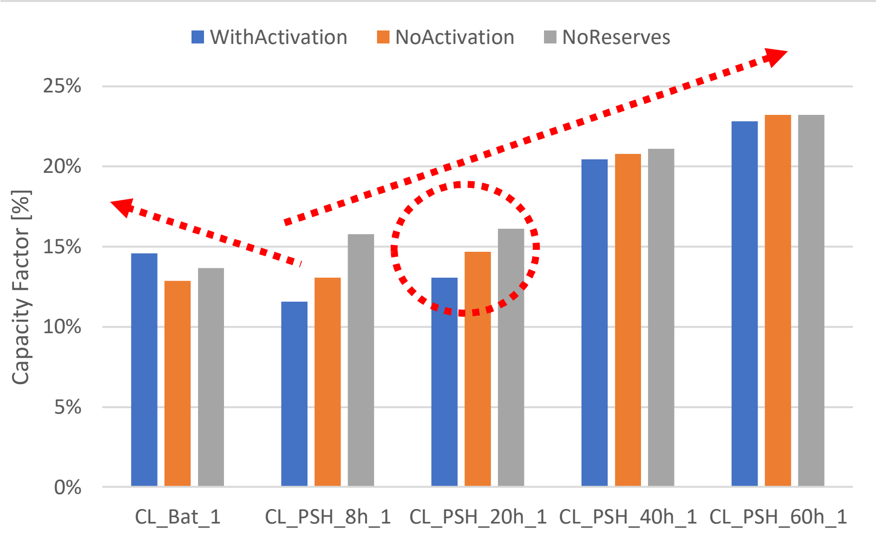
Energy demand: 334,270 GWh





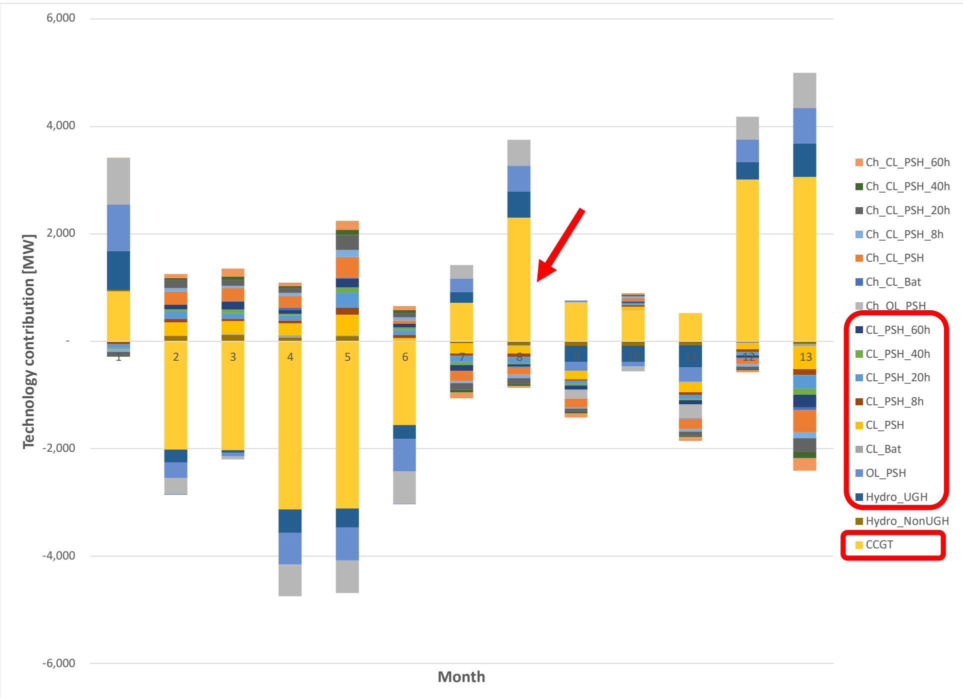
Capacity factor of pumped-storage hydro vs. battery

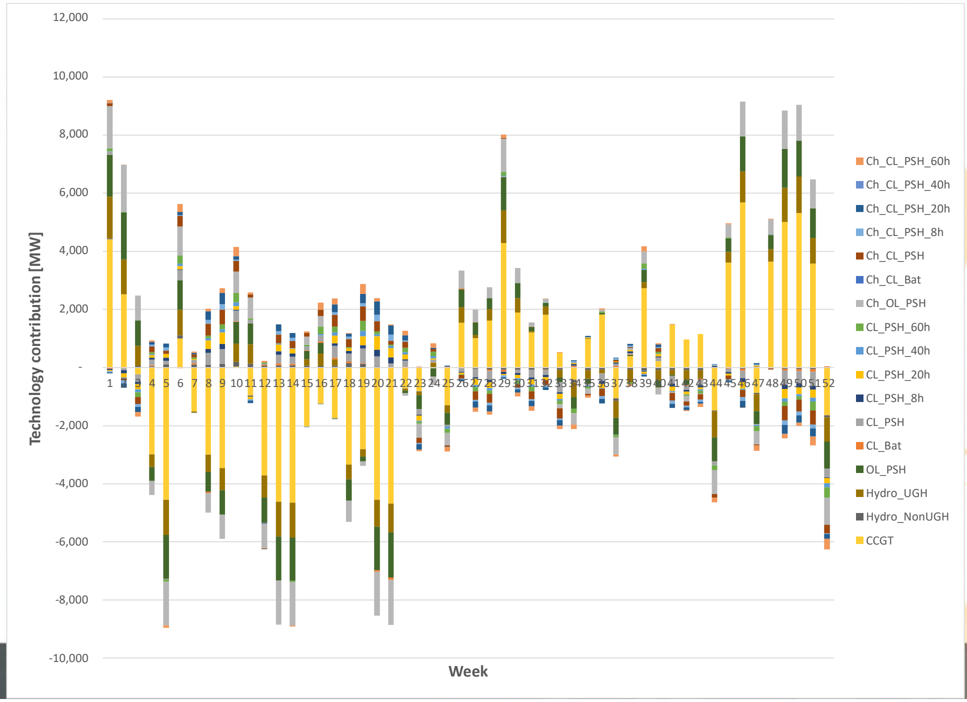
- Larger storage size is worthy for the system
  - ➢ Increase from 12 to 23 % for 8 to 60 h size for PSH
- For the same size round-trip efficiency matters
  - ➢ Increase from 12 to 15 % for 8 h PSH to battery
- Operating reserves affect the ESS operation
  - ➢ Variations in the CF due to considering or not operating reserves and their activation



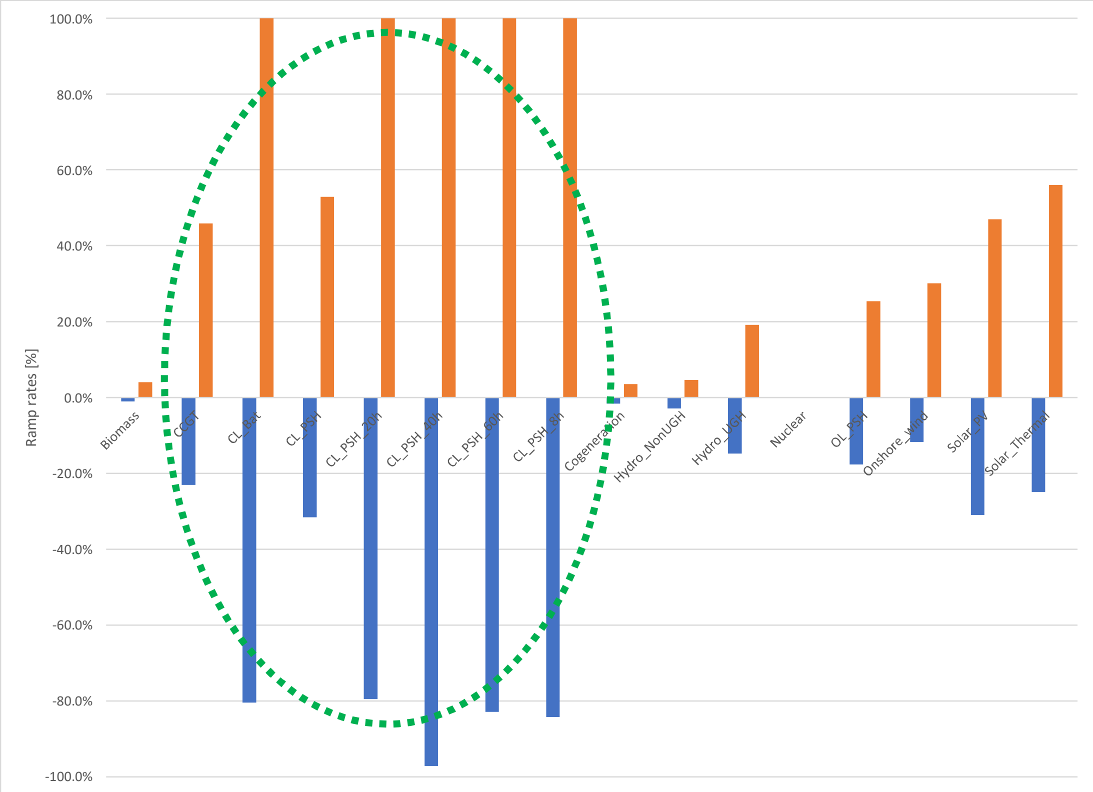
Operational flexibility

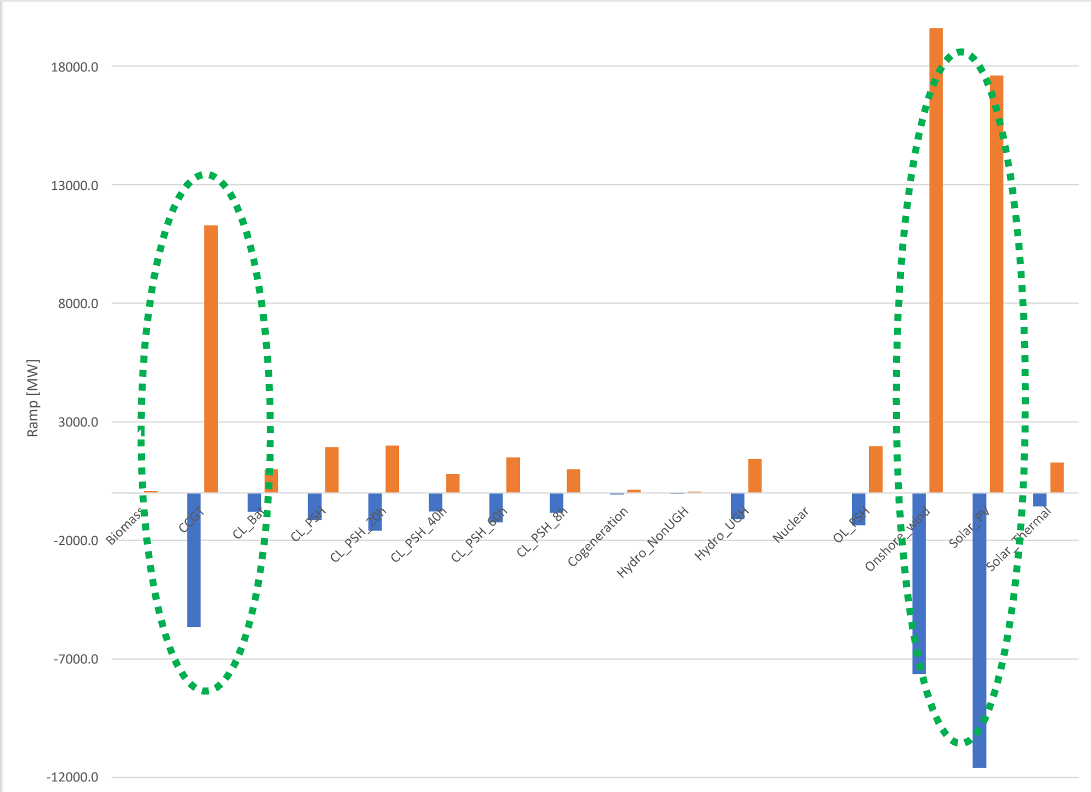
Technology contribution to the monthly/weekly variation of the net demand (difference between the value and its mean)





Relative and absolute ramps by technology





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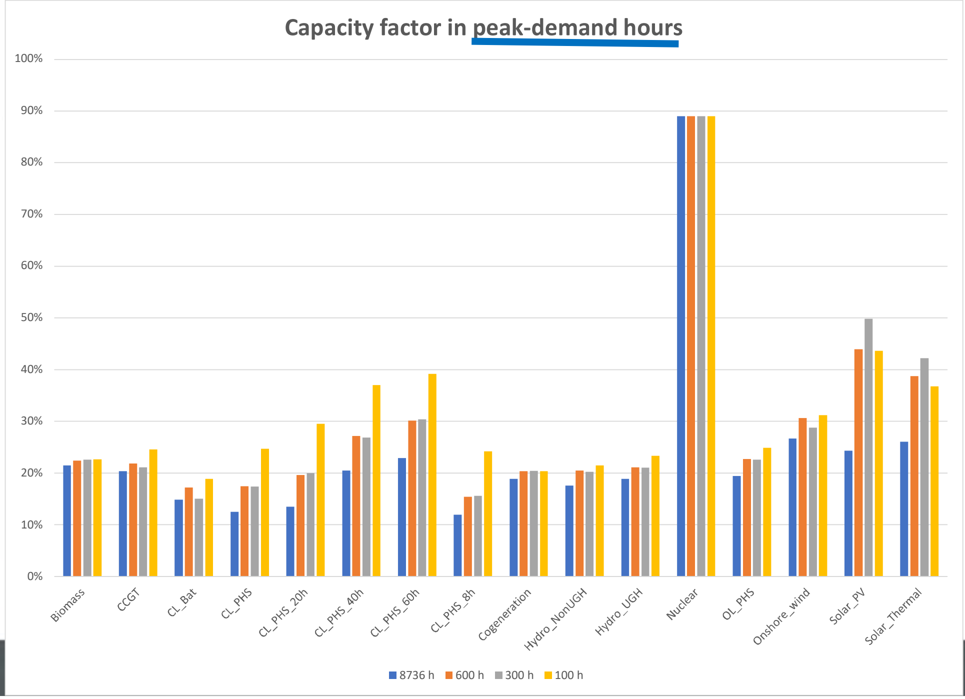
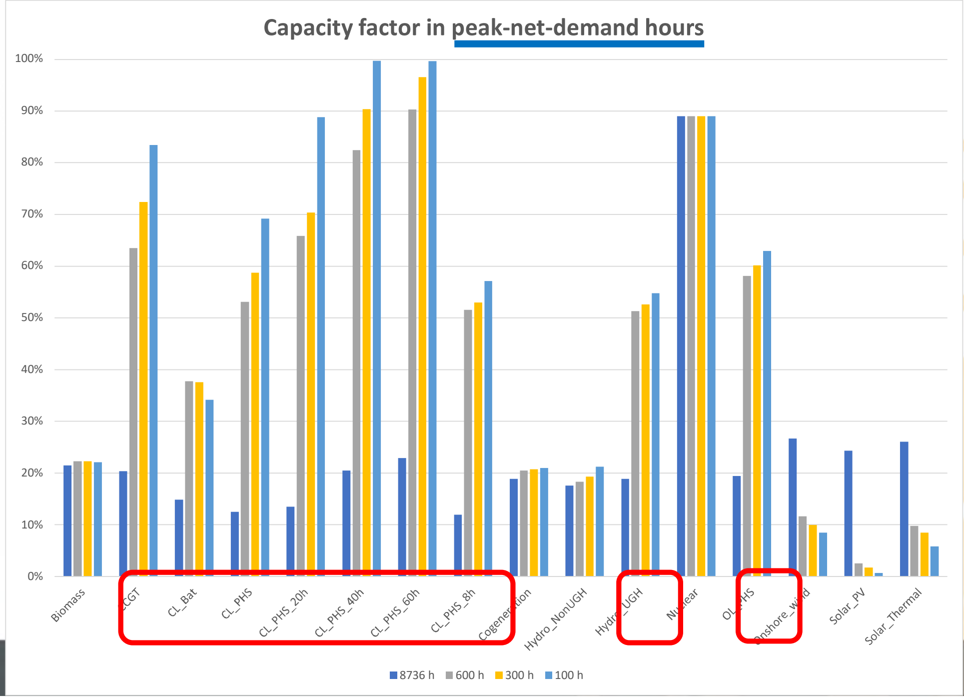
Firmness/Electric Load Carrying Capability (ELCC)

Capacity factors of the different technologies at peak hours of demand and of net demand





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Conclusions

- The higher storage capacity more the ESS is used (PSH with large reservoirs preferred over smaller ones). Batteries compete with the PSH with small size (8 h)
- Operational flexibility provided by CCGT, hydro, PSH, and batteries
- ESS and hydro provide hourly full ramp rate to cope with VRES variability
- At peak net-demand hours, CCGT, hydro, open- and closed-loop PSH have larger capacity factors while VRES decrease their capacity factor

Other projects that use openTEPES

- Open ENergy TRansition ANalyses for a low-carbon Economy (openENTRANCE), developed for the European Union, aims at developing, using and disseminating an open, transparent and integrated modelling platform for assessing low-carbon transition pathways in Europe.
- Analysis of the expansion and operation of the Spanish electricity system for a 2030-2050 time horizon, developed for Iberdrola, aims at evaluating the potential and role that each generation, storage and consumption technology can play in the future mix of the Spanish electricity system.
- Assessment of the storage needs for the Spanish electric system in a horizon 2020-2050 with large share of renewables, developed for the Instituto para la Diversificación y Ahorro de la Energía (IDAE), aims at assessing, from a technical and economic point of view, the daily, weekly and seasonal storage needs for the Spanish electricity system in the 2020-2050 horizon.
- MODESC – Platform of innovative models for speeding the energy transition towards a decarbonized economy, developed for the Ministry of Science and Innovation, aims at developing of a global platform that integrates innovative energy simulation and impact assessment models that allow speeding the decarbonization of the electricity system including the electrification of the energy demand.
- Improving energy system modelling tools and capacity, developed for the European Commission, aims at improving the description of the Spanish energy system in model TIMES-SINERGIA, from the technologies considered or a higher time resolution to the detailed modeling of the power sector, such as the inclusion of transmission constraints.
- European Climate and Energy Modelling Forum (ECEMF), developed for the European Commission, aims at providing the knowledge to inform the development of future energy and climate policies at national and European levels. In support of this aim, ECEMF proposes a range of activities to achieve five objectives and meet the four challenges set out in the call text. ECEMF's programme of events and novel IT-based communications channel will enable researchers to identify and co-develop the most pressing policy-relevant research questions with a range of stakeholders to meet ambitious European energy and climate policy goals, in particular the European Green Deal and the transformation to a climate neutral society.

Thank you for your attention

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https://pascua.iit.comillas.edu/aramos/Ramos_CV.htm

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https://pascua.iit.comillas.edu/aramos/openTEPES/index.htm

GitHub - IIT-EnergySystemModels/openTEPES: Open Generation and Transmission Operation and Expansion Planning Model with RES and ESS (openTEPES)