Artelys | OPTIMIZATION SOLUTIONS

Power system flexibility - The METIS approach to identify needs and solutions

3rd PAC Modellers' Exchange Workshop
30/01/2020

AGENDA

1. **Introduction Artelys**
2. The METIS project
3. Flexibility needs
4. Flexibility solutions
5. Optimal flexibility portfolios
6. Conclusions

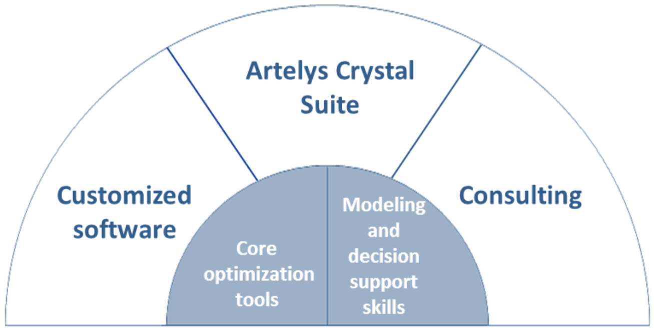
ARTELYS – COMPANY PROFILE

Independent company founded in 2000

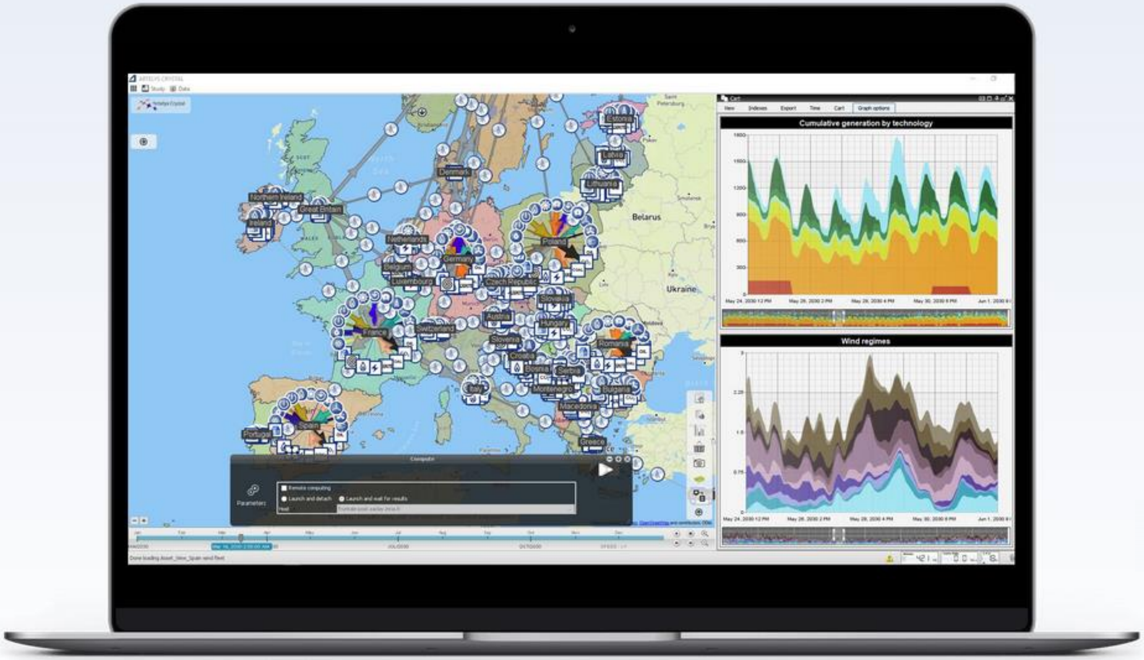
- 60+ consultants specialized in applied mathematics, software development & engineering
  - Numerical optimization, forecast, simulation
- Locations
  - Paris, France
  - Brussels, BE
  - Chicago, USA
  - Montréal, Canada

Our core skills

- Numerical optimization and decision-support
- Consulting services and software
- Strong specialization in the **energy** sector



ARTELYS CRYSTAL SUITE



Artelys Crystal
Super Grid

Optimization of interconnected systems

— Artelys Crystal Super Grid provides the quantitative elements to evaluate the costs and benefits of an energy strategy and to optimize it.

LEARN MORE

City

Super Grid

Energy Planner

Forecast

Resource Optimizer

Network Designer

ARTELYS – OUR CLIENTS

Public institutions

European Commission

COMMISSION DE RÉGULATION DE L'ÉNERGIE

economie SPF Economie, P.M.E., Classes moyennes et Energie

Bureau fédéral du Plan Analyses et prévisions économiques

BANQUE MONDIALE

FERC

dgcis direction générale de la compétitivité de l'industrie et des services

Ontario MINISTRY OF ENERGY

Ressources naturelles Canada / Natural Resources Canada

Canada

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Office fédéral de l'énergie OFEN

Grid operators

Rte Réseau de transport d'électricité

elia

EIRGRID

eRDF

Medgrid

GrDF GAZ RÉSEAU DISTRIBUTION FRANCE

Utilities

TOTAL

Kuwait Oil Company

CIE

eDF

eNGie

AIR LIQUIDE

GazMétro la vie en bleu

Dalkia

e.on

Associations/NGOs

European Climate Foundation

bdew German Association of Energy and Water Industries

UFE Union Française de l'Électricité

Market platforms

EPEXSPOT EUROPEAN POWER EXCHANGE

Equipment vendors

Schneider Electric

AREVA

saft

ALSTOM

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RENEWABLES INCREASE VARIATION IN THE POWER SYSTEM

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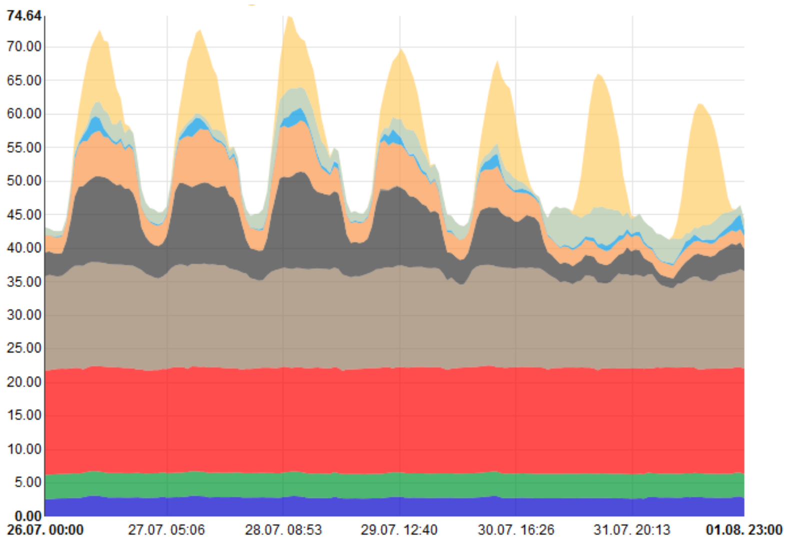
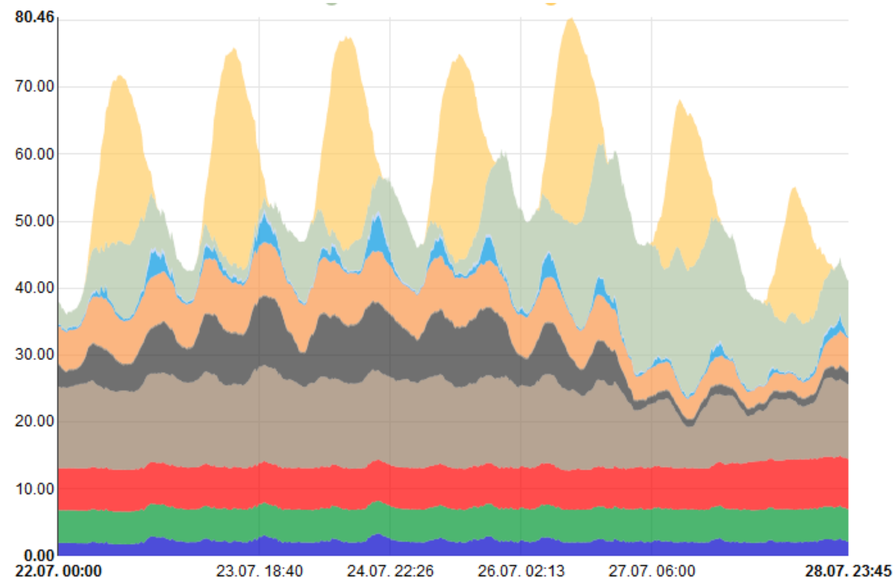
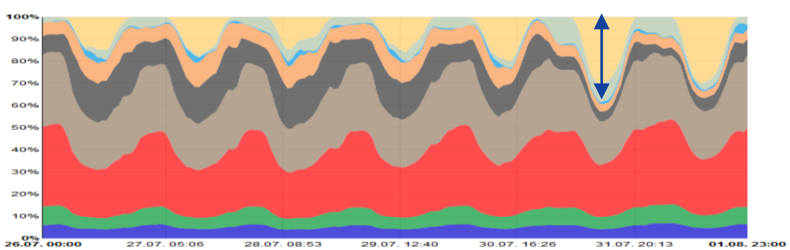
Germany, July week, 2010



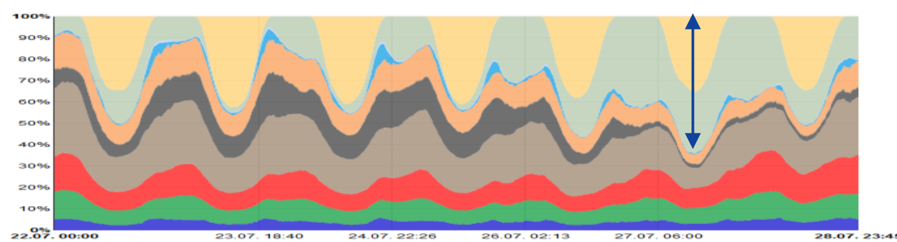
Germany, July week, 2019



vRES share = 38%



vRES share = 64%



Source: www.energy-charts.de

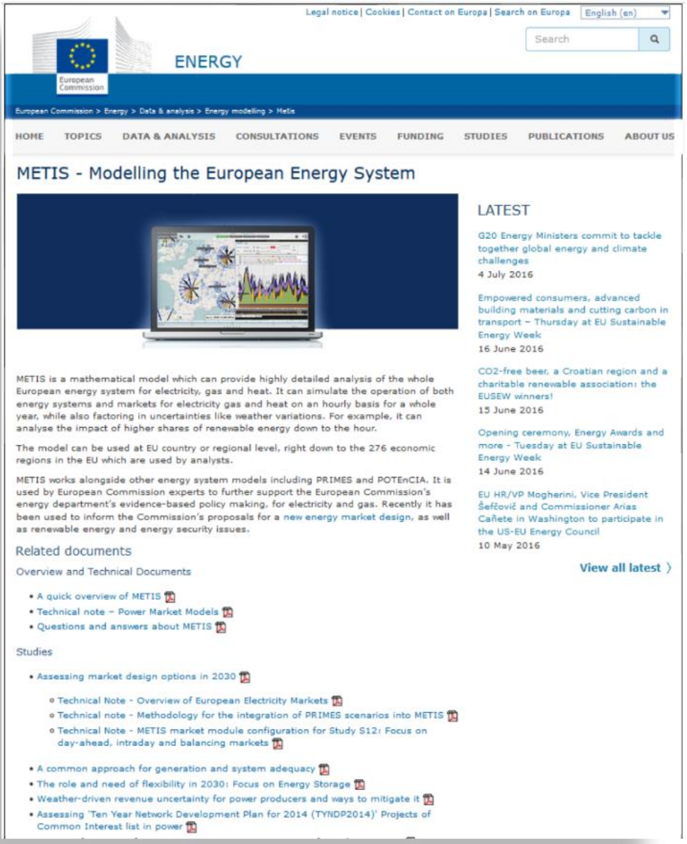
- Pumped Storage consumption
- Import Balance
- Hydro Power
- Biomass
- Uranium
- Brown Coal
- Hard Coal
- Oil
- Gas
- Others
- Pumped Storage
- Seasonal Storage
- Wind
- Solar

THE METIS PHILOSOPHY

Artelys | OPTIMIZATION SOLUTIONS

- Objectives
  - Complement existing modelling tools in EC
  - Provide stronger analytical capabilities to EC
  - Increase transparency
  - Offer a platform for coordination of related analyses across EU

- Publication
  - METIS Studies and Technical Notes are publicly available: https://ec.europa.eu/energy/en/data-analysis/energy-modelling/metis
  - METIS datasets publication upcoming



DG ENER's METIS webpage

THE METIS PROJECTS

Major METIS 1 outcomes

- EU energy system model METIS
- Detailed database (publication upcoming)
- Comprehensive documentation (online)
- 15 studies addressing different policy questions
  - Integration of renewables
  - Market design
  - CBA of infrastructure projects
  - Impact of transport electrification on the power sector
  - The future role of district heating

Project history

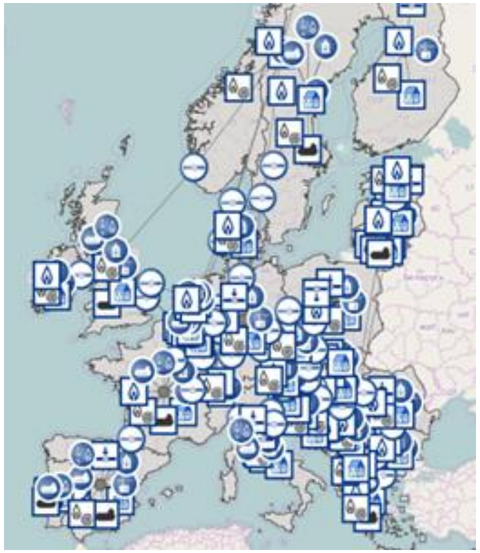
- METIS 1
  - Focus: EU energy system model integrating power, gas and district heat
  - Duration: 2015-2018
- METIS 2
  - Focus: Integration of distribution and transmission networks
  - Duration: 2018-2021
- METIS 3
  - Focus: Modelling of transition pathways towards economy-wide decarbonisation
  - Duration: 2020-2024

For additional information see: https://ec.europa.eu/energy/en/data-analysis/energy-modelling/metis

THE CURRENT METIS TOOL

- Geographical coverage
  - EU 28 + other continental ENTSO-E/G countries
- Focus on a given year (e.g. 2030 or 2050)
  - Exogeneous capacity mix and yearly demand serve as input
  - Provides detailed analysis of the impact of high shares of RES or infrastructure questions on an hourly level
- Power
  - Generation, storage and demand response capacity by country
  - Cross-border NTC capacities between countries
  - Ongoing: integration of distribution and transmission networks
- Gas
  - LNG terminals, gas fields, storage and imports
  - Cross-border network capacities and main constraints within countries
- Heat
  - Stylized representation of District Heating and Cooling by class
  - Statistics on DHC classes at country level

European power model



European gas model

THE METIS FLEXIBILITY APPROACH

Step 1 – Evaluation of the flexibility needs

- Analysis based on the **demand** and generation of **variable RES-e** technologies
- Indicators computed on several **timescales** to reflect the structure of the underlying dynamics

Step 2 – Identification and characterisation of local flexibility solutions

- Identification of the **technologies** that can provide flexibility to the system
- Techno-economic **characterisation** (costs, potential, technical parameters)

Step 3 – Optimisation of flexibility portfolio

- Based on a **whole system** analysis in coordination with neighbouring countries
- Joint optimisation of investments and operations to capture the **synergies** between flexibility solutions

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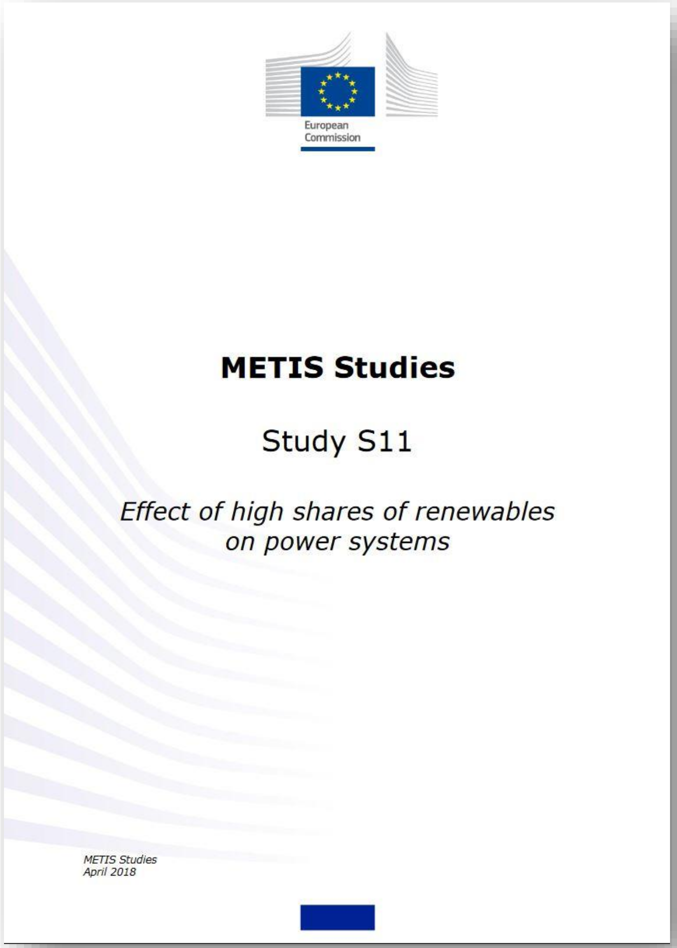
METIS STUDY S11

- Focus on flexibility needs in 2030
  - Assessment of impacts of enhanced RES generation on the overall power system
  - Three different scenarios
    - REF16
    - EUCO30
    - EUCO30 w/ coal phase-out
  - Dedicated indicators for flexibility needs, based on the residual load


European Commission

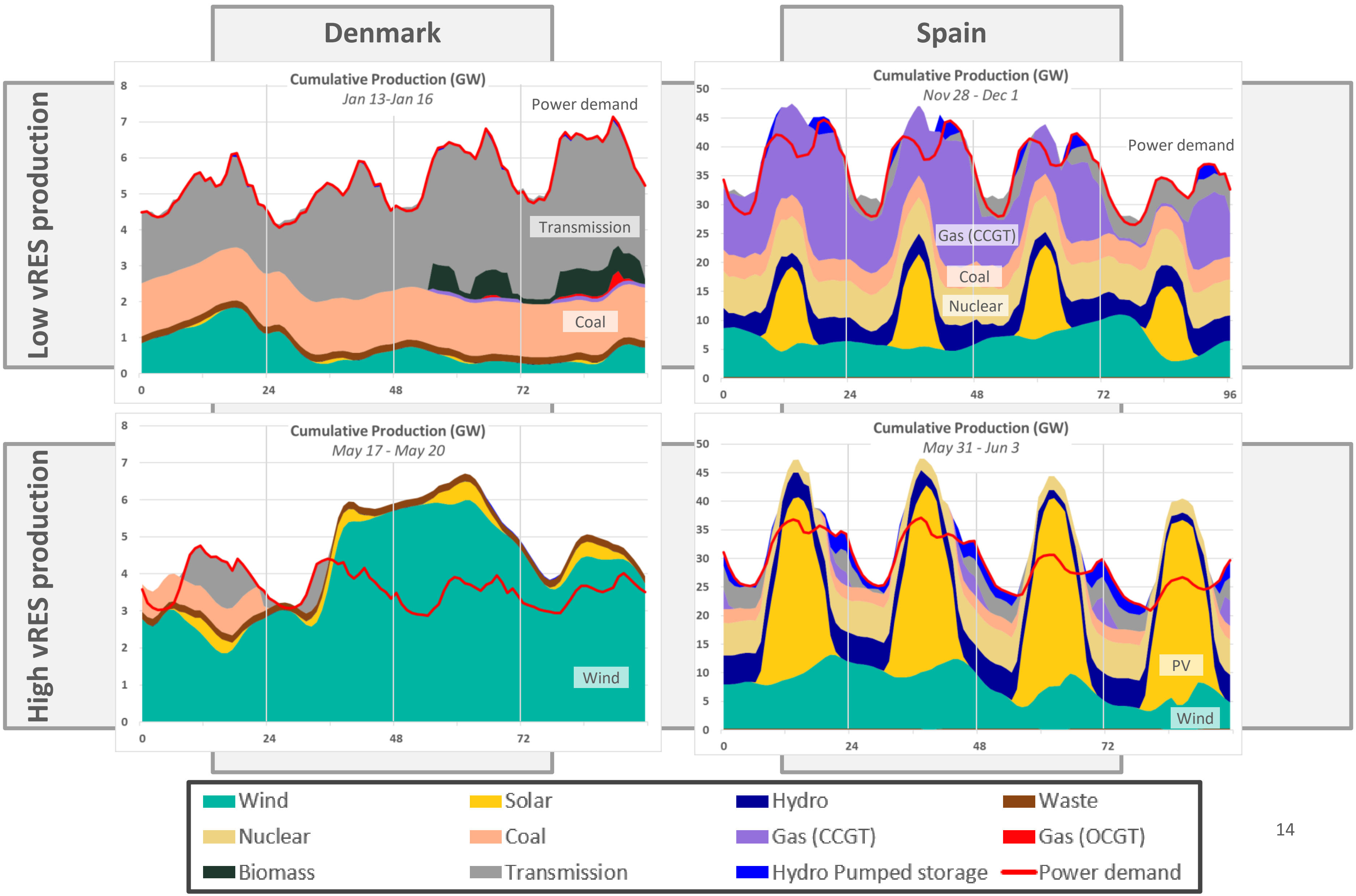
METIS Studies

Study S11

Effect of high shares of renewables on power systems

METIS Studies
April 2018

RENEWABLES WILL JUMBLE THE GENERATION MIX IN 2030



RESIDUAL LOAD WILL BE SUBJECT TO INCREASED VARIATION

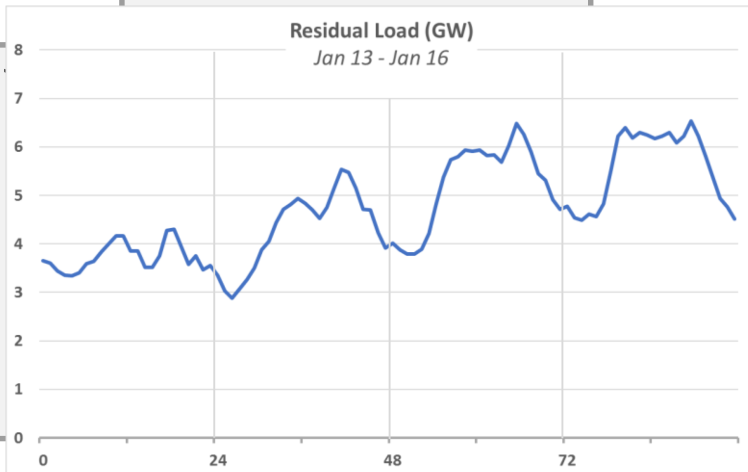
Artelys | OPTIMIZATION SOLUTIONS

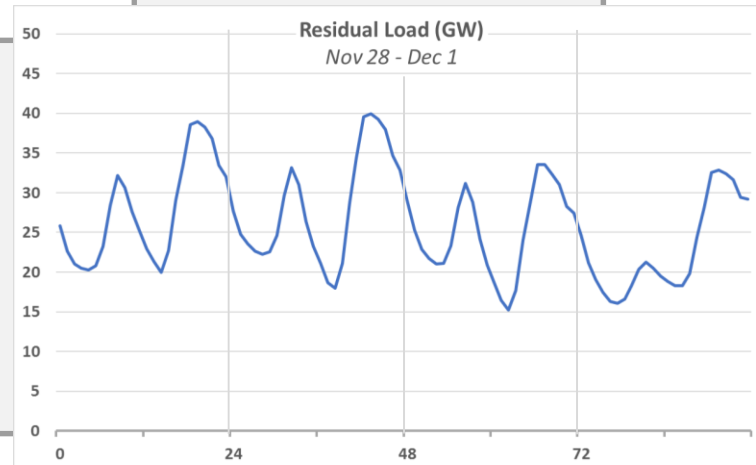
Denmark

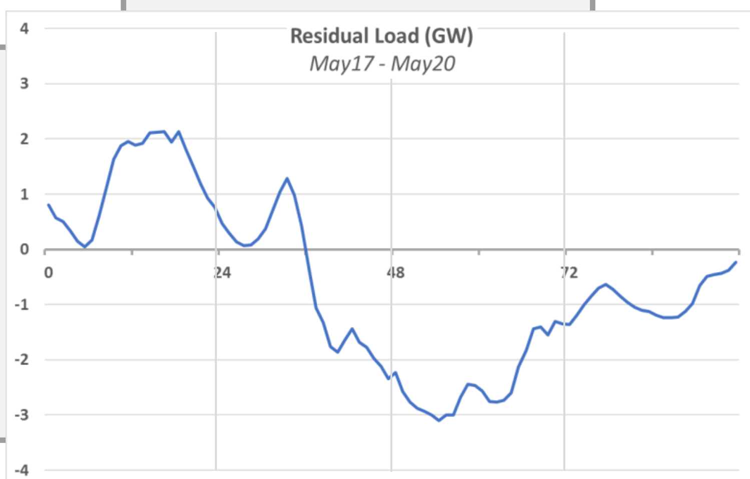
Spain

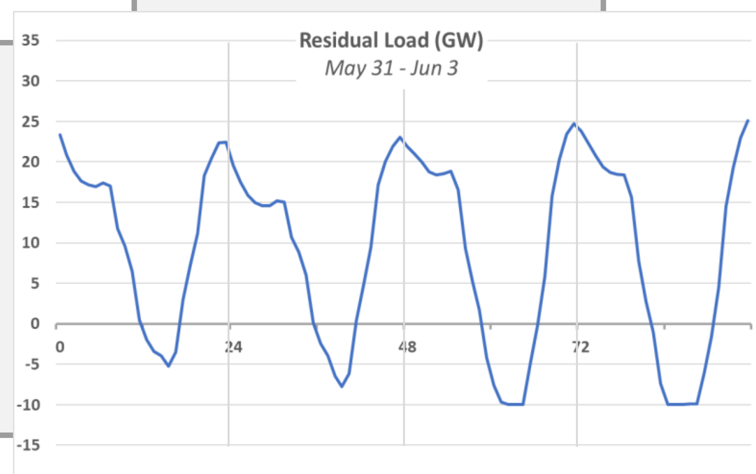
Low vRES production

High vRES production



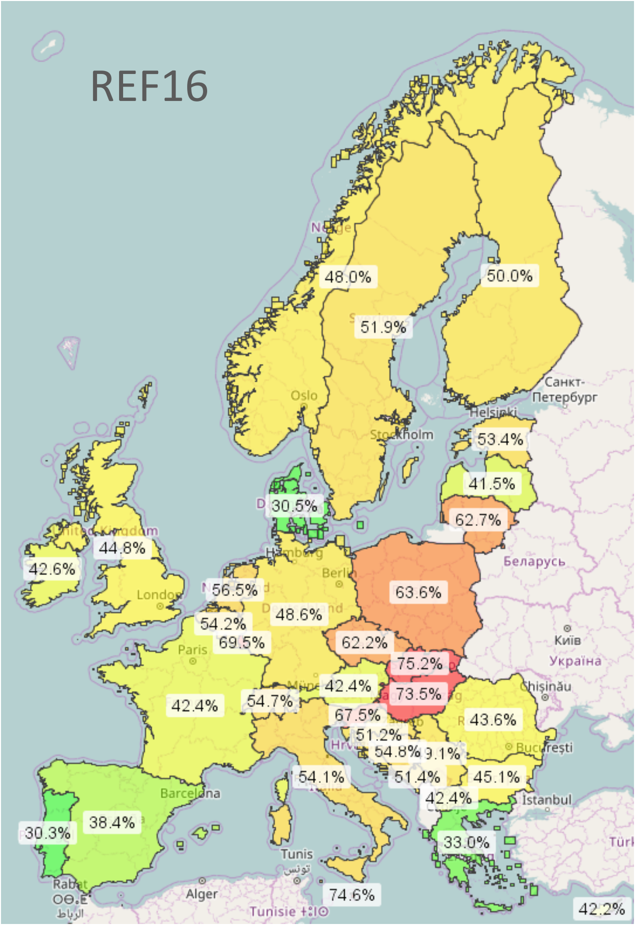


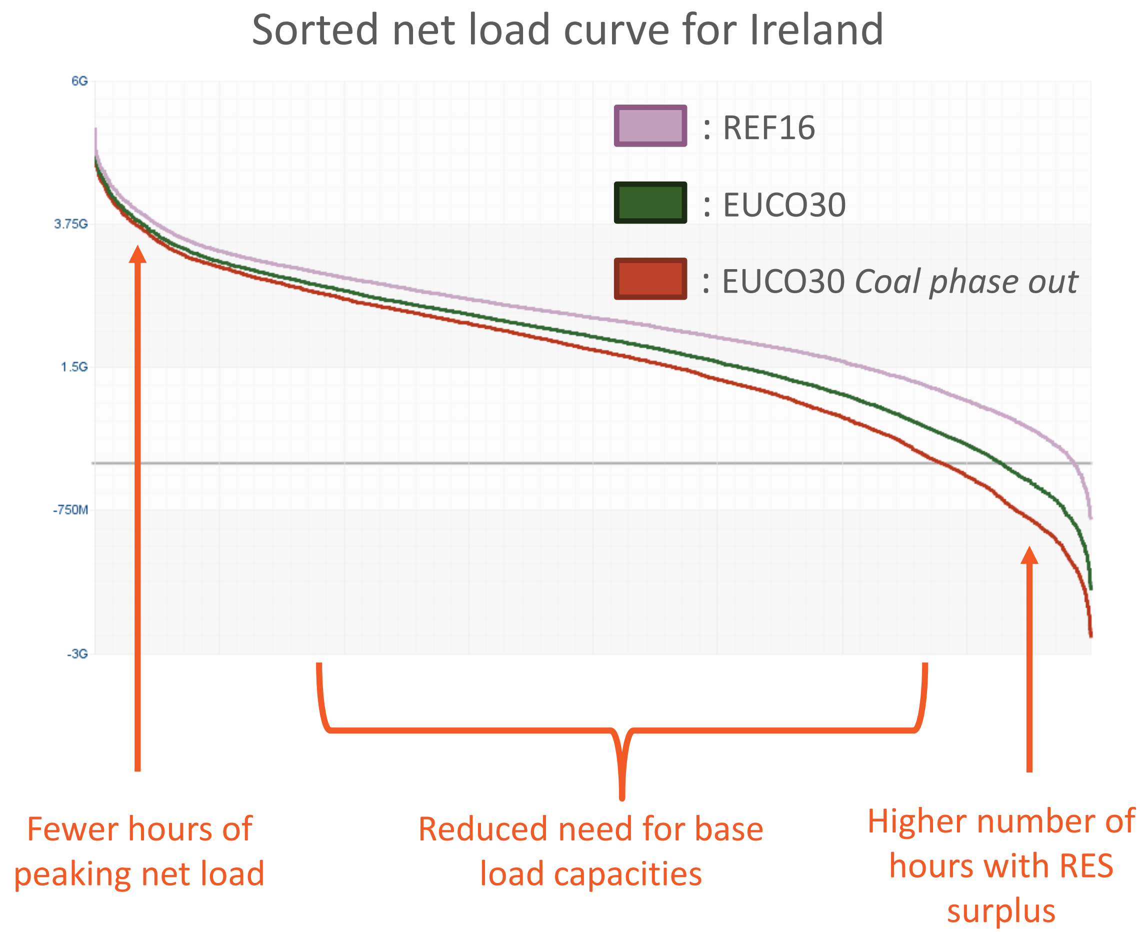




MORE HOURS OF RES SURPLUS, LESS NEED FOR BASE LOAD

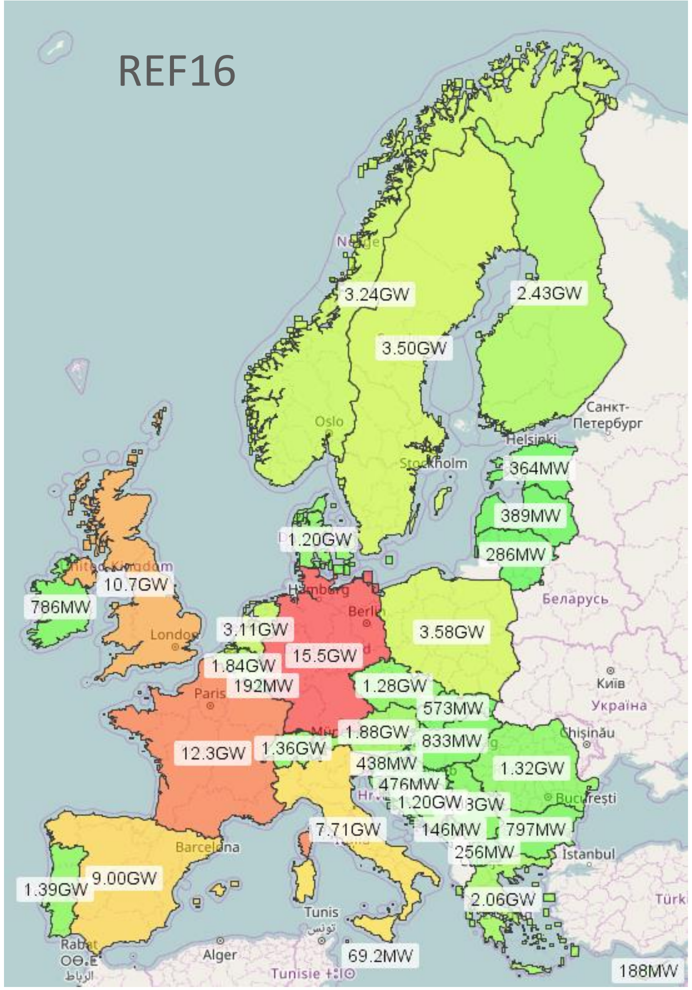
Net load capacity factor

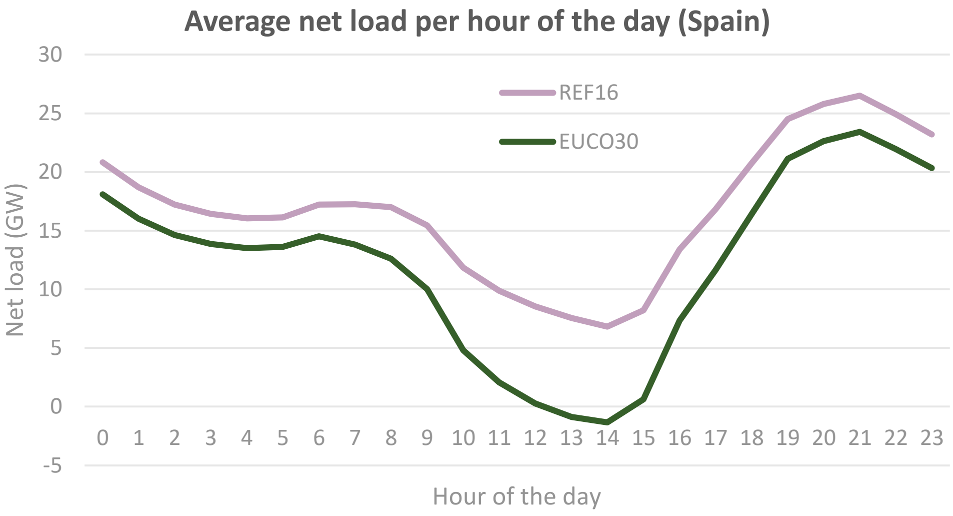


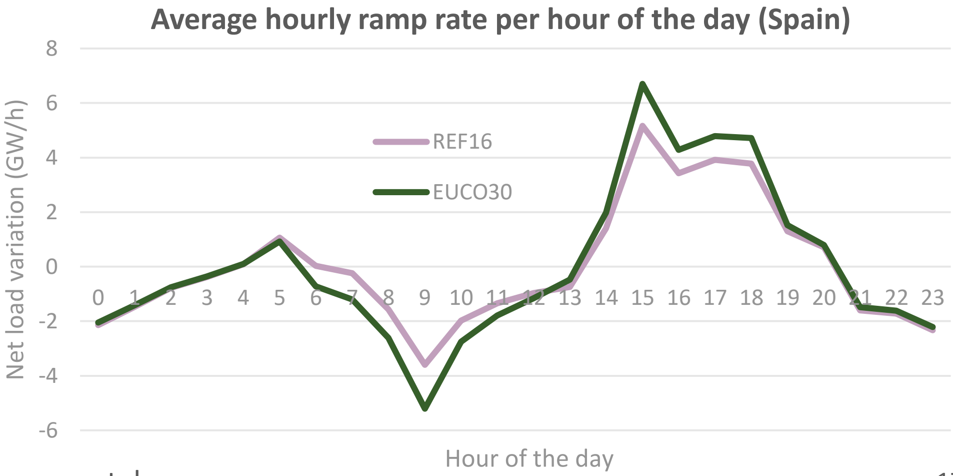


HOURLY LOAD GRADIENTS BECOME STEEPER

- Maximal hourly **ramp rates** across Europe







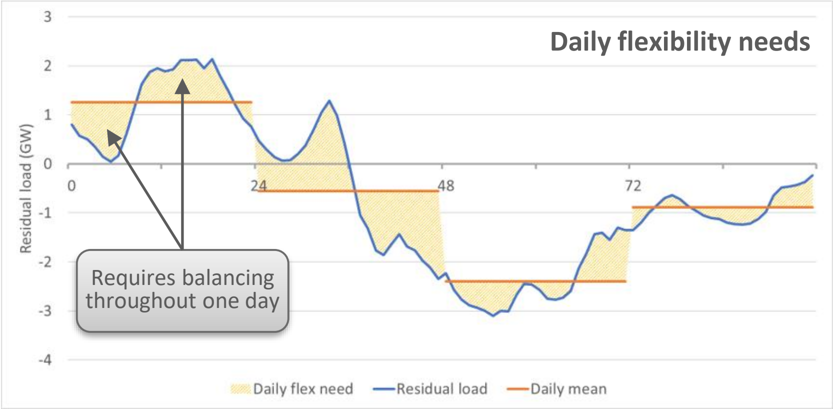
How to systematically assess flexibility needs?

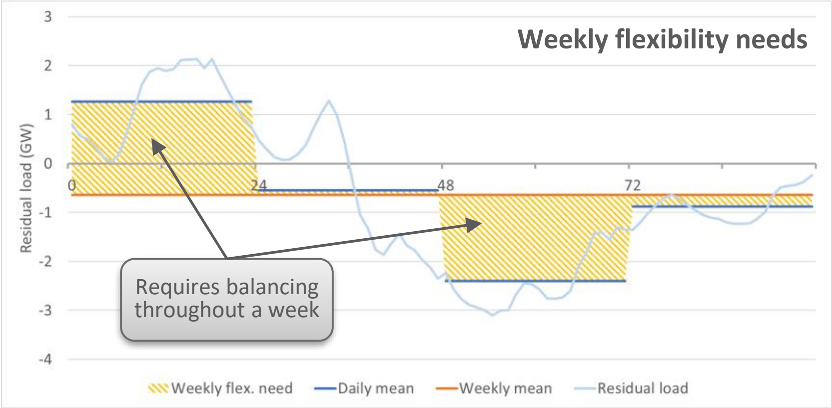
Apply indicators that measure national **flexibility requirements on various timescales** based on the MS's **residual load** (cf. RTE (2015), Bilan prévisionnel).

The **daily flexibility needs** equal the difference between the residual load and its daily average (sum of coloured areas).

Similar calculations can be realised for **weekly and annual flexibility needs**, contrasting the daily/weekly averages with the overall average across each week/year.

High RES production period in Denmark (cf. slide 13)

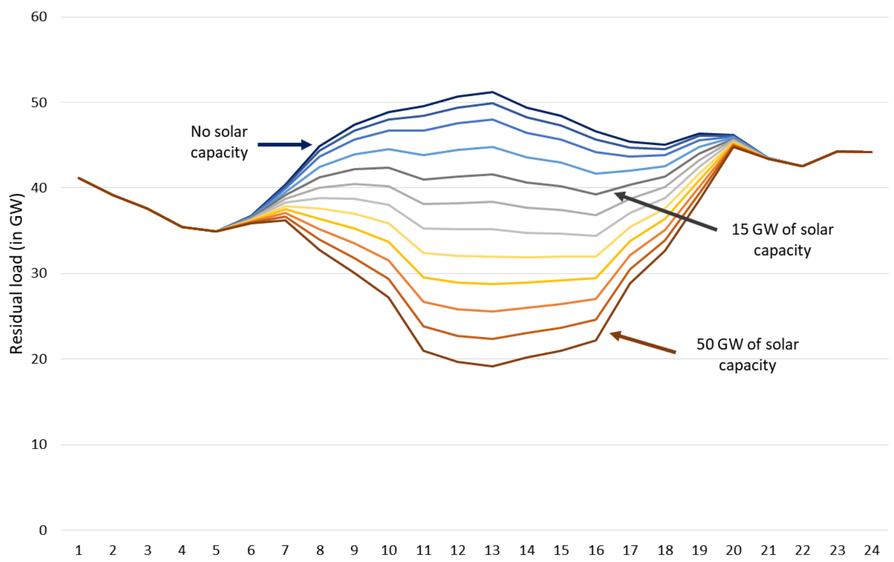


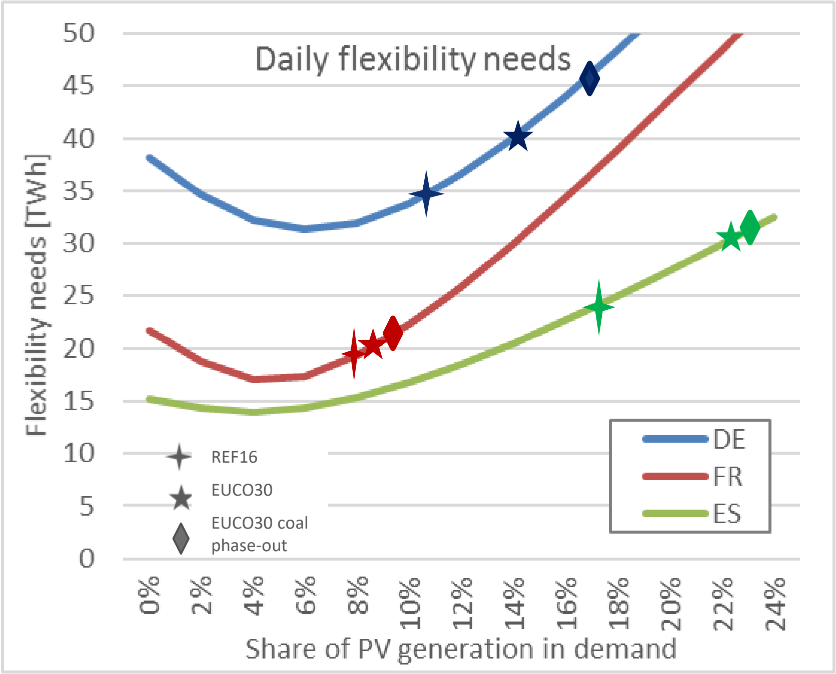


PV GENERATION DRIVES DAILY FLEXIBILITY NEEDS

Daily flexibility needs

- increase in most countries with rising **shares of PV** (daily production cycle)
- for relatively low PV shares, **PV production peaks coincides with midday demand** and allows for net load smoothing; more elevated PV shares create **duck curve**





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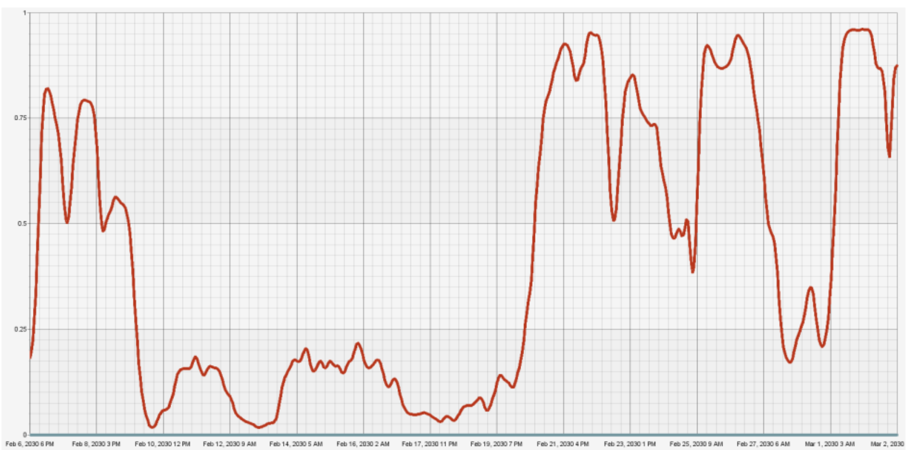
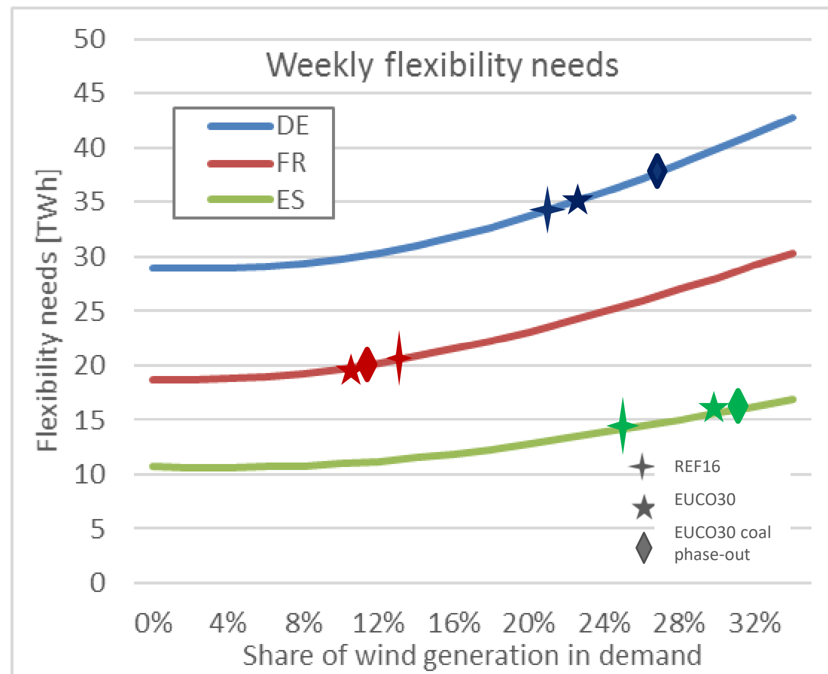
WIND POWER DRIVES WEEKLY FLEXIBILITY NEEDS

Weekly flexibility needs

- primarily **driven by wind power generation**, featuring more irregular generation
- for low wind energy shares, weekly flexibility needs are driven by weekly load pattern

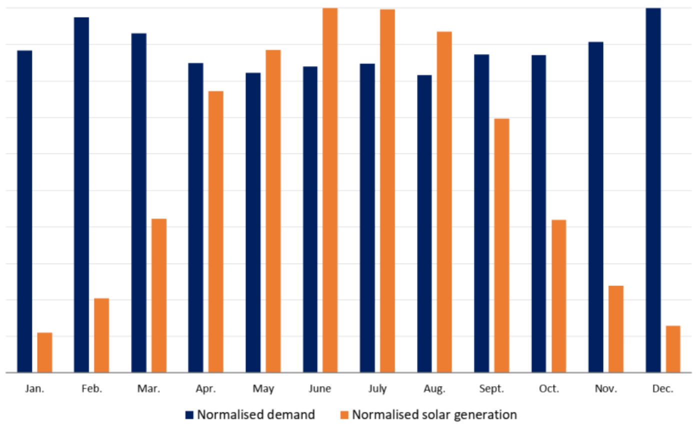


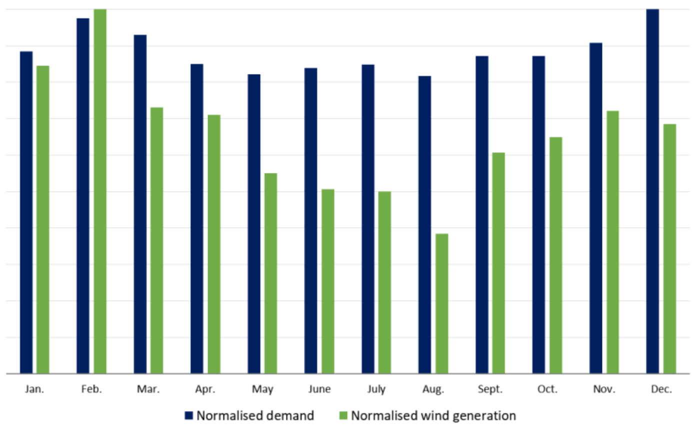


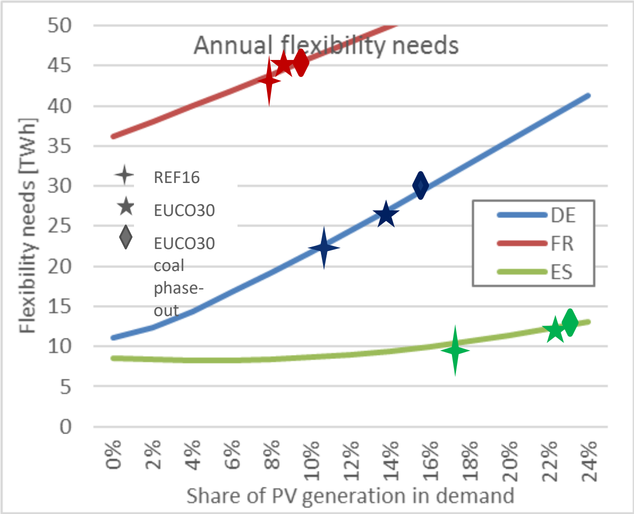
ANNUAL FLEXIBILITY NEEDS DEPEND ON LOAD PATTERN AND RES MIX

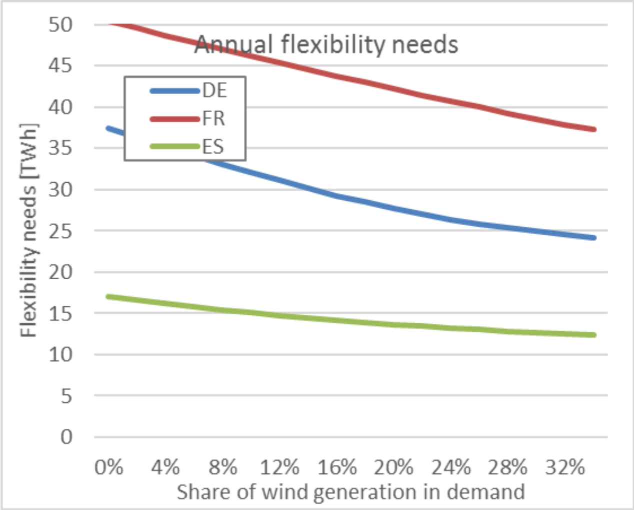
Annual flexibility needs

- primarily **driven by** seasonal variation in PV power production and demand
- **wind** power production reduces needs









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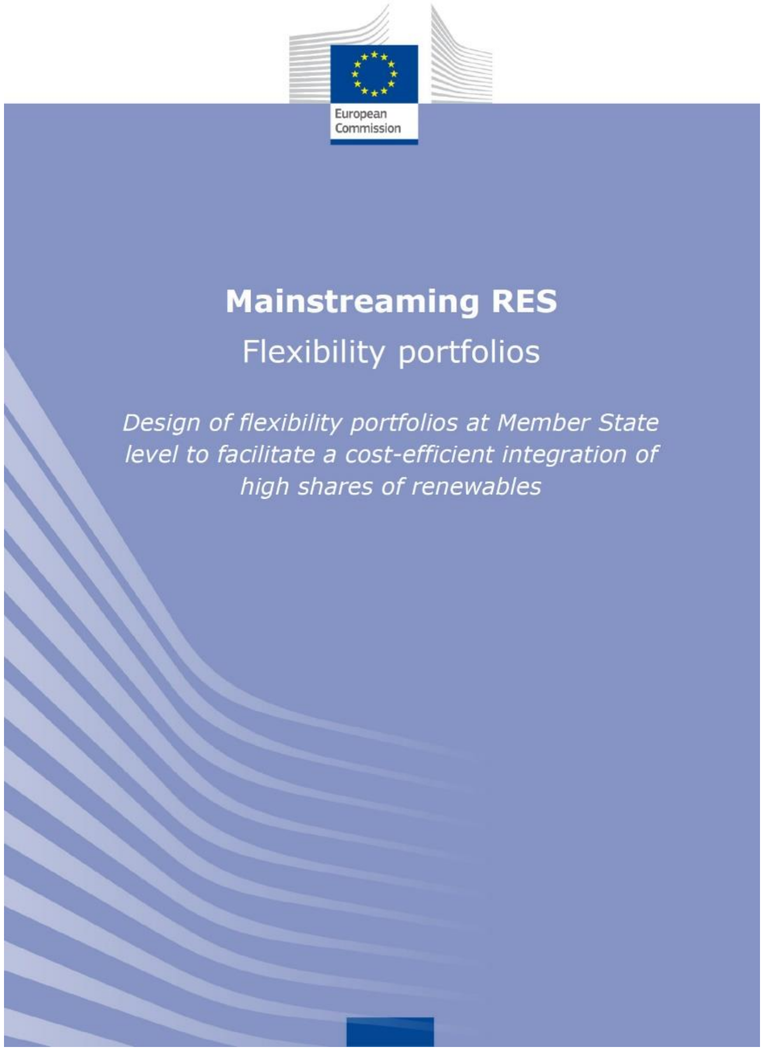
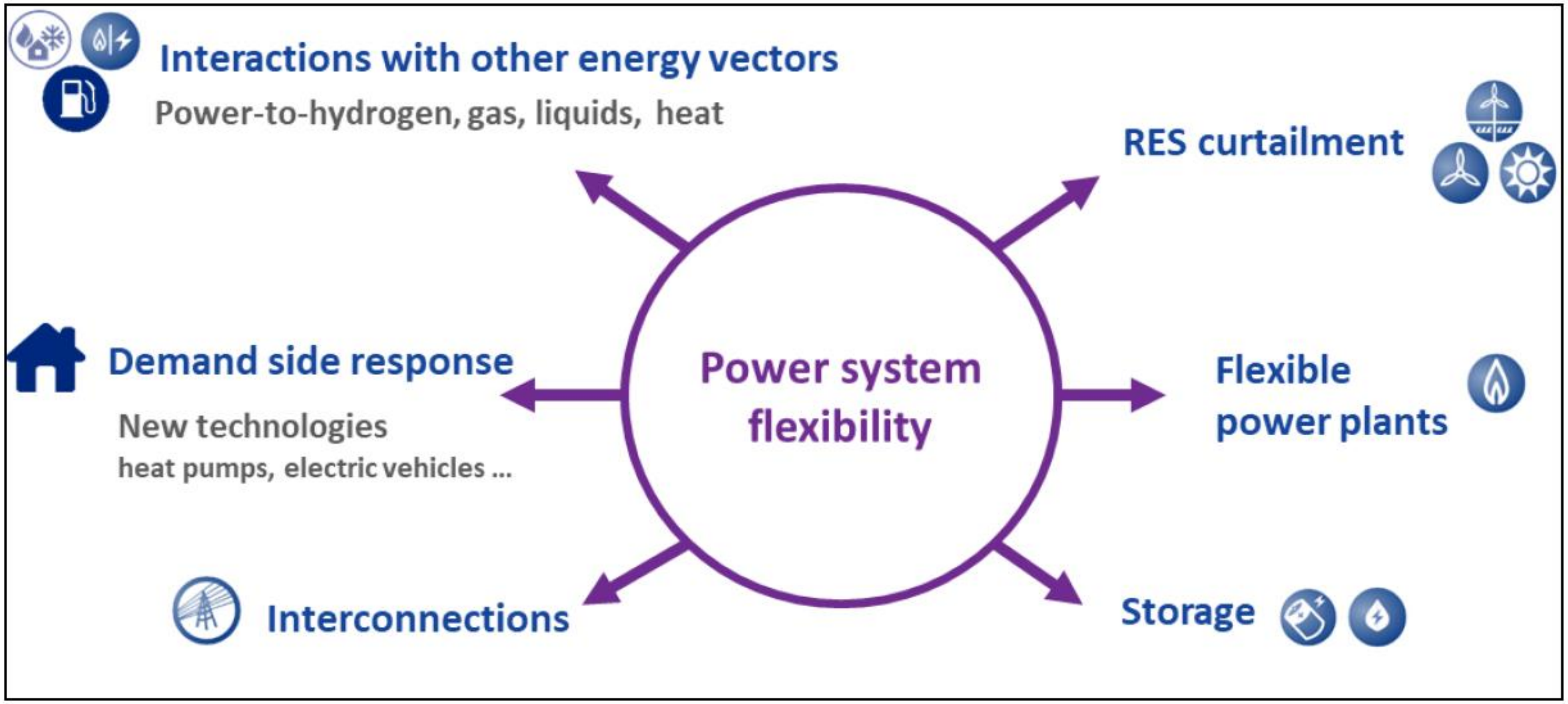
MAINSTREAMING RES

- Characterisation of flexibility solutions and portfolio optimisation
  - Identification of available flexibility solutions
  - Assessment of the flexibility value of individual solutions
  - Determination of cost-optimal portfolios



Potential flexibility solutions to be considered



FLEXIBILITY SOLUTIONS

- List of relevant techno-economic parameters
  - Investment costs
  - Operation and maintenance costs
  - Fuel costs
  - Activation costs / start-up costs
  - CO_2 intensity
  - Efficiency
  - Storage discharge times / max. load shifting duration
  - Potential
  - Availability throughout the year
  - Technical constraints: minimum stable generation, ramping rates, minimum off-time, availability
  - Potentially, environmental constraints

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OPTIMISATION OF FLEXIBILITY PORTFOLIOS

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Long-term scenarios

Demand, fuel and CO2 prices, weather scenarios

Capacity mix

Installed capacities, interconnection capacities, investment options to ensure adequacy

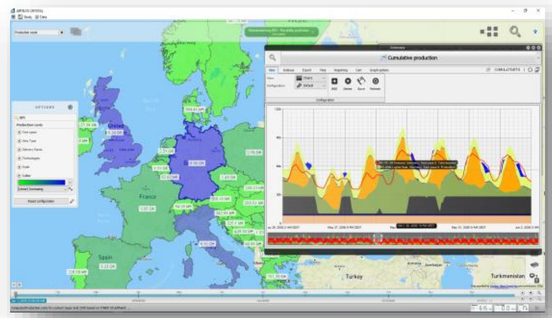
Policy decisions

RES and nuclear capacities, capacity adequacy criterion

Flexibility *investment* options

OCGT/CCGT, storage, interconnectors, batteries, pumped hydro, PtX

METIS & Artelys Crystal Super Grid



Joint stochastic optimisation of the investments and of the hourly electricity dispatch in the entire EU

- Installed capacities
- Hourly dispatch
- Production costs
- Electricity prices
- Revenues
- Social welfare
- CO_2 emissions
- RES curtailment
- …

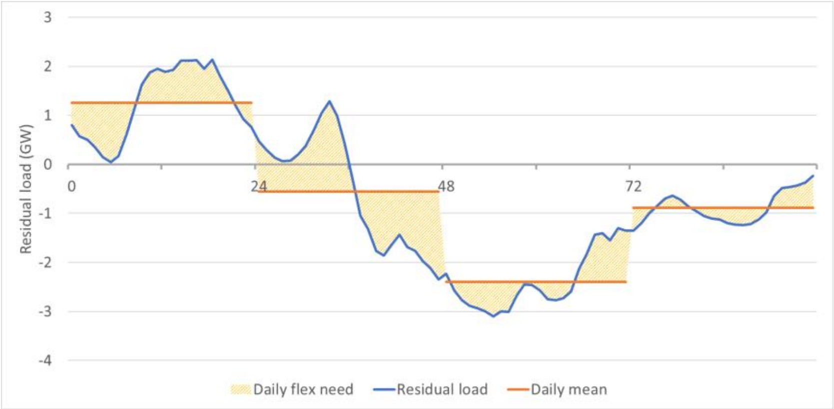
More information on METIS - http://ec.europa.eu/energy/en/data-analysis/energy-modelling/metis

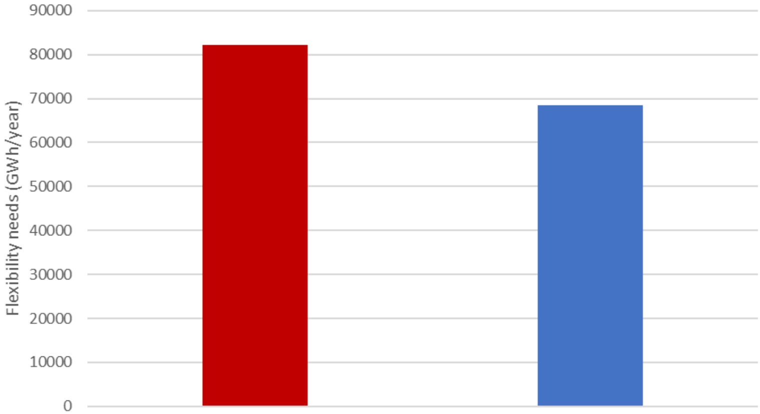
FLEXIBILITY CONTRIBUTIONS

How to measure the contribution of technology X to flexibility needs?

Step A – Compute the daily flexibility needs based on the ***net demand***
Step B – Compute the residual daily flexibility needs based on the ***net demand – technology X generation profile***

The difference between the two quantities is the contribution of technology X to flexibility needs.



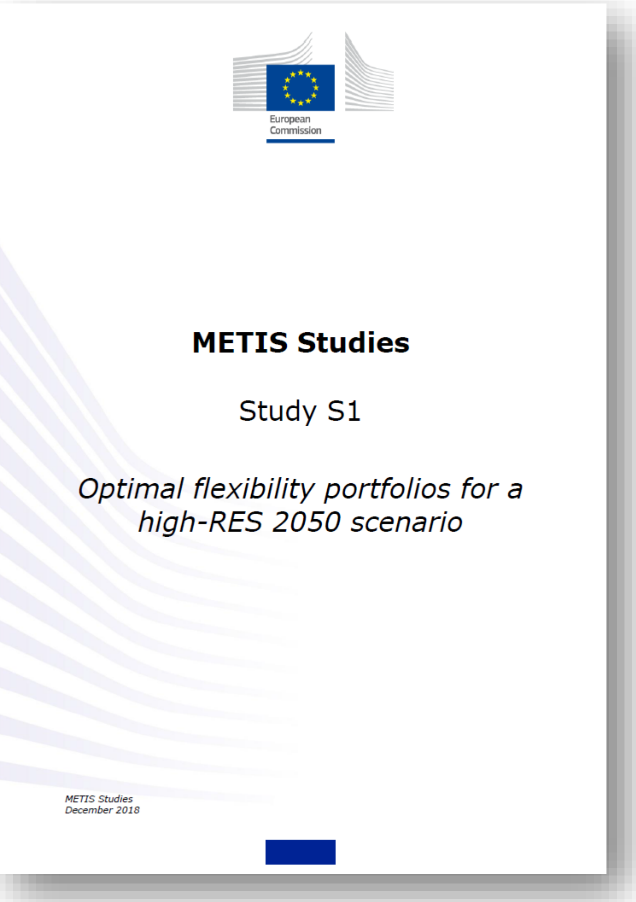


Step A
Flexibility needs

Step B
Residual flexibility needs

METIS STUDY S1

- Flexibility portfolios in a high-RES context
  - Focus on 2050
  - Fully decarbonised EU power sector
    - ↳ 80% RES share
  - Partial decarbonisation of other economic sectors (industry, transport) via power-to-gas


European Commission

METIS Studies

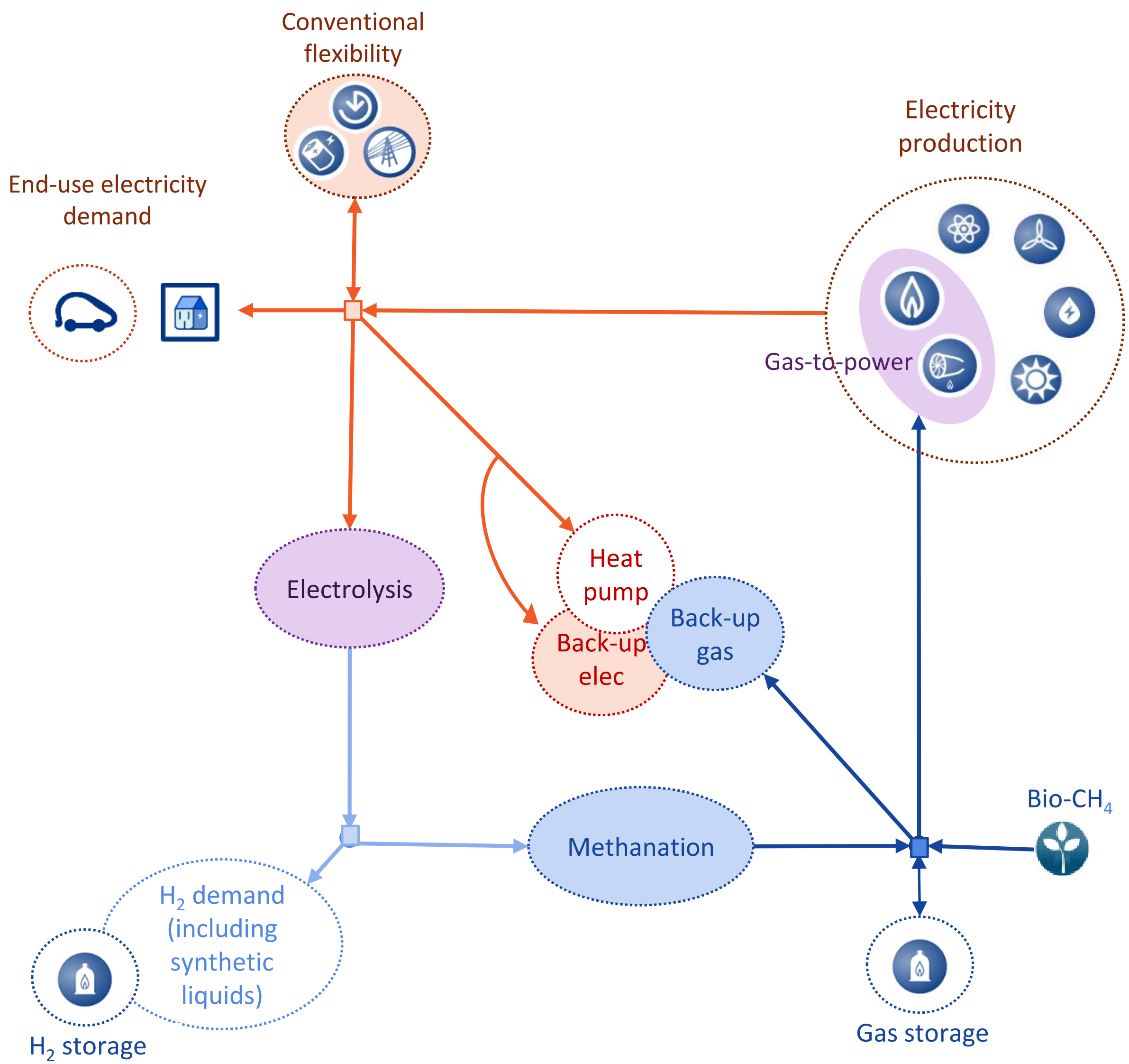
Study S1

Optimal flexibility portfolios for a high-RES 2050 scenario

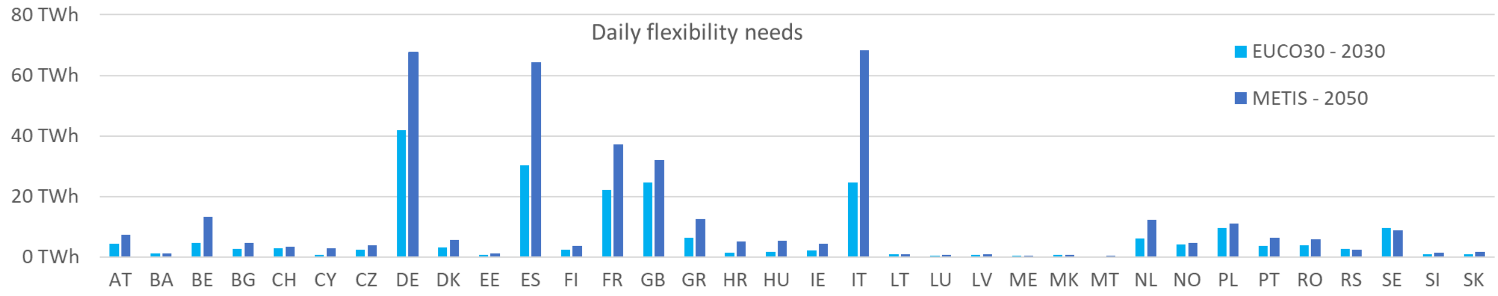
METIS Studies
December 2018

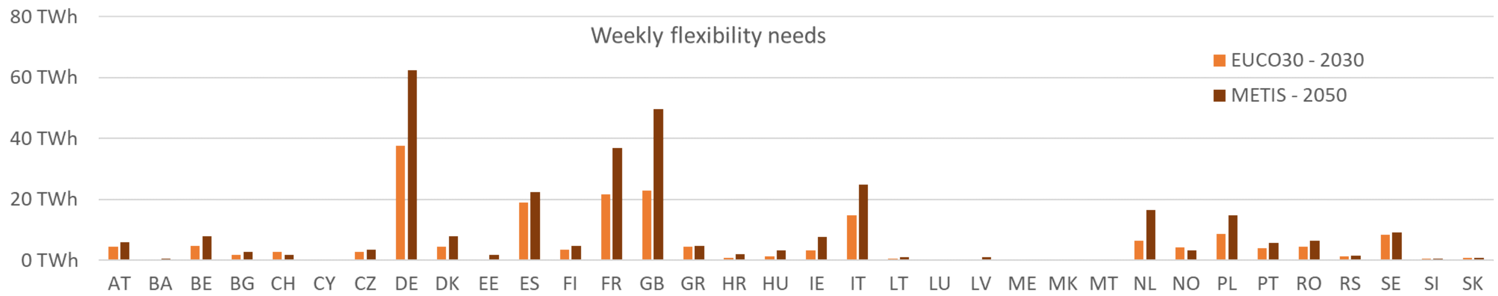
OPTIMISATION OF FLEXIBLE INFRASTRUCTURES

- Hourly supply-demand equilibrium
- Electricity
- H2
- CH4
- Power-to-gas / gas-to-power
- Optimised operations
- Optimised capacities

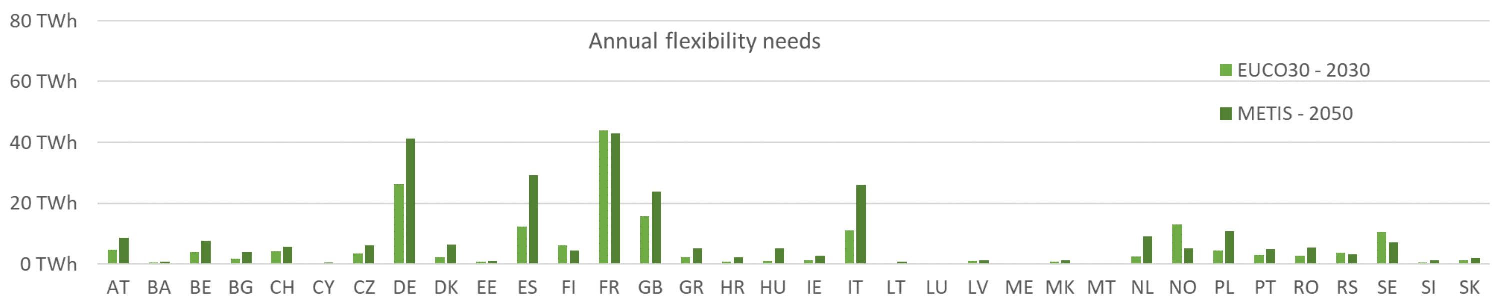


- PV and wind energy additional capacities increase significantly daily and weekly flexibility needs



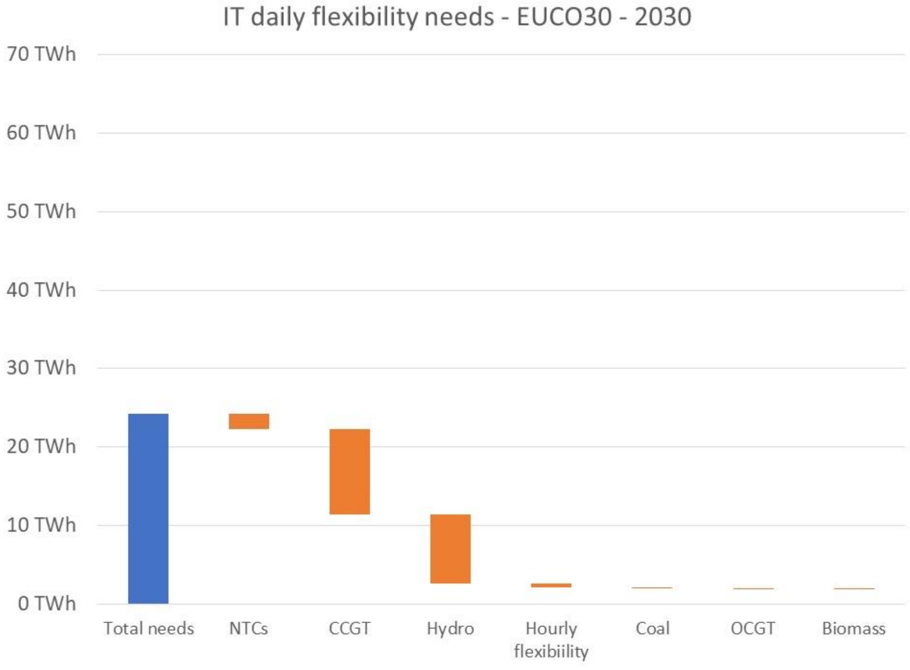


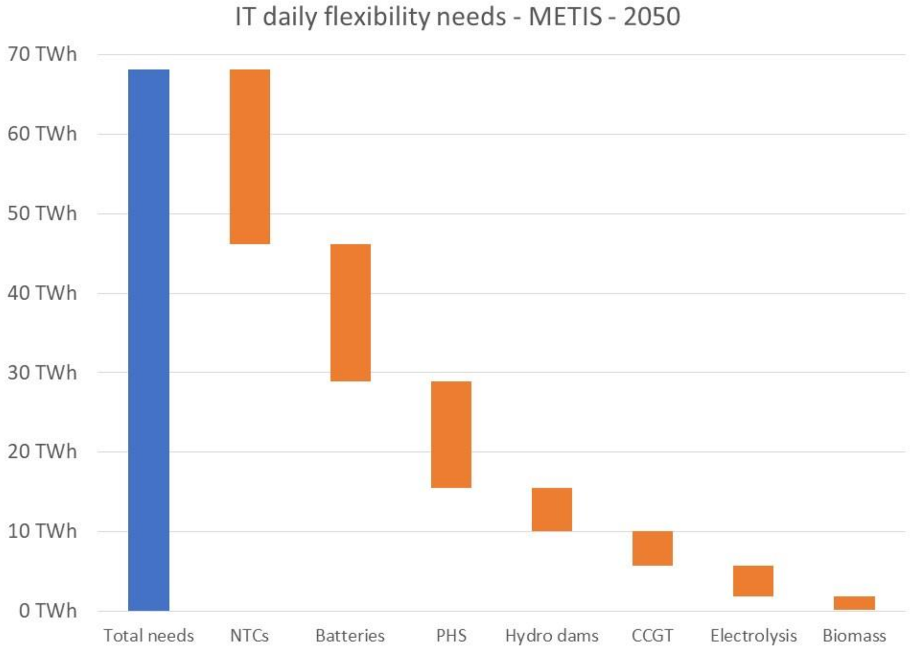
- Limited increase of annual flexibility needs (wind energy partially compensates heat pump and PV development)



SYSTEM FLEXIBILITY NEEDS AND CONTRIBUTIONS

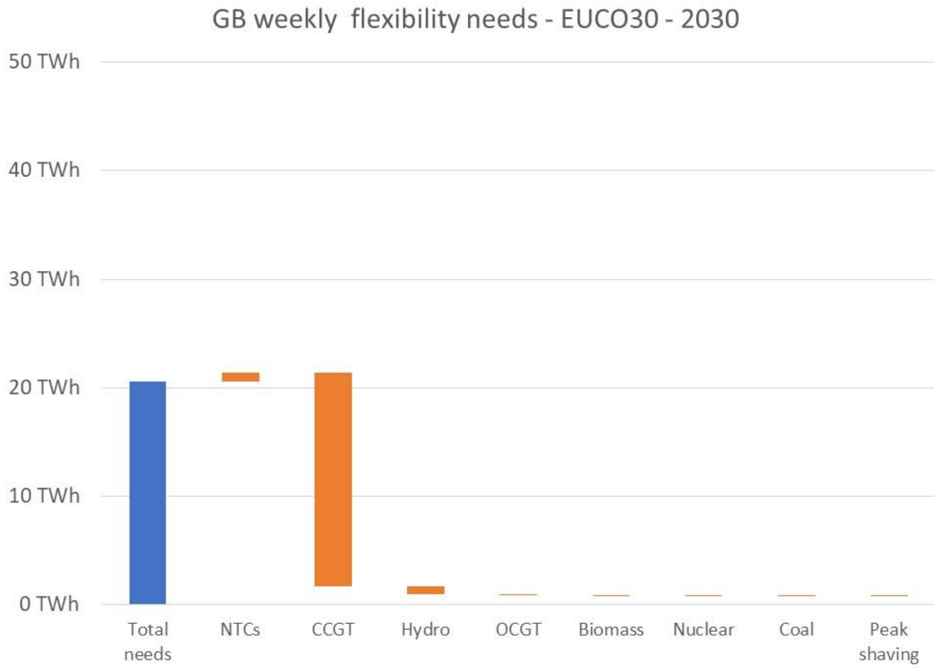
- **Interconnections are the main <u>daily</u> flexibility provider** for Italy in 2050, decreasing needs by over 30 %
- **Batteries and hydro** also have significant impacts
- Contributions of power-to-gas and gas-to-power are limited (while CCGTs remain the main contributor in 2030)

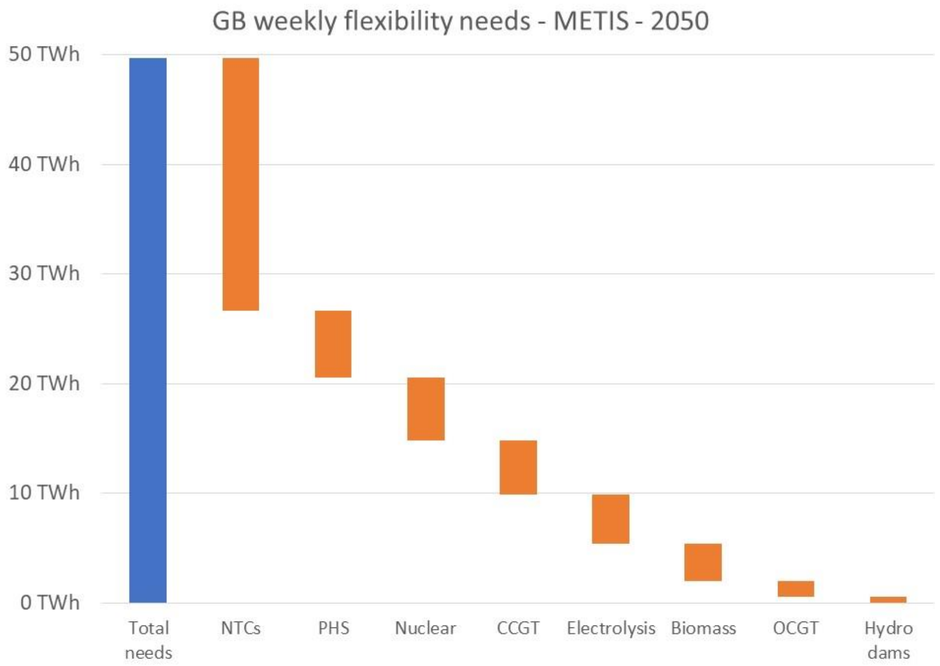




SYSTEM FLEXIBILITY NEEDS AND CONTRIBUTIONS

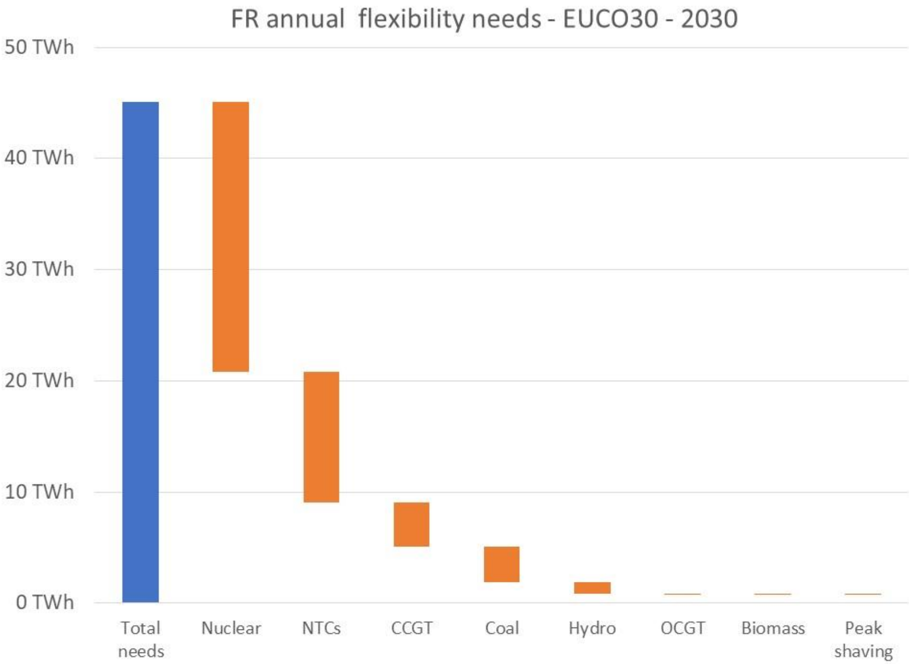
- **Interconnections are the main <u>weekly</u> flexibility provider** for Great Britain in 2050, decreasing needs by nearly 50%
- Conventional thermal capacities and electrolysis have similar contributions

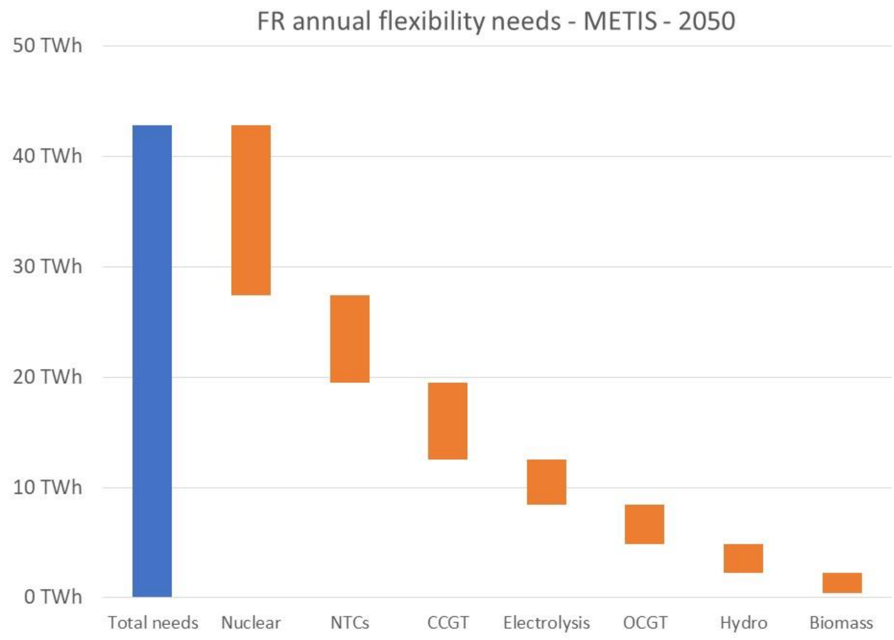




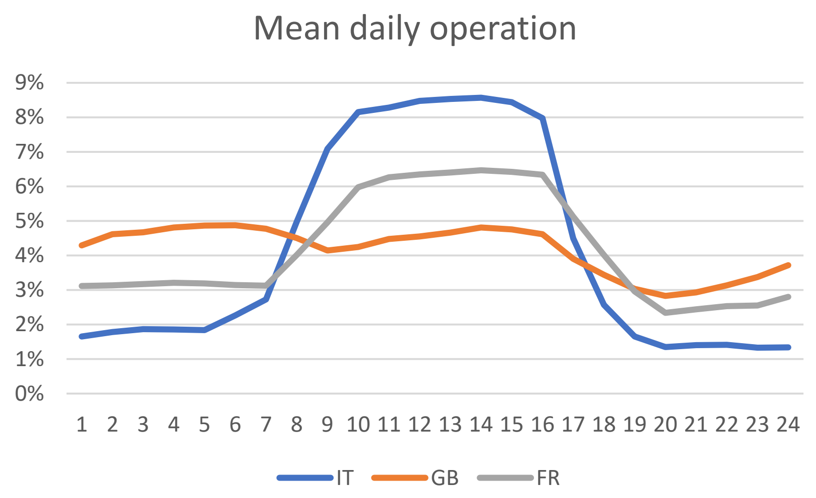
SYSTEM FLEXIBILITY NEEDS AND CONTRIBUTIONS

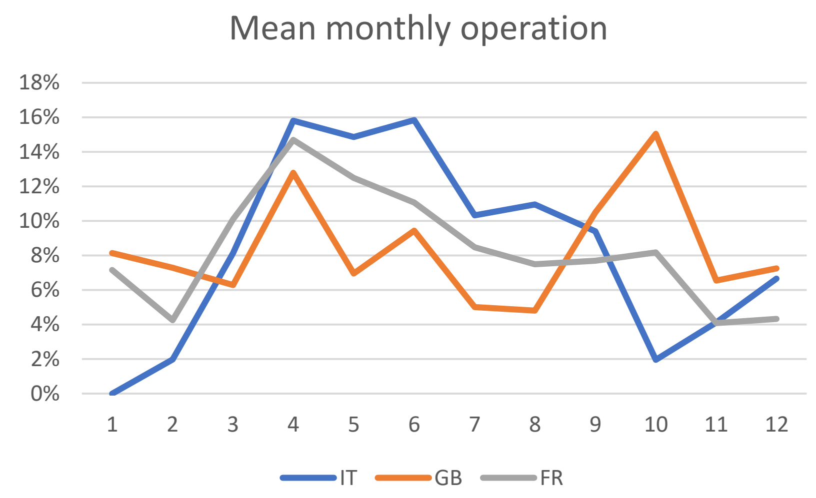
- **Conventional thermal units** (nuclear and gas-to-power) **and interconnections are the main annual flexibility providers** for France
- **Interconnection and electrolysis** can also provide 30% of flexibility needs



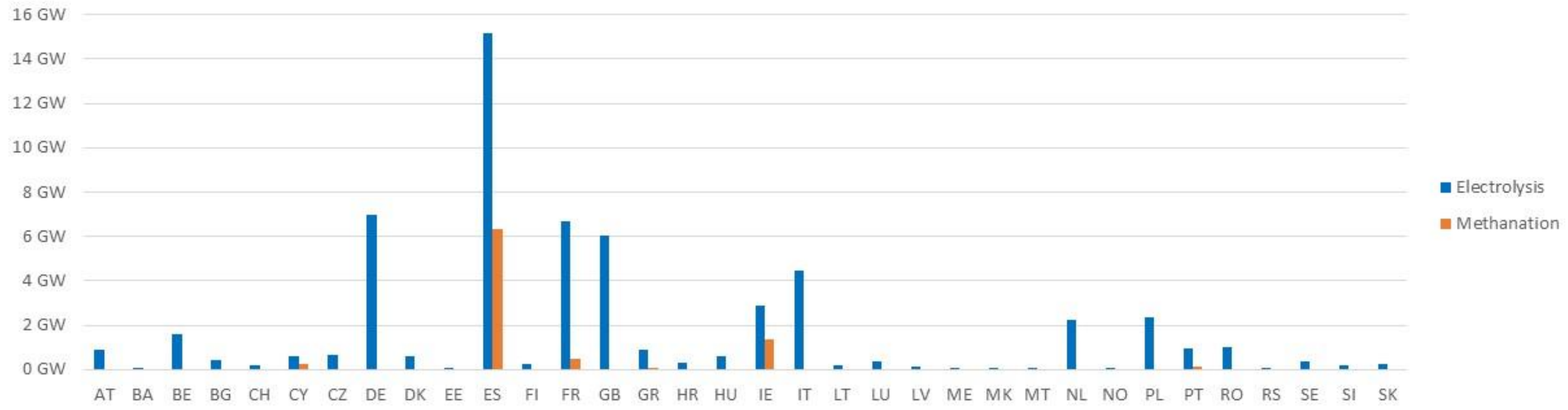


Power-to-gas can be used at different time scales to help integrate RES



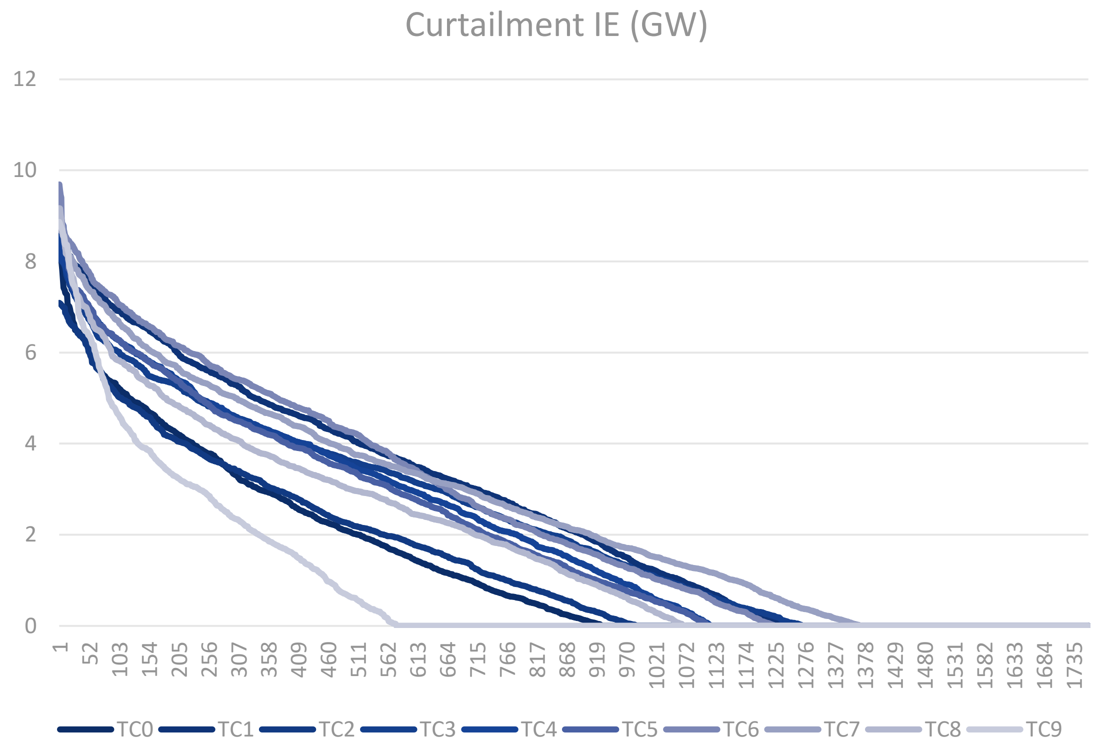


Investment in power-to-gas requires high full load hours



Curtailment as last resort

- In the given scenario, 7% of wind generation in Ireland is curtailed
- Surplus electricity concentrated in a few hours of the year



AGENDA

1. Introduction Artelys
2. The METIS project
3. Flexibility needs
4. Flexibility solutions
5. Optimal flexibility portfolios
6. **Conclusions**

CONCLUSIONS

- Flexibility needs arise at different time scales
  - Static power demand and variable RES generation as main drivers
  - Needs tend to rise

- There is no “one-size-fits-all” solution to the flexibility challenge
  - Suitability of flexibility solutions depend on flexibility needs and techno-economic characteristics of the flexibility solutions
  - Flexibility portfolios need to be individually designed for each country

- Holistic modelling to determine optimal (national) flexibility portfolios
  - Considering hourly dynamics
  - Covering the entire year
  - Considering several weather years
  - Full coverage of technology solutions
  - Adequately reflecting techno-economic constraints of flexibility solutions
  - Regional modelling
  - Joint optimisation of investment and dispatch

Outlook

- Other drivers for flexibility deployment to be considered
  - To resolve grid congestion => potential competition between market and grid
  - Decarbonisation technologies (PtX) that are installed for other reasons than solely to serve the power sector
  - Behind the meter optimisation (maximised auto consumption)
- Infra-hourly flexibility needs
- Long-term investment planning (=> pathway modelling)

Thank you for your attention!

For any question you may contact

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