

MINOA March, 2, 2021 Sandrine Charousset

Solving European Electricity System Optimization problems using the latest Modelling and Optimisation methods advances

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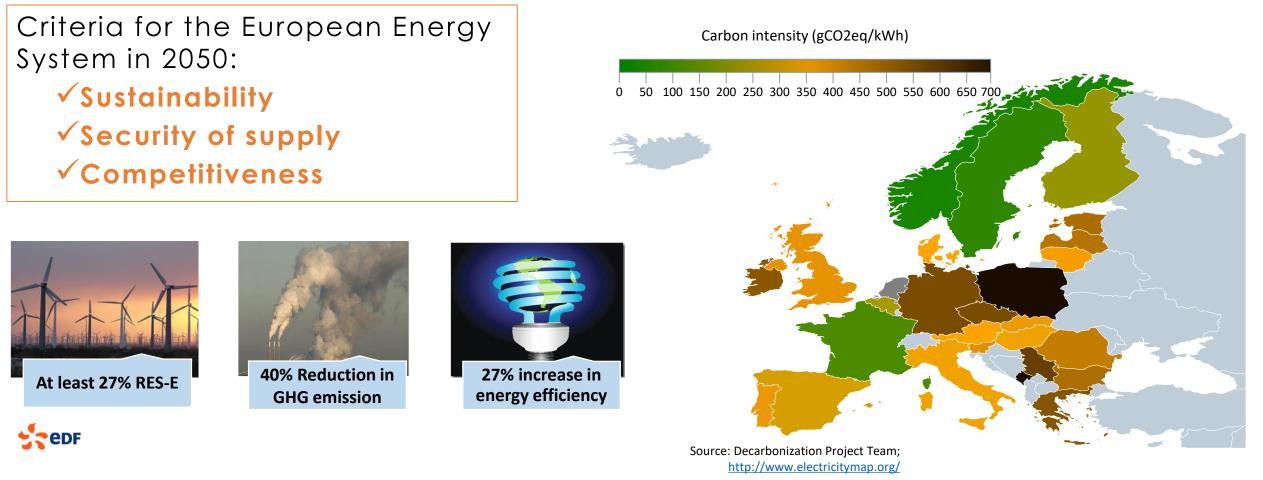




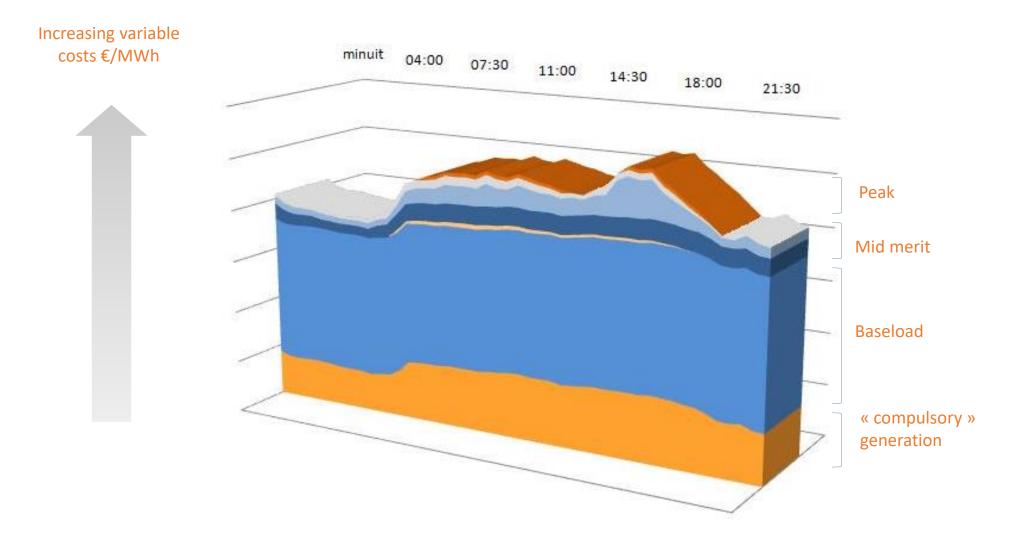
The electricity system: context and challenges

The European Energy Transition

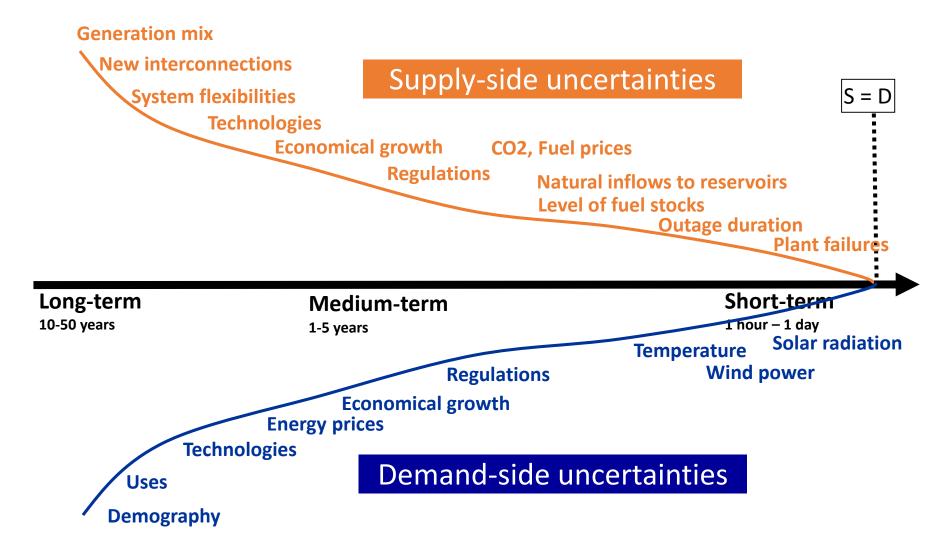
2050 EU's carbon reduction targets \Rightarrow High share of Renewable Energy



Scheduling of electricity: supply-demand balance

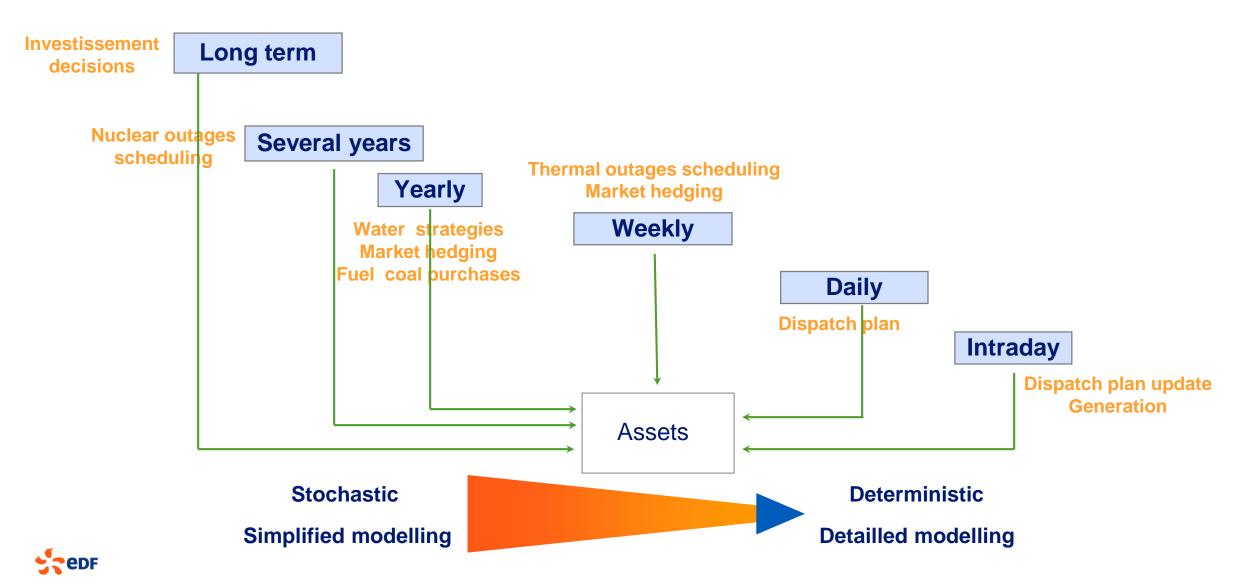


From long to very short term

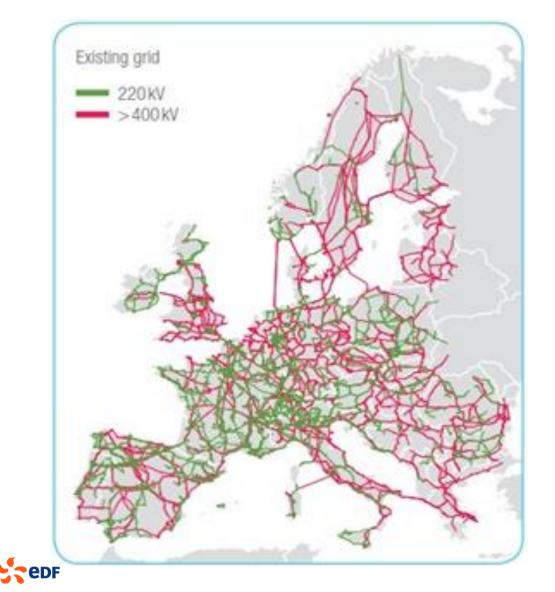


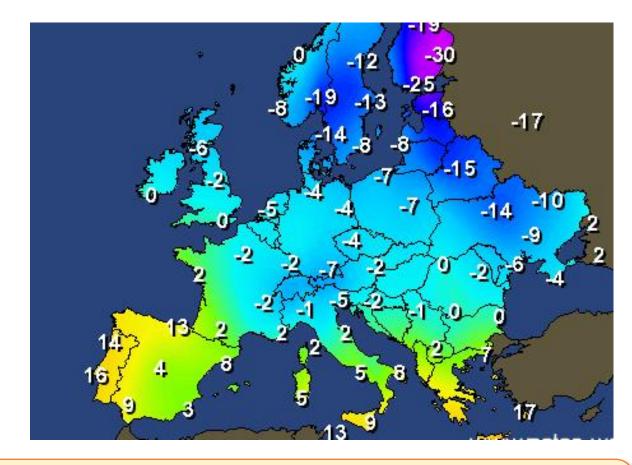
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The management process



A highly interconnected system





Significant and increasing interconnections Demands and RES generations (partially) correlated at European level

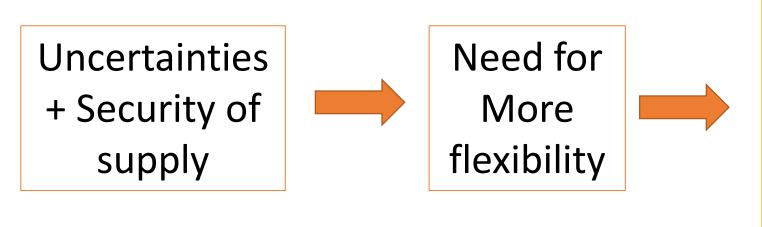
With and increasing level of uncertainties Large-scale RES Hydro 100 GW Wind ECEM Timeseries: Wind (WIN) Power (PWR) Solar 50 GW Biomass 10 GW Fossil IN PWR RAIC EH2 R85 01m FR WIN PWR RAIC EH3 R85 01m FR WIN PWR ARCN EH3 R85 01m — FR WIN PWR REMP EH3 R85 01m FR WIN PWR HIIC EH3 R85 01m WIN PWR WRIP EH3 R85 01m Nuclear — FR WIN PWR RCIC EH3 R85 01m average load 80k 70k 60k (PWR) [MW] 50k Wind (WIN) Powe 40k 30 20k 10k 0 2015 2020 2030 2035 2040 2055 2060 2065 2025 2045 2050 Produced by the ECEM Demonstrator Vn9.1 (http://ecem.climate.copernicus.eu/demo)

Source: C3S Energy/ECEM demonstrator

Source: eHighway2050

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An increased Need for flexibility



Need for Integrated simulation models:

- Detailed (as much as possible) representation of all flexible assets and network
- Including uncertainties



Need for enhanced solving methods



Detailed Modelling of complex and big size problems



Modelling and solving



The plan4res project



plan4res: Synergistic approach of Multi-Energy Models for a European Optimal Energy System Management Tool



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773897

The plan4res project



Implement models and tools that provide an integrated energy system representation able to optimize and simulate expansion and operation with a high share of Renewable Energy

For contributing to European targets for reduction of emissions while maintaining high quality of supply at lowest cost



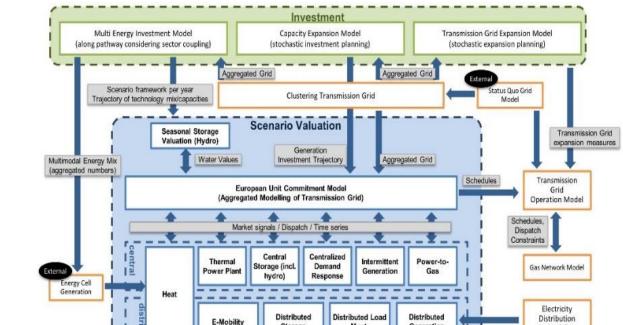






An end-to-end planning and operation tool, composed of a set of optimization models based on an integrated modelling of the pan-European Energy System

- Investment layer: Determine investment decisions
- Scenario valuation: Evalute investment decisions/operational planning
- Analysis/additional tools: Impact of scenario on electricity & gas grid



Storage

Generation

Distribution

constraints/costs

Model

Mngt.

Integrated modelling of the electricity system plana

Design the optimal generation, transmission and distribution mix for a given long-term horizon (eg. 2050)

$$\min_{\kappa} \left\{ C^{inv}(\kappa) + \max_{\eta \in \Upsilon} C^{op}(\kappa, \eta) \right\}$$

κ: Investment decisions (generation assets, transmission)
Y: Set of uncertainty scenarios
C^{inv}: Costs induced by installing capacitiy κ
C^{op}: Expected operational costs with given capacity κ



Seasonal Storage Valuation

Compute strategies for managing seasonal storage on a mid-term horizon (eg 1 year)

$$C^{op}(\kappa) = \min_{x \in \mathcal{M}} \mathbb{E}\left[\sum_{s \in S} C_s(x_s)\right]$$

C^{op}(κ): Operational costs depending on investment decisions κ
C_s: Operational costs on sub-period s
M: Feasible set associated with operation decisions
Set of sub-periods (e.g. weeks)
x: Operation decisions on sub-period s
κ: Investment decisions taken by capacity expansion model

Unit Commitment

Compute dispatch for all assets on a short-term horizon (eg. 1 week)

$$\min \sum_{i} C_{i}^{op}(p_{:,i}, p_{:,i}^{pr}, p_{:,i}^{sc}, p_{:,i}^{he}) + \alpha(v^{hy})$$

 C_i^{op} : Operational costs of unit *i* subject to it's operational variables $p_{t,i}, p_{t,i}^{pr}, p_{t,i}^{sc}, p_{t,i}^{he}$: Provision of power, primary/secondary reserve, heat by unit *i* in timestep *t* and dynamic constraints α : Approximation of the value of seasonal storages v^{hy} : Storage level

Submodels

Power plants

- Operational decision of power plants based on their specific fuel costs
- Technical constraints (ramping, min up-/downtimes,...)

Storages

- Hydro storages including complex cascaded systems
- Battery storages

Intermittent generation

Generation of wind, solar, run of river based on meteorological profiles

DE-mobility

- Storage capability of electric vehicles (vehicle-to-grid, power-to-vehicle)
- Limitation of storage availability by driving profiles

Load management

- Load shifting of a given energy consumption during a sub-period
- Load curtailment based on a given potential (e.g. during one year)

Detailed modelling

Detailed equations are available on:

https://zenodo.org/record/3904272#.YD3yFmhKjIU

zenodo

Search

Upload Communities

June 23, 2020

plan4res D3.1: Description of model interconnections

💿 Beulertz Daniel; 💿 Franken Marko; 💿 Oudjane Nadia; 💿 van Ackooij Wim; 💿 Schweiger Jonas; Konstaltelos ioannis; 💿 Djapic Pedrag; 💿 Pudjianto Danny

Q

The goal of plan4res is to develop a modeling framework that allows to obtain a holistic assessment of the energy system. Having such an ambitious goal, it is required to divide the energy system in models that cover the dierent aspects of the energy system. This modular framework allows to make use of the most promising solving techniques and the most efficient optimization solvers, each tailored towards the needs of every single submodel.

In order to guarantee a flawless work ow, it is vital to have a detailled description of the interconnections between these models. The goal of this deliverable is to give an overview of the plan4res modeling framework and describe these model interconnections.

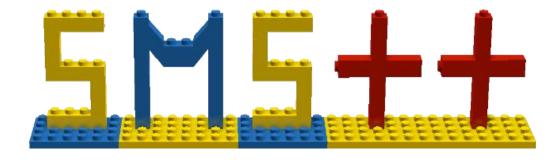
The plan4res model framework is divided into Expansion models Valuation/operation models Supplemental models

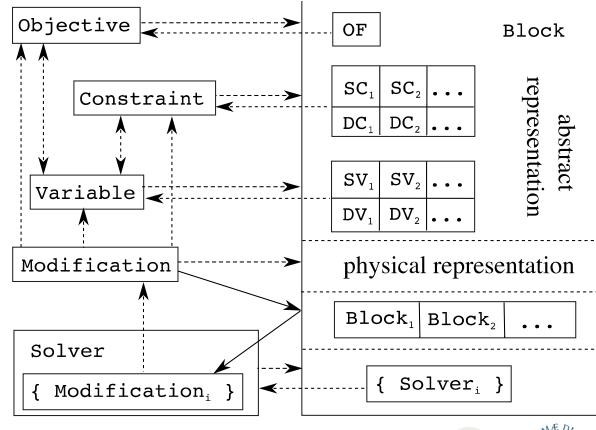
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Project deliverable Open Access

Modelling with SMS++

- SMS++ is a set of C++ classes implementing a modelling system that:
- allows exploiting specialised solvers
- manages all types of dynamic changes in the model
- Explicitly handles reformulation/restriction/relaxation
- does parallel from the start
- should be able to deal with almost anything (bilevel, PDE,..)
- Includes specialized blocks for energy system modelling







presentation at 'ESR Days', Thursday 11'30, by Antonio Frangioni

Collapse sidebar

Listen for a full SMS++

Mettre à jour gitlab.com/smspp/smspp/-/blob/master/README.md $\leftarrow \rightarrow$ С ☆ 🛸 (S) (່ ຊ 😵 • Sign in / Register GitLab Projects Groups Snippets Help SMS++ > SMS++ > Repository S SMS++ smspp / README.md Find file Blame History Permalink Project overview master Repository Add "Getting help" section to README.md 9eff9d41 🔓 Niccolò lardella authored 3 weeks ago Files Commits To learn more about this project, read the wiki. Branches Tags E README.md 🔓 5.33 KB <>> ₽ Web IDE 6 🖸 🕹 Edit Contributors Graph SMS++ Compare Locked Files D Issues 2 11 Merge Requests 0 SMS++ is a set of C++ classes intended to provide a system for modeling complex, block-structured mathematical models (in particular, but not exclusively, single-=v Requirements

SMS++ is a set of C++ classes intended to provide a system for modeling complex, block-structured mathematical models (in particular, but not exclusively, singlereal-objective optimization problems), and solving them via sophisticated, structure-exploiting algorithms (in particular, but not exclusively, decomposition approaches and structured Interior-Point methods).



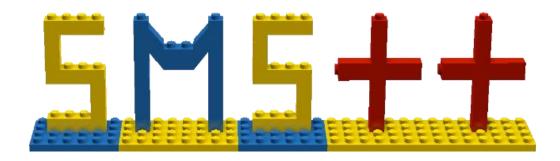
UNIVERSITÀ DI PISA

available on

SMS++ is

https://gitlab.com/smspp

Modelling with SMS++

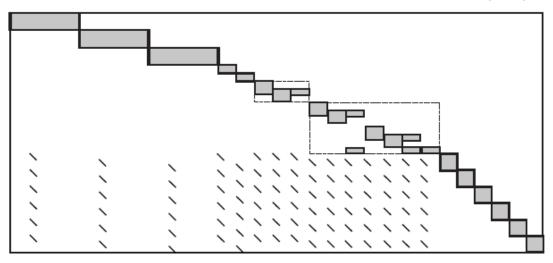


Modelling with SMS++



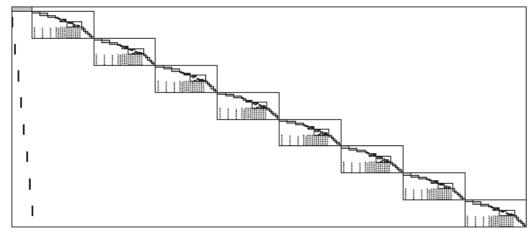
Nested decompositions at different time horizons

• Schedule a set of generating units to satisfy the demand at each node of the transmission network at each time instant of the horizon (24h)



- Several types of almost independent blocks + linking constraints
- Perfect structure for Lagrangian relaxation^{1,2}

• Manage water levels in reservoirs considering uncertainties (inflows, temperatures, demands, ...) to minimize costs over the time horizon



- Very large size, nested structure
- Perfect structure for Stochastic Dual Dynamic Programming^{3,4} with multiple EUC inside

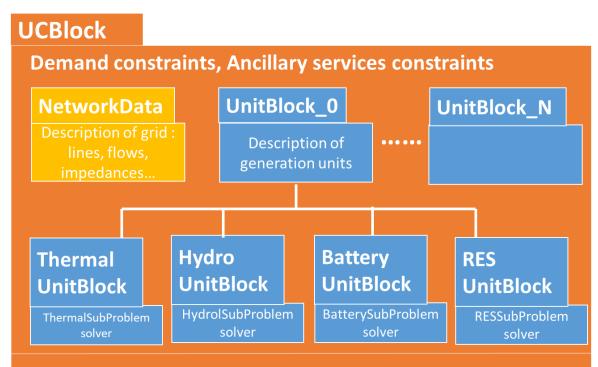
Pereira, Pinto "Multi-stage stochastic optimization applied to energy planning" *Math. Prog.*, 1991 van-Ackooij, Warin "On conditional cuts for Stochastic Dual Dynamic Programming" arXiv:1704.06205, 2017



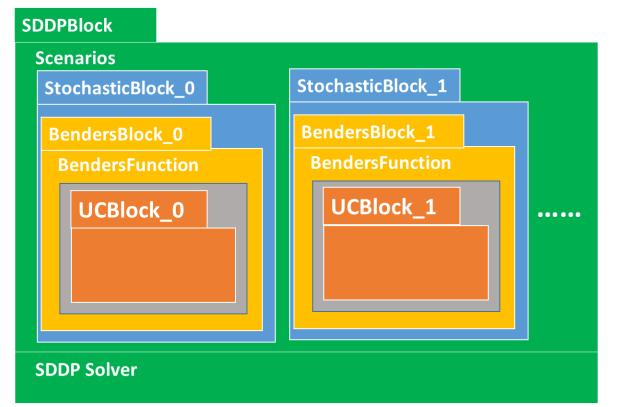


Borghetti, F., Lacalandra, Nucci "Lagrangian Heuristics Based on Disaggregated Bundle Methods [...]", IEEE TPWRS, 2003
² Scuzziato, Finardi, F. "Comparing Spatial and Scenario Decomposition for Stochastic [...]" IEEE Trans. Sust. En., 2018

The Seasonal Storage Valuation and Unit Commitment in SMS++

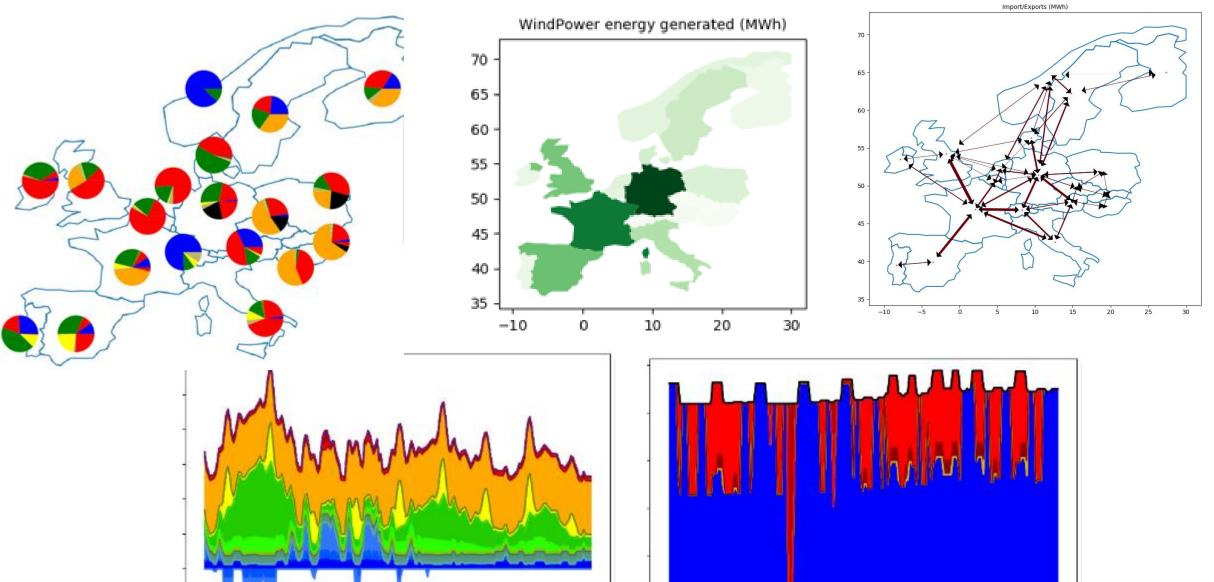


SCIP / Bundle Solver





Examples of Results





Perspectives



Use Cases



What Impact do different levels of RES integration have on system costs?

- Electricity generation cost
- Cost to ensure the dynamic robustness of the system (Reserves, Inertia)
- What is the value of flexibility? (system cost reduction coming from using flexibility potentials of different system assets)
 - RES can be represented as non-flexible, i.e. all generation is 'fatal' or we can account for their ability to be curtailed or can contribute to ancillary services
 - Flexibilities from storages and additional storages can be represented
 - Different demand response flexibilities can be modelled



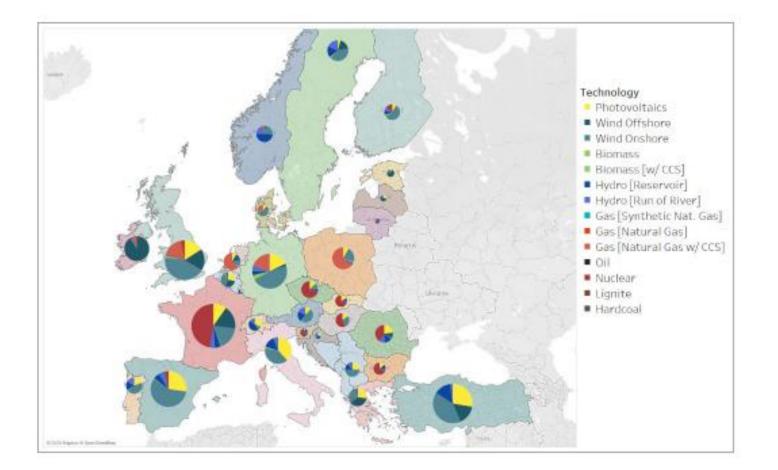


□ Assesment of the feasibility and cost of a long-term scenario

openENTRANCE scenarios 2025-2050

file:///C:/Users/F04340/Downloads/ openENTRANCE-D3.13.pdf





Use Cases

Case Studies in openENTRANCE

Demand response – behaviour of individuals

Exploits recent real-life data on households' demand-response capabilities from field-tests across the EU to assess accurate response potentials and their impacts on the European power system.

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Need of flexibility – sector coupling

Focus on transport sector coupling technologies such as electric vehicles and electric overhead-line trucks. It aims to assess how associated flexibility potentials can be tapped when local information and regional (distribution) network constraints are included in the analysis.



Decentralisation

Comparison of different levels of European/national coordination aimed at facilitating the integration of local/regional decentralisation.

See more : <u>www.openentrance.eu</u>

Further potential uses

□ Short-term generation management (including detailed hydro)

Other energy related problems



Sedf Thanks



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www.plan4res.eu