EERA
European Energy Research Alliance
JP Smart Grids

H2020 FlexPlan project

2023-03-07
Web

Workshop

Agenda

nr.	Title	Name and affiliation	Duration
0	Introduction	Andrei Morch, SINTEF Energi/EERA JP SG	10 min
1	Presentation of FlexPlan project	Gianluigi Migliavacca, RSE (IT)	10 min
2	The FlexPlan methodology	Hakan Ergun, KU Leuven (BE)	20 min
3	The main results from the six regional cases	Nicolò Italiano, R&D Nester (PT)	30 min
4	The Final Regulatory Guidelines	Lattanzio Giorgia, RSE (IT)	20 min
5	Questions and discussion	All	20 min

EERA JP Smart Grids SP5

- **The overall objectives of EERA JP SG Sub-program 5 “Transmission Network Flexible Operation” is to contribute to the development of tools and methods for planning and operation of transmission networks which are needed to achieve a high share of renewable energy sources in the supply mix while maintaining a reliable level of supply in the system**

- **The sub-programs will focus among others:**
  - Definition and highlighting of the most significant challenges to planning and operation of the Transmission Networks, which should be addressed in order to meet the goals of the European Energy policy.
  - What are the needs for new and improved methods and tools suited for expansion planning of the future European power system with high-RES share and high level of inter-operability and market integration?

EERA JP Smart Grids SP5

- Organisation of thematic workshops and webinars for EERA JP Smart Grids members
- Common papers and articles
- Participation in Pan-European level public consultations and interactions
- Involvement in HEU Brokerage events and follow-up of the relevant calls

This project has received funding from the European Union's Horizon2020
research and innovation programme under grant agreement N° 863819

FlexPlan

EERA workshop| 7th March 2023

Presentation of the FlexPlan project

Gianluigi Migliavacca
RSE S.p.A.

Agenda

- Critical aspects of the present grid planning methodologies
- Outline and partnership of the FlexPlan project
- Availability of FlexPlan toolbox and open access libraries

Critical aspects of the present grid planning methodologies

FlexPlan

- The new context (high-speed deployment of RES in electric T&D grids, increased penetration of DER in distribution grids, consequent strong need for flexibility in the electric grids) should bring grid planners to rethink some foundations of the grid planning methodologies which are applied nowadays.

Critical drivers	Problems in coping with it in present grid planning
Massive penetration of RES in T&D grids also in consequence of ambitious decarbonization targets (and, lately, the need to increase Europe independency from fossil fuels purchase) **and public opposition to deploy new lines** (resulting in long times for getting building permission)	• **to compensate short lasting congestion created by RES variability the deployment of new lines could prove economically inefficient,** but traditional grid planning disregards the role of flexibility! • **according to Directive (EU) 2019/944 (Art. 32, Art. 40) storage and DSM should become full fledged planning candidates for TSOs and DSOs; according to Regulation (EU) 2022/869 (Art. 13) ENTSO-E's infrastructure gap analysis must "consider with priority all relevant alternatives to new infrastructure" (i.e. include storage and DSM)**: "with-without planning approach" is too limiting to co-evaluate a high number of candidates. • need for a new grid planning approach considering **multi-scenarios in a probabilistic way** to incorporate the effect of different climate years. • need to find a **quantitative methodology to internalize environmental externalities in an objective way** (i.e. quantitatively) to compare costs/benefits of RES wrt conventional plants generation.
New scenarios need to look at short and long term for an optimal management of decarbonization path	• **traditional grid planning analyses one year a time** (e.g. first expansion at 2030, then 2040 then 2050). This can bring to a sub-optimal strategy.
Distribution grids are becoming active. Most flexible resources are connected to distribution but could provide flexibility to transmission	• **distribution grid planning based on fit-and-forget methodology** i.e. on sizing the grid for a "worst case" disregarding actual flows and real time grid bottlenecks. • **lack of integration between T&D grids planning**.

The FlexPlan project

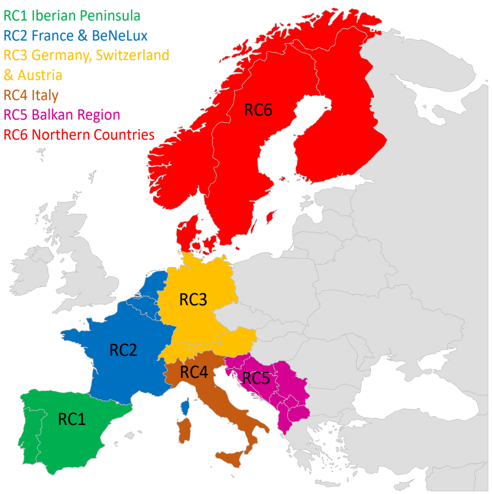
FlexPlan

- **Start date: 01.10.2019**
- **End date: 31.03.2023**

… aims at establishing a new grid planning methodology considering the opportunity to introduce new storage and flexibility resources in electricity transmission and distribution grids as an alternative to building new grid elements.

What FlexPlan achieved

1 – New planning methodology - Creation of a **new tool for optimizing T&D grid planning**, considering the **placement of flexibility elements** located both in transmission and distribution networks **as an alternative to traditional grid planning**: in particular, storage, PEV, demand response)



2 – Scenario analysis 2030-40-50 - New methodology applied to analyse **six regional grid planning scenarios at 2030-2040-2050.** A **pan-European scenario** has delivered border conditions to initialize in a coherent way the 6 regional cases.

3 – Regulatory guidelines - on top of the new planning methodology, FlexPlan provided some regulatory reflections resulting in a set of indications for NRAs on which barriers should be removed for the implementation of the new methodology.

Partnership of the FlexPlan project

- 13 Partners
- 8 European Countries
- 3 TSOs
- 1 Major DSO Concern

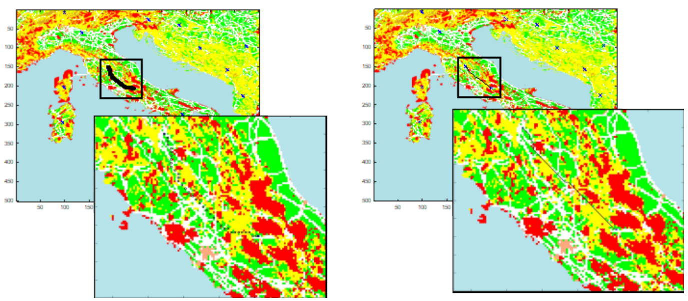
FlexPlan Grid Expansion tool: availability of demo version

- A **video** is available to illustrate the main GUI features (see news item: https://flexplan-project.eu/2022/11/23/flexplan-grid-explansion-tool-gui-look-and-feel/ on the FlexPlan web).
- A **demo version** of the FlexPlan planning tool is available at: https://flexplan.eu.n-side.com/. This demo version has the goal to give the possibility to external stakeholders such as TSOs, DSOs and regulators to access and test the tool with simple test cases. It allows to run and analyze simulations with up to 20 buses (AC or DC buses). Credentials allowing to test this demo version of the software can be requested by writing an email to flexplan@n-side.com.

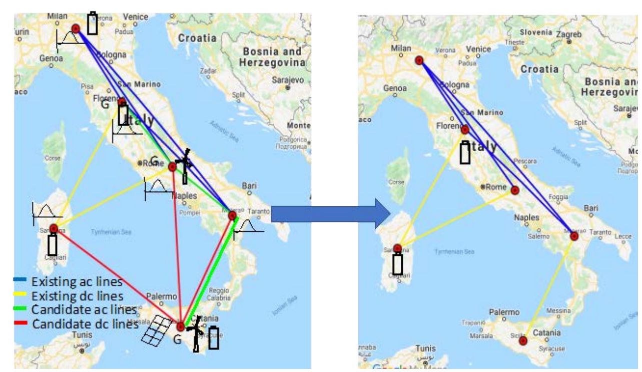
FlexPlan web and open access resources

All project publications (deliverables, papers, important presentations) are publicly downloadable from: https://flexplan-project.eu

The OptimalTransmissionRouting.jl package is a Julia/JuMP package to determine the **optimal transmission system route** considering spatial information. The open access license toolbox and can be found on: https://github.com/Electa-Git/OptimalTransmissionRouting.jl



FlexPlan.jl is a Julia/JuMP **package to carry out transmission and distribution network planning** considering AC and DC technology, storage and demand flexibility as possible expansion candidates. A mixed-integer linear problem is constructed to be solved with any commercial or open-source MILP solver. The open access license toolbox can be found under: https://github.com/Electa-Git/FlexPlan.jl Installation instructions, information regarding problem types and network formulations are provided in the package documentation (https://electa-git.github.io/FlexPlan.jl/dev/).



Thank you…

Gianluigi Migliavacca

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This project has received funding from the European Union's Horizon2020 research and innovation programme under grant agreement N° 863819

FlexPlan

The FlexPlan planning methodology

07.03.2023

Hakan Ergun, KU Leuven / EnergyVille

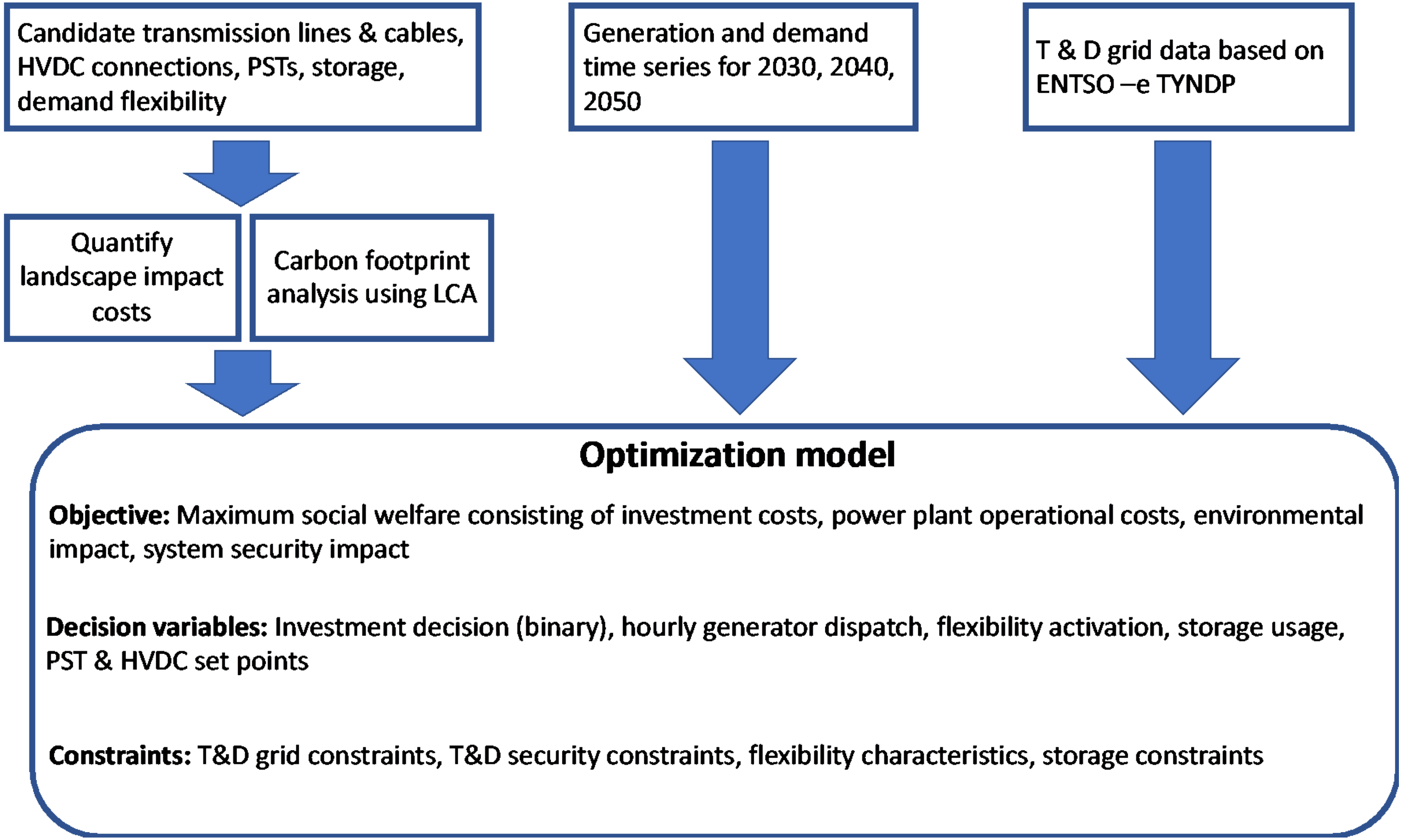
FlexPlan

Main objectives of the planning methodology

- Finding trade-offs between classical network expansion, storage and demand flexibility investments
- Taking a holistic approach on transmission and ditribution grid investments
- Considering the environmental impact and benefits of the network expansion in terms of emission reduction, carbon footprint and landscape impact

FlexPlan

The FlexPlan planning methodology



Optimization objective – General structure

- The maximum social welfare objective formulated as a cost minimization
  - Quantification of potential benefits not straight-forward without market assumptions
  - Danger of double counting benefits / costs due to complex flow of money
  - Eventually, all cost needs to be borne by consumers in some in way
- Objective function structure:
  - $\min \sum_y [\sum_t [\sum_i \boxed{(C_{y,t,i})} + \boxed{\sum_{y,j} \alpha_{y,j} (C_{y,t,j}}) + \boxed{\widetilde{U}_{y,t,c} \Delta t \sum_c C^{voll}_{u,t,y} \, \Delta P_{u,c,t,y}}] + \boxed{\sum_j \alpha_{y,j} I_{y,j}}]$

Operational cost of existing equipment

Operational cost of candidate equipment

Expected cost due to outages

CAPEX of candidate equipment

i… set of existing equipment
j… set of candidate equipment
α… binary decision variable
t….set operational time points (8760h)
y... set of planning horizons (2030, 2040, 2050)

  - Environmental impact cost considered as part of operational and CAPEX cost

Detailed formulation of the objective function

Air quality impact cost

$$
\min \sum_{y \in S_y} \left\{
\begin{aligned}
& f_y^{d,o} \sum_{t \in S_t} \left[
\begin{aligned}
& \sum_{g \in S_g} \left[C_{g,y}^{aq} + \left(\theta^{CO_2} G^{pf} + \theta^{f}\right)\eta_g^{f}\right] P_{g,t,y} + C_{g,y}^{res,curt} \Delta P_{g,t,y}^{res} + \\
& \sum_{j \in S_j} \left[C_{j,t,y}^{abs} P_{j,t,y}^{abs} + C_{j,t,y}^{inj} P_{j,t,y}^{inj}\right] + \sum_{j \in S_{jc}} \left[C_{jc,t,y}^{abs} P_{jc,t,y}^{abs} + C_{jc,t,y}^{inj} P_{j,t,y}^{inj}\right] + \\
& \sum_{u \in S_u} \left[C_{u,t,y}^{nce}\left(P_{u,t,y}^{ref} - P_{u,t,y}^{nce}\right) + C_{u,t,y}^{ds}\left(\Delta P_{u,t,y}^{ds,up} + \Delta P_{u,t,y}^{ds,dn}\right) + C_{u,t,y}^{lc} \Delta P_{u,t,y}^{lc}\right] + \\
& \sum_{n \in S_n} \left(C_{n,t,y}^{EE} EE_{n,t,y} + C_{n,t,y}^{LL} LL_{n,t,y}\right)
\end{aligned}
\right] + \\
& f_y^{d} \left[
\begin{aligned}
& \sum_{j \in S_{jc}} \alpha_{jc,y}\left(I_{jc,y}^{E}\left(E_j^{max}\right) + I_{jc,y}^{P}\left(P_j^{max}\right) + FP_{jc,y}^{CO_2}\right) + \sum_{u \in S_u} \alpha_{u,y}\left(I_{u,y} + FP_{u,y}^{CO_2}\right) + \\
& \sum_{lc \in S_{lc}^{ac}} \alpha_{lc,y}\left(I_{lc,y} + FP_{lc,y}^{CO_2} + LS_{lc,y}\right) + \sum_{dc \in S_{lc}^{dc}} \alpha_{dc,y}\left(I_{dc,y} + FP_{dc,y}^{CO_2} + LS_{dc,y}\right) + \\
& \sum_{zc \in S_{zc}} \alpha_{zc,y}\left(I_{zc,y} + FP_{zc,y}^{CO_2} + LS_{zc,y}\right) + \sum_{bc \in S_{bc}} \alpha_{bc,y}\left(I_{bc,y} + FP_{bc,y}^{CO_2} + LS_{bc,y}\right)
\end{aligned}
\right]
\end{aligned}
\right\}
$$

Generator operational costs

Storage operational costs

Flexible demand operational costs

Grid security related costs

Capex storage + Capex demand flexibility

Capex AC and DC lines

Capex DC converters & PSTs

Carbon footprint & landscape impact cost

Model dimensions:

- Set of grid elements (x1000)
- Set of planning hours (8760)
- Set of planning years (2030 – 2040 - 2050)

Detailed formulation of the objective function

$$
\begin{aligned}
\min \sum_{s} \pi_s \Bigg\{ \sum_{y \in S_y} f_y^{d,o} \Bigg\{ & \sum_{t \in S_t} \Bigg[\sum_{g \in S_g} \left[C^{aq}_{g,y} + \left(\theta^{CO_2} G^{pf} + \theta^{f} \right) \eta^{f}_{g} \right] P_{g,t,y,s} + C^{res,curt}_{g,y} \Delta P^{res}_{g,t,y,s} + \\
& \sum_{j \in S_j} \left[C^{abs}_{j,t,y} P^{abs}_{j,t,y,s} + C^{inj}_{j,t,y} P^{inj}_{j,t,y,s} \right] + \sum_{j \in S_{jc}} \left[C^{abs}_{jc,t,y} P^{abs}_{jc,t,y,s} + C^{inj}_{jc,t,y} P^{inj}_{j,ct,y,s} \right] + \\
& \sum_{u \in S_u} \left[C^{nce}_{u,t,y} \left(P^{ref}_{u,t,y,s} - P^{nce}_{u,t,y,s} \right) + C^{ds}_{u,t,y} \left(\Delta P^{ds,up}_{u,t,y,s} + \Delta P^{ds,dn}_{u,t,y,s} \right) + C^{lc}_{u,t,y} \Delta P^{lc}_{u,t,y} \right] + \\
& \sum_{n \in S_n} \left(C^{EE}_{n,t,y} EE_{n,t,y,s} + C^{LL}_{n,t,y} LL_{n,t,y,s} \right) \Bigg] + \\
f_y^{d} \Bigg[& \sum_{j \in S_{jc}} \alpha_{jc,y} \left(I^{E}_{jc,y} \left(E^{max}_{jc} \right) + I^{P}_{jc,y} \left(P^{max}_{jc} \right) + FP^{CO_2}_{jc,y} \right) + \sum_{u \in S_u} \alpha_{u,y} \left(I_{u,y} + FP^{CO_2}_{u,y} \right) + \\
& \sum_{lc \in S^{ac}_{lc}} \alpha_{lc,y} \left(I_{lc,y} + FP^{CO_2}_{lc,y} + LS_{lc,y} \right) + \sum_{dc \in S^{dc}_{lc}} \alpha_{dc,y} \left(I_{dc,y} + FP^{CO_2}_{dc,y} + LS_{dc,y} \right) + \\
& \sum_{zc \in S_{zc}} \alpha_{zc,y} \left(I_{zc,y} + FP^{CO_2}_{zc,y} + LS_{zc,y} \right) + \sum_{bc \in S_{bc}} \alpha_{bc,y} \left(I_{bc,y} + FP^{CO_2}_{bc,y} + LS_{bc,y} \right) \Bigg] \Bigg\} \Bigg\}
\end{aligned}
$$

Model dimensions:

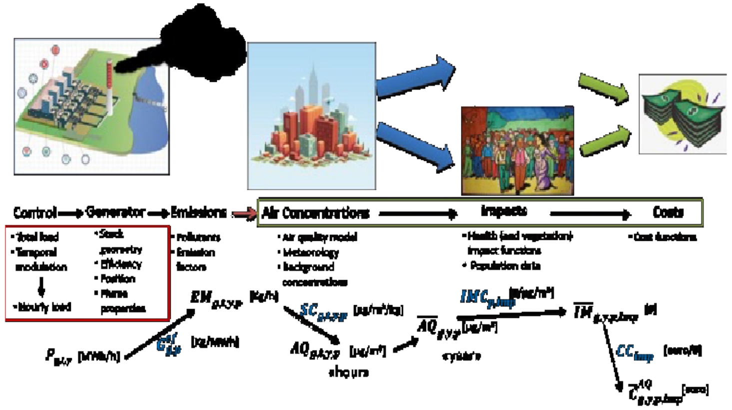
- Set of grid elements (x1000)
- Set of planning hours (8760)
- Set of planning years (2030 – 2040 - 2050)
- Set of planning scenarios

MILP problems will millions of decision variables and constraints

Model decompositions are needed!

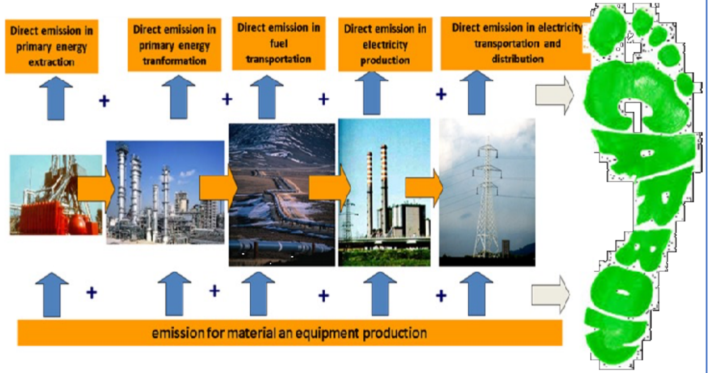
Environmental impact modelling

Air quality impact modelling



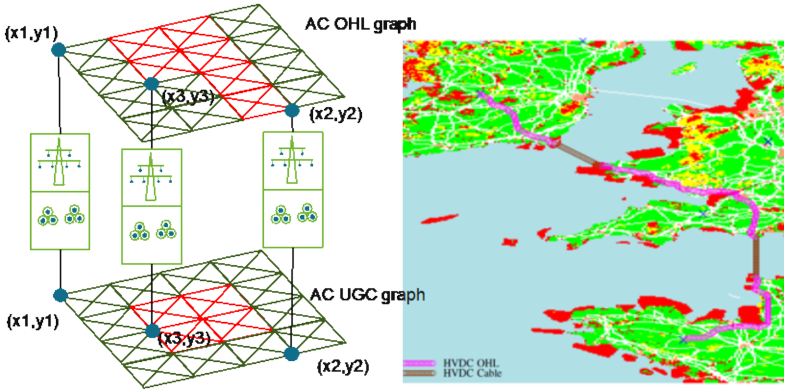
Linearized model quantifying air quality impact related costs in dependence of generation

Carbon footprint modelling



CO_2 emission cost of power generation as direct input, CO_2 impact of new grid investments using LCA

Landscape impact modelling



Using optimal routing routing algorithm quantifying landscape impact cost for OHL and cable investments

Flexible load modelling

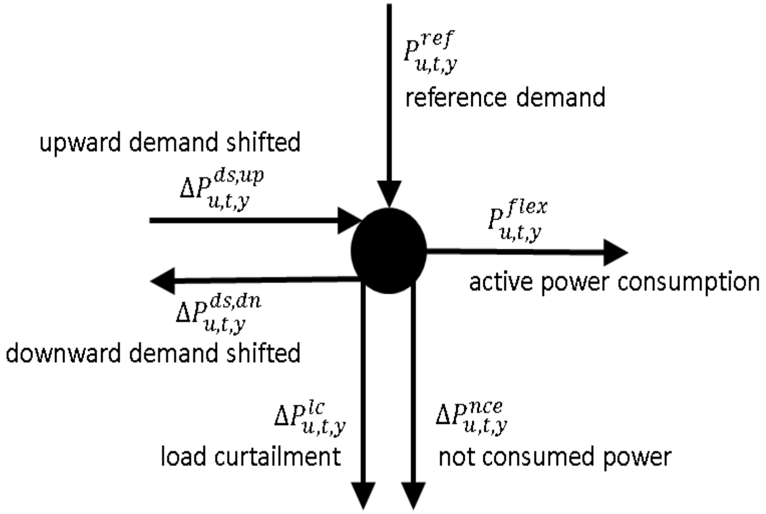
upward and downward Demand Shifting

voluntary reduction (Not Consumed Energy)

involuntary reduction (Load Curtailment)

$$\boxed{P^{flex}_{u,t,y} = P^{ref}_{u,t,y} + \Delta P^{ds,up}_{u,t,y} - \Delta P^{ds,dn}_{u,t,y} - \Delta P^{nce}_{u,t,y} - \Delta P^{lc}_{u,t,y}}$$

$$\left.\begin{aligned}
&P^{flex}_{u,t,y} \geq 0 \\
&0 \leq \Delta P^{ds,up}_{u,t,y} \leq \Delta^{ds,up,max}_{u,t,y} \\
&0 \leq \Delta P^{ds,dn}_{u,t,y} \leq \Delta^{ds,dn,max}_{u,t,y} \\
&0 \leq \Delta P^{nce}_{u,t,y} \leq \Delta P^{nce,max}_{u,t,y} \\
&0 \leq \Delta P^{lc}_{u,t,y} \leq P^{ref}_{u,t,y}
\end{aligned}\right\} \text{bounds on variables}$$



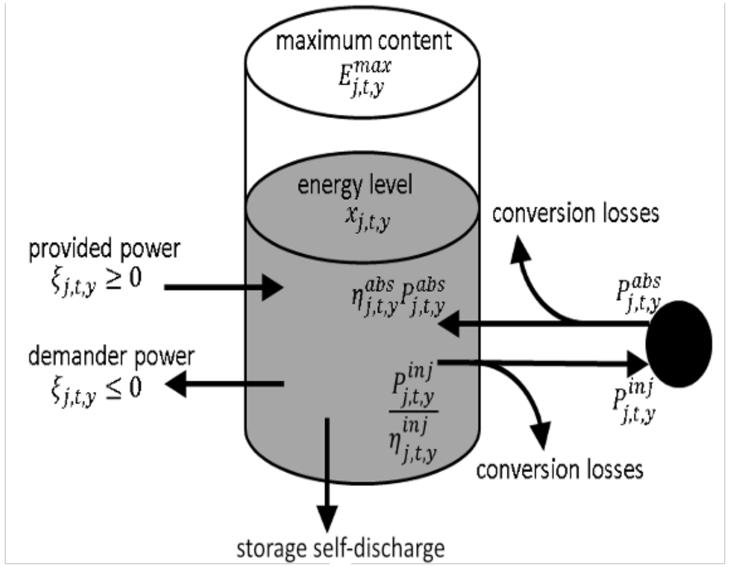
$$\sum_{t\in\{\tau-T^r+1,\dots,\tau\}} \left(\Delta P^{ds,up}_{u,t,y} - \Delta P^{ds,down}_{u,t,y}\right) = 0 \quad \forall\tau : \tau \bmod T^r = 0$$

upward and downward demand shifts are rebalanced every T^r periods

Storage modelling

$$E_{j,y}^{max} x_{j,t,y} = \left(1 - dr_{j,y}\right)^{\Delta t} E_{j,y}^{max} x_{j,t-1,y} + \Delta t \left(\eta_{j,y}^{abs} P_{j,t,y}^{abs} - \frac{P_{j,t,y}^{inj}}{\eta_{j,y}^{inj}} + \xi_{j,t,y} \right)$$

energy stored at time t | self-discharge | energy stored at time $t-1$ | energy absorbed from network | energy injected into network | exogenous term

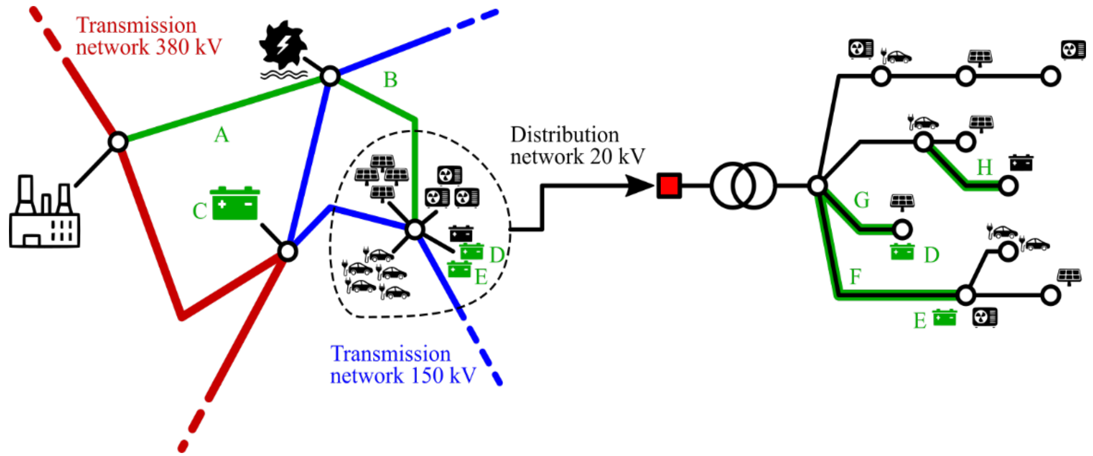


$E_{jc,y}^{min} \leq E_{jc,y}^{max} x_{jc,t,y} \leq E_{jc,y}^{max}$ bounds to energy level *x*

$0 \leq P_{jc,t,y}^{abs} \leq P_{jc,y}^{abs,max}$ bounds on power absorbed from network

$0 \leq P_{jc,t,y}^{inj} \leq P_{jc,y}^{inj,max}$ bounds on power injected into network

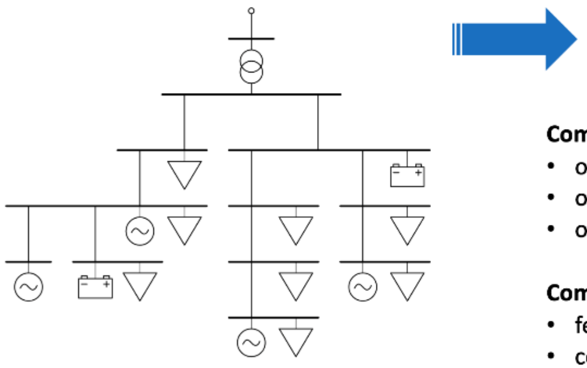
Transmission and distribution grid modelling



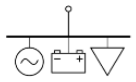
In order to maintain computational tractability, linearized models are adopted:

- DC approximation for AC/DC transmission grids
- linearized approach (DISTFLOW-like) simplifying but not eliminating reactive power for distribution grids
- Synthetic distribution grids are generated on the basis of few metrics/statistics of real networks

Original distribution network



Surrogate model



Components

- one generator
- one storage device
- one flexible load

Component parameters such that:

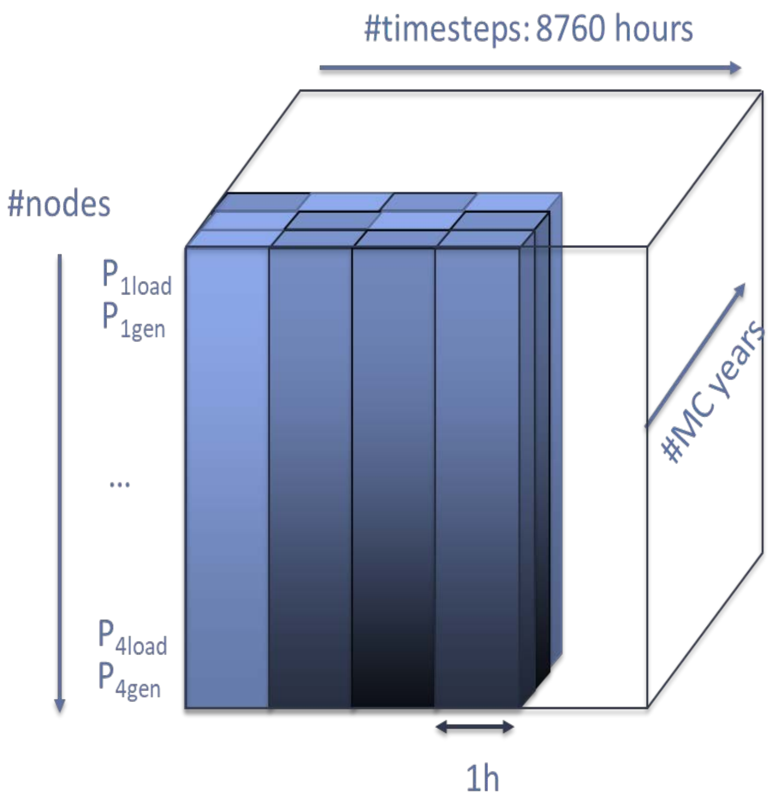
- feasibility *implies* feasibility in original model
- cost *approximates* cost in original model

The grid model is decomposed into TNEP and DNEP.

1. Compute one surrogate model for each distribution network
2. Run TNEP problem with the surrogate distribution networks attached to calculate optimal solution for transmission network, costs related to transmission network, power exchanges between transmission and distribution networks
3. Fix power exchanges and run DNEP problem for each distribution network to calculate optimal solution for distribution networks and costs related to distribution networks

FlexPlan

Stochastic optimisation



Climate variants of 35 years (variability of RES time series and load time series) are considered in the framework of a stochastic optimisation.

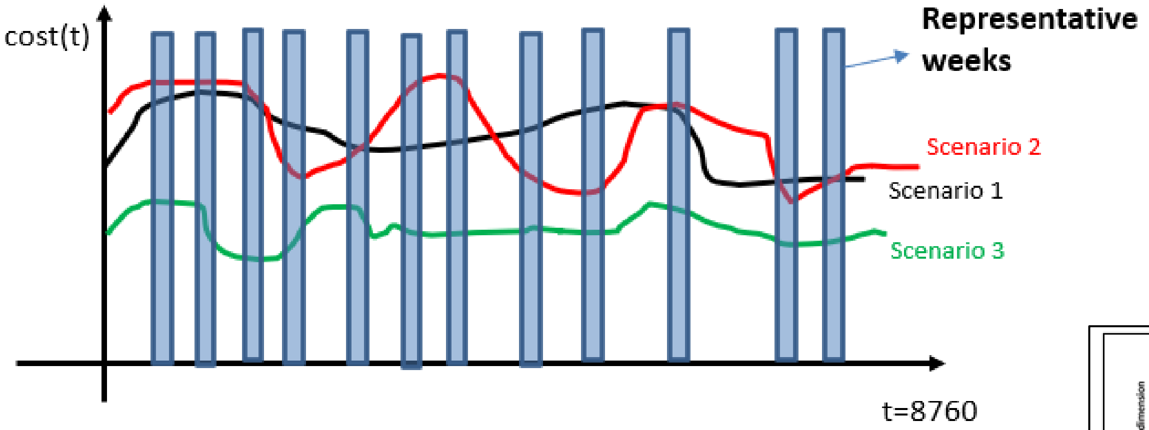
The number of combinations is reduced to two by using **clustering-based scenario reduction techniques**.

Adopting a Monte Carlo approach would present a modeling problem: if every Monte Carlo run is executed separately, then investment decisions are taken separately and there is a problem in putting together results that can be substantially diverging.

So, the dispatch costs of the different variants are weighted together in the target function, each with their own probability (**stochastic optimization**).

In order to retain numerical tractability, the dispatch calculation of the different variants is split by using the **Benders' decomposition**. Such methodology allows to decompose a master problem dealing with the investment decisions from the optimum dispatch calculation for each Monte Carlo variant and for all target years.

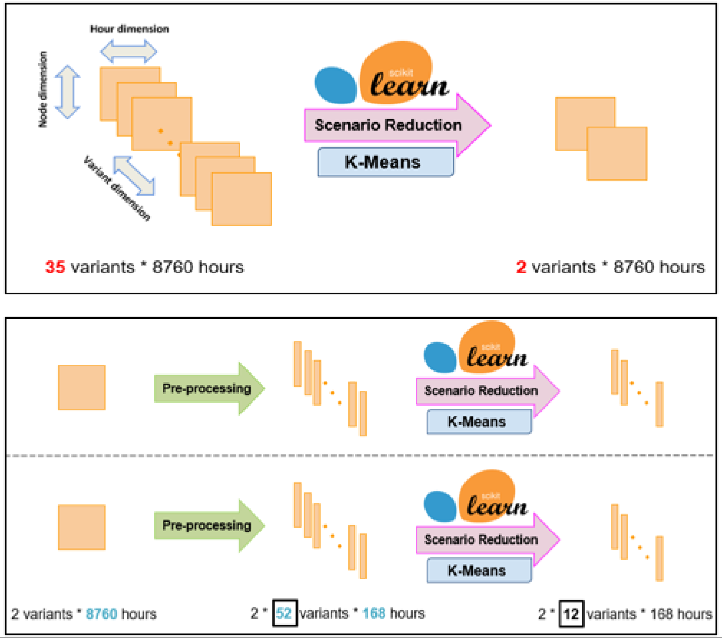
Reduction of the model size through clustering



In order to simplify the problem, only a few representative weeks are selected

A two-step approach is adopted in order to:

- select 12 representative weeks
- reduce 35 climatic variants to 2 equivalent ones:

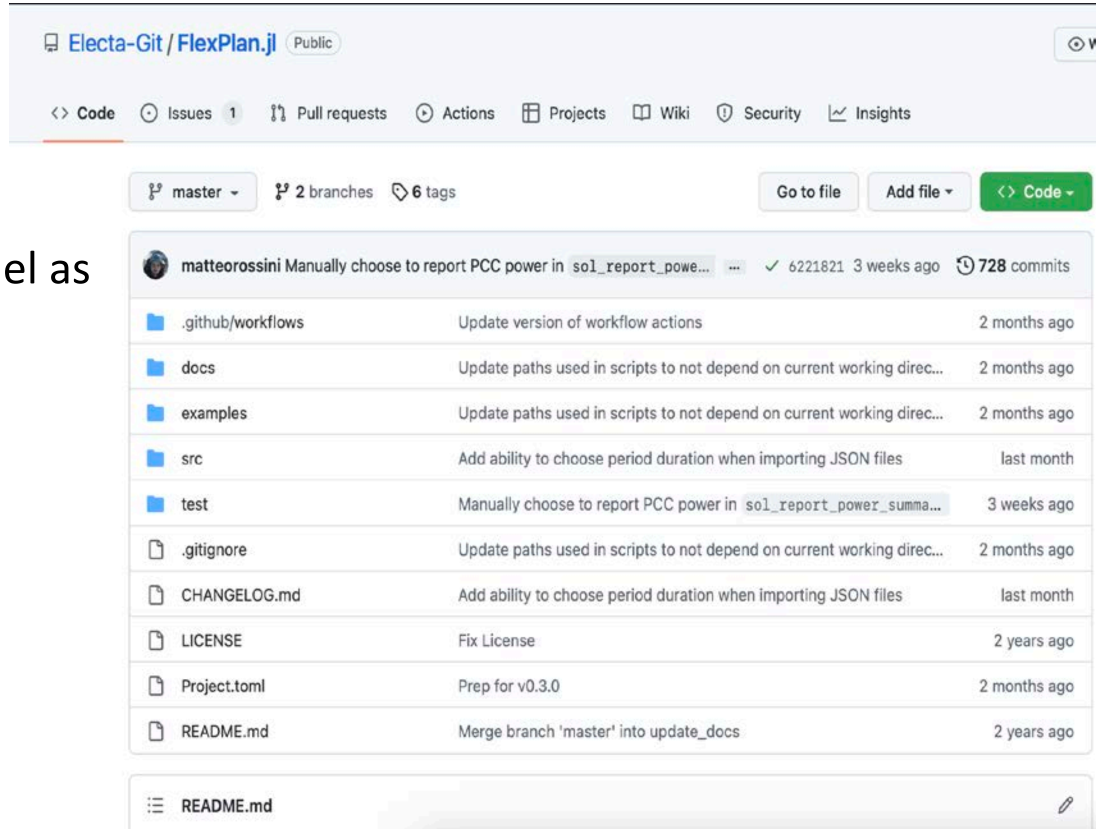


***STEP 1** – It consists in performing a standard reduction on the number of yearly variants.*

***STEP 2** – it consists in splitting independently every remaining yearly variant in 52 weekly variants (pre-processing) and then performing a standard reduction on the number of weekly variants independently for each initial yearly variant.*

FlexPlan

FlexPlan.jl

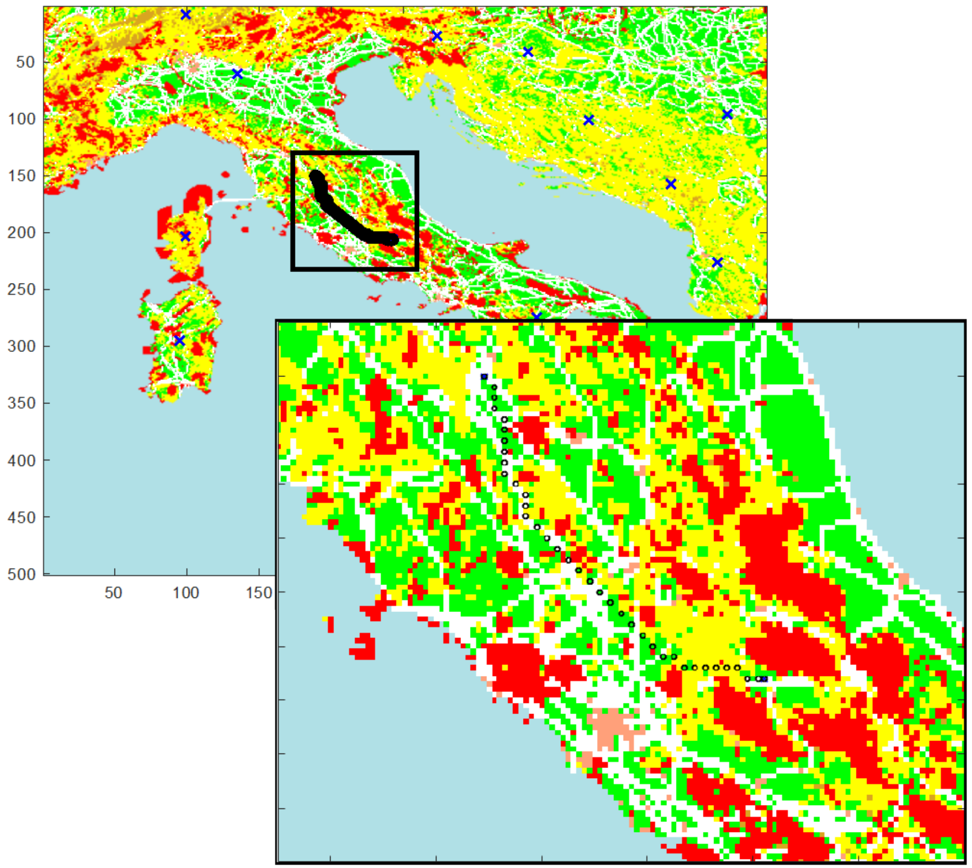


- Open-source Julia/JuMP implementation of the planning model as a design reference:
  - A variety of different problem types
  - Two distinct network formulations for meshed AC/DC and AC radial distribution grids
  - Parametrised models for demand flexibility, storage and HVDC connections
  - T & D grid decomposition, Benders decomposition
- Easy to extend, easy to use a variety of commercial and open source optimisation solvers, registered Julia package
- Current version v0.3.0, further improvements planned w.r.t. to tool documentation, problem types, examples……
- More information under: https://github.com/Electa-Git/FlexPlan.jl

FlexPlan

Open-source implementation of landscape impact model

- Current version (v0.1.4) features
  - Routing algorithms: A* (Dijkstra to be implemented)
  - Separate routing for AC & DC technology
    - Due to focus of FlexPlan
    - Hybrid extension easily possible
  - Conversion of latutide & longitude information to x-y geoimage file using coordinate transformation based on IOGP Geomatics (EPSG Dataset coordinate operation method code 9820)
  - Registered as official julia package



- Current version v0.1.4, further improvements planned w.r.t. to tool documentation, examples……

- More information under: https://github.com/Electa-Git

FlexPlan

Thank you…

Hakan Ergun

KU LEUVEN

EnergyVille

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This project has received funding from the European Union's Horizon2020
research and innovation programme under grant agreement N° 863819

FlexPlan

EERA JP Smart Grids Workshop| 7th March 2023

The main results from the six regional cases

Nicolò Italiano
R&D NESTER

Agenda

- Power system modelling
- Model simplifications
- Results of the planning process

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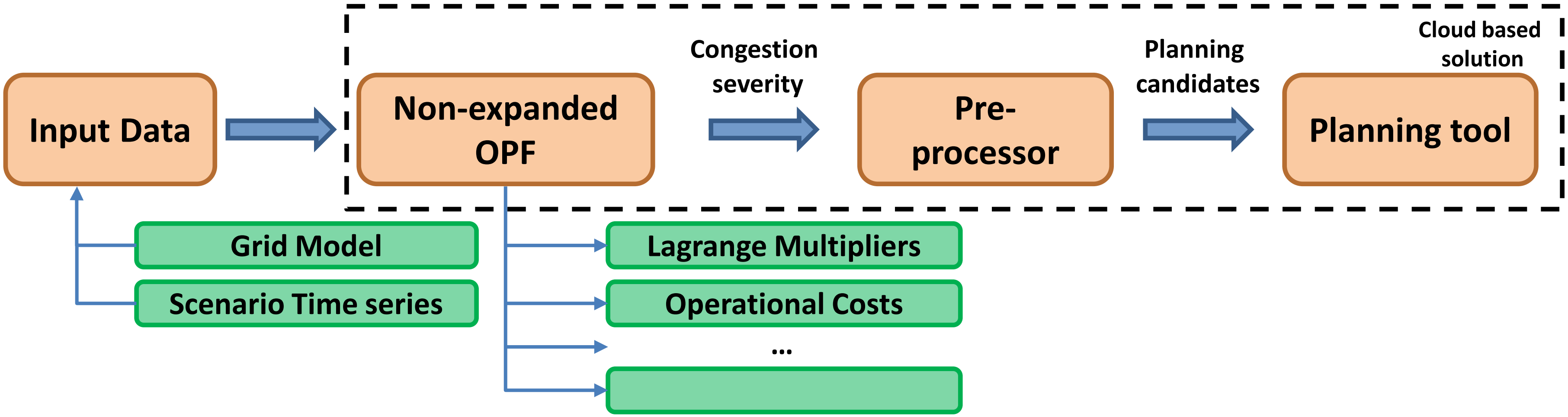
- Power system modelling
- Model simplifications
- Results of the planning process

Power system modelling

Grid Expansion Planning (GEP) process



- Role of the **non-expanded Optimal Power Flow**
  - Simulation of the scenario and indication of the level of congestion for grid elements
- Role of the **Pre-processor**
  - Identification of potential asset investments aimed at solving congestion (with priorities depending on congestion severity – Lagrange Multipliers)
  - Identification of nodes in which storage/demand flexibility can be beneficial for congestion management (using Locational Marginal Prices)
  - Proposal of storage technology on the basis of characteristics of congestions and territory
- Role of the **Planning tool**
  - Returns the list of the candidates which minimizes the total costs (CAPEX+OPEX), and details on their behaviour

Power system modelling

Transmission network model

Germany, Switzerland and Austria

- ENTSO-E model for EU transmission network (NDA)
- OpenStreetMap for sub-transmission
- Local Grid Development Plans

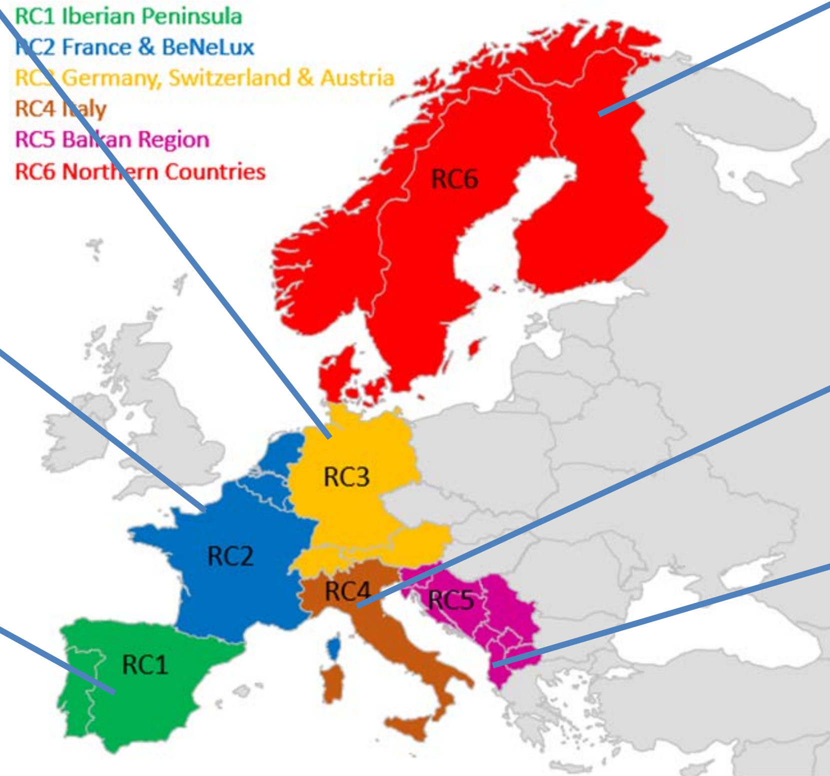
France and BeNeLux

- ENTSO-E model for EU transmission network (NDA)
- French TSO
- Google Maps (location)

Iberian Peninsula

- ENTSO-E model for EU transmission network (NDA)
- Spanish TSO and OpenStreetMap for sub-transmission network, complemented with PyPSA-Eur model and Google Maps (location)

The main source
ENTSO-E model for EU transmission network (NDA)



Northern Countries

- Norwegian energy regulator, local TSO (Norway, NDA)
- PyPSA-Eur model, OpenStreetMap (DK,SE,FI)
- Local Grid Development Plans

Italy

- ENTSO-E model for EU transmission network
- Ministero della Transizione Ecologica
- OpenStreetMap
- Local Grid Development Plans

Balkan Region

- ENTSO-E model for EU transmission network
- OpenStreetMap

entsoe
Transparency Platform

Data for model validation
ENTSO-E TP

Power system modelling

Distribution network model

Data provided from DiNeMo (Distribution Network Models) platform

↓

Synthetic distribution networks are generated

↓

Level of congestion is estimated for each distribution network

↓

Grid reduction performed in order to consider congested areas only

↓

Distribution network is integrated into the transmission model

https://ses.jrc.ec.Europa.eu/dinemo

PDF

G. Viganò, M. Rossi, C. Michelangeli and D. Moneta, "Creation of the Italian Distribution System Scenario by Using Synthetic Artificial Networks" 2020 AEIT International Annual Conference, 2020, pp. 1-6

Power system modelling

Pan-European Scenarios

- Data in TYNDP 2020:
  - Installed generation capacities by technology
  - Annual mean capacity factors for renewable energy sources
  - Annual electricity consumption and peak load
  - Hourly time series data for consumption
  - Net transfer capacities
  - Commodity prices for different types of fuel
  - Total operational reserve power
- Missing data was also validated with “A Clean Planet For All” from European Commission

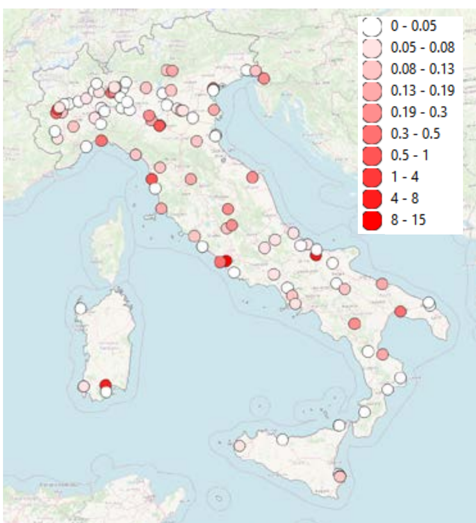
- Three Scenarios
  - Distributed Energy (DE)
  - Global Ambition (GA)
  - National Trends (NT)
- Three target years
  - 2030
  - 2040
  - 2050

Power system modelling

Environmental impact – Air Quality

Health impact (YOLL/µg·m^{-3})
Cost (€/YOLL)
Reference production (MWh)

Air quality impact cost (€/MWh)



Impact areas around power plants (25 km radius)

Resident population

Weighting factor of individual power plant with respect to others

Pollutant concentration cumulative impact due to all generators, estimated with air quality simulations

Power system modelling

Environmental impact – Carbon Footprint

Planning investments

2750÷3500 kg of CO_2*km^{-1}*$year^{-1}$

114÷173 kg of CO_2*kWh^{-1}*$year^{-1}$

100÷900 kg of CO_2*MVA^{-1}*$year^{-1}$

Climate change avoidance costs €/tCO_2 equivalent (€2016)

	Low	Central	High
CO_2 Emissions – short and medium run (until 2030)	60	100	189
CO_2 Emissions – long run (from 2040 to 2060)	156	269	498

Agenda

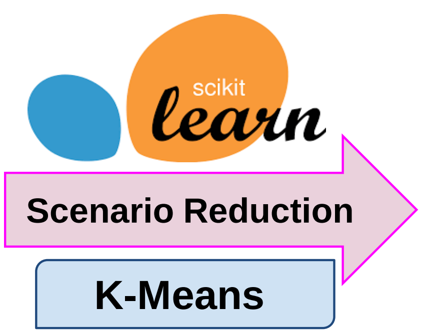
- Power system modelling
- Model simplifications
- Results of the planning process

Model simplifications

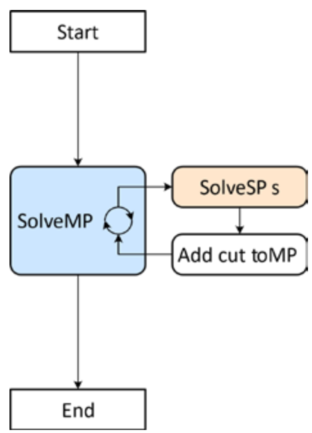
Dealing with real-size power systems

The development of the planning procedure has been carried out in order to be able to manage:

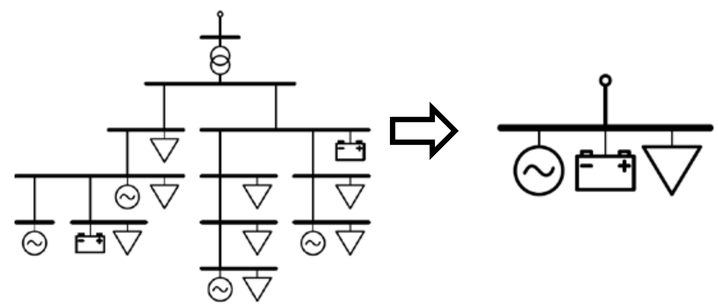
- **Real/size power systems** with more voltage levels simultaneously (transmission, sub-transmission and distribution)
- **Multiple scenarios** to consider both variability of electricity demand and renewable power production (climate variants)
- **Multiple target years**, to optimally select investments by considering planning impact over their entire lifetime



Scenario reduction



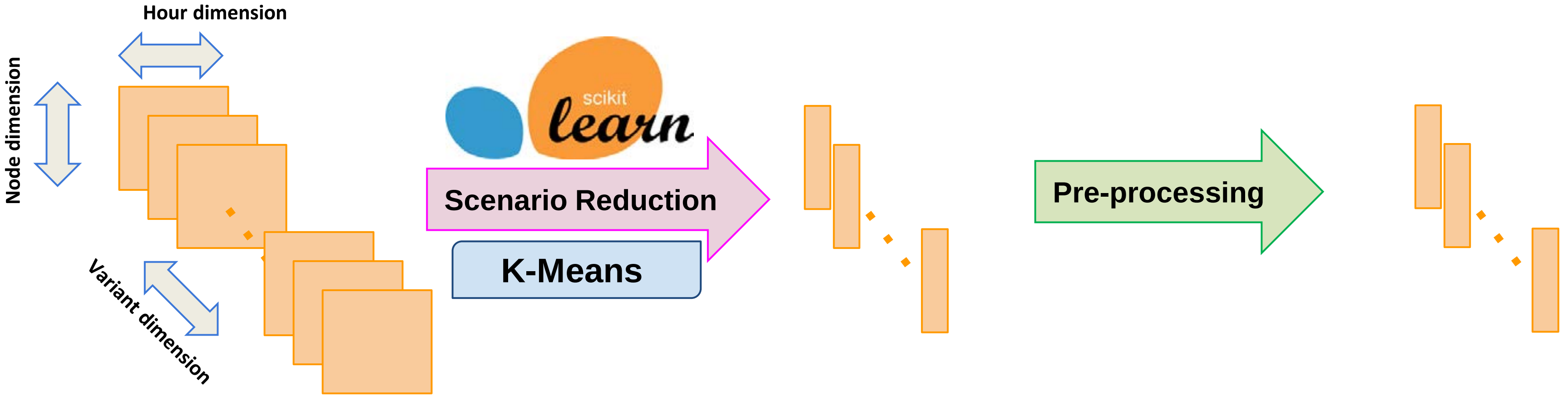
Benders decomposition



Transmission & Distribution decomposition

Model simplifications

Scenario reduction



35 yearly variants * 8760 hours

2 yearly variants * 8760 hours

1 yearly variant * 52 weekly variants * 168 hours

Time profiles of 35 climate variants for each decade (2030-40-50) and scenario (DE, GA, NT)

- 2 representative climate variants
  (with different probabilities)
- 12 representative weeks
  (one for each month of the year)
- Time resolution: 1 hour
  (168 time steps per week)

Model simplifications

Additional simplifications

Event though the tools have been optimized in order to manage **real-size systems**, operating in a multitude of **scenarios** and **climate variants**, some further **simplifications** were needed to be applied to **FlexPlan** regional cases.

4 representative weeks
(instead of 12)

Reduced time resolution
(2-hour time blocks)

Limited portion of Distribution Network
(~10%)

~100 planning candidates

Total processing time per reference year
3÷5 days

Relaxed optimality tolerance
(0.01% MIP-gap)

1-decade time horizon
(instead of 3)

Reduced amount of Transmission AC lines
(short lines neglected)

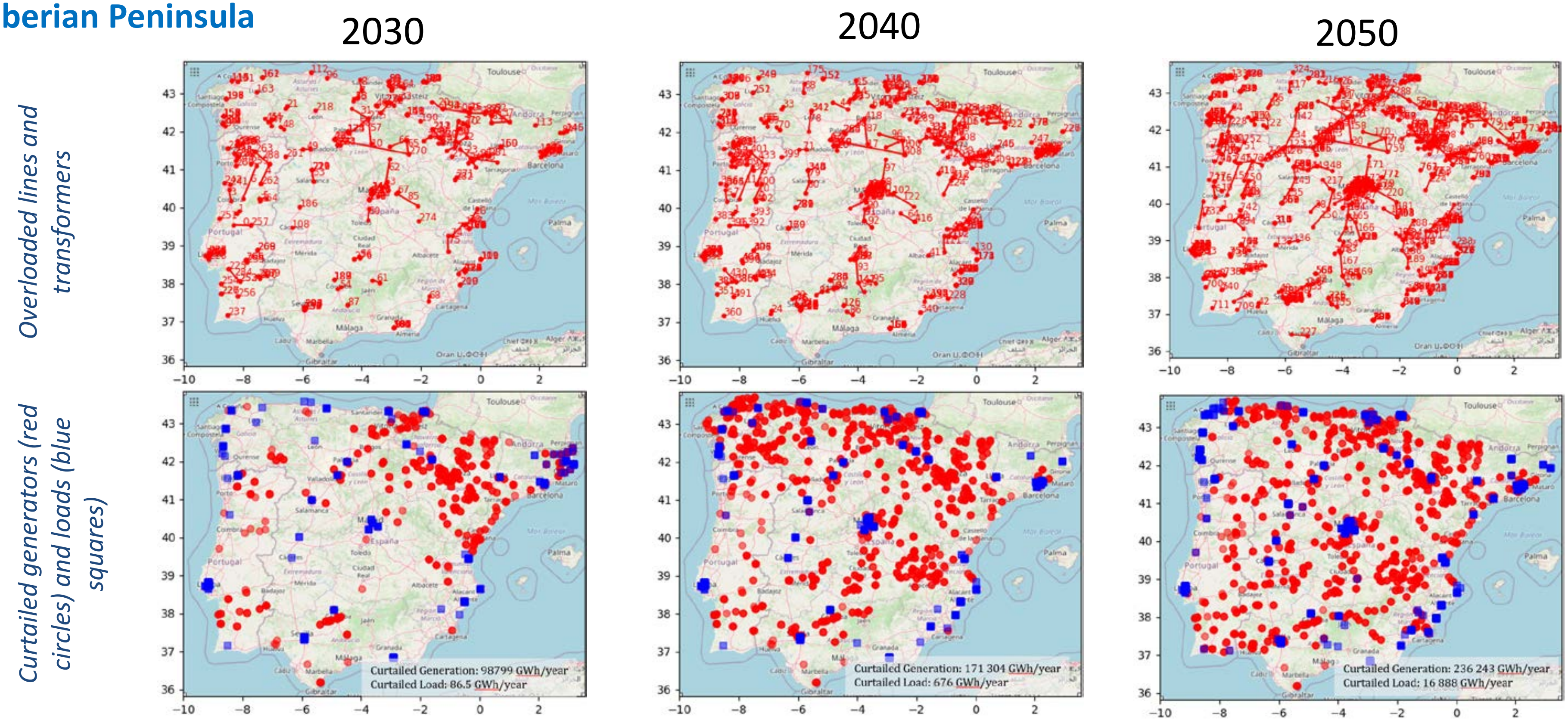
1 climate variant
(instead of 35)

Agenda

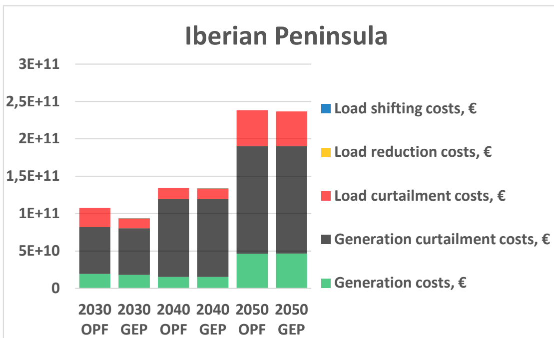
- Power system modelling
- Model simplifications
- Results of the planning process

Results of the planning process

Iberian Peninsula



Type	AC Branch			Transformer			Storage			Flexibility load			Total		
	2030	2040	2050	2030	2040	2050	2030	2040	2050	2030	2040	2050	2030	2040	2050
Number of candidates	57	74	98	4	0	0	6	5	2	33	21	0	100	100	100
Investment decisions	6 (T)	0 (T)	0 (T)	0 (T)	0 (T)	0 (T)	2	2	2	9	5	0	49	44	38
	30 (D)	37 (D)	36 (D)	2 (D)	0 (D)	0 (D)									
Investment rejected	1 (T)	0 (T)	0 (T)	2 (T)	0 (T)	0 (T)	4	3	0	24	16	0	51	56	62
	20 (D)	37 (D)	62 (D)	0 (D)	0 (D)	0 (D)									

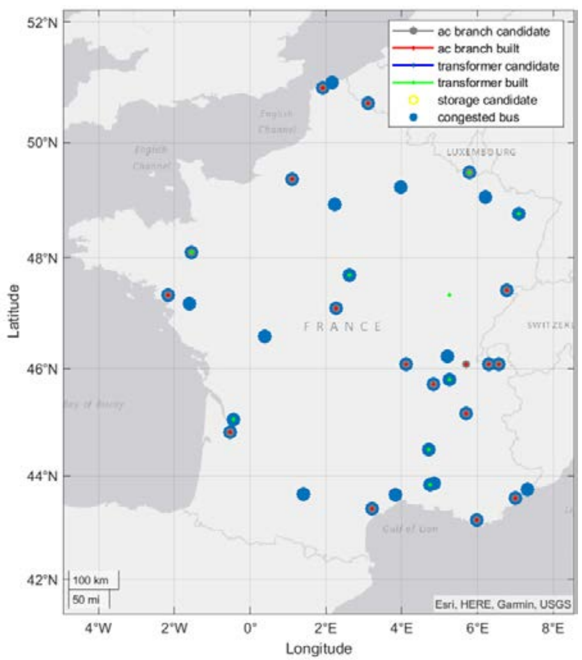


Results of the planning process

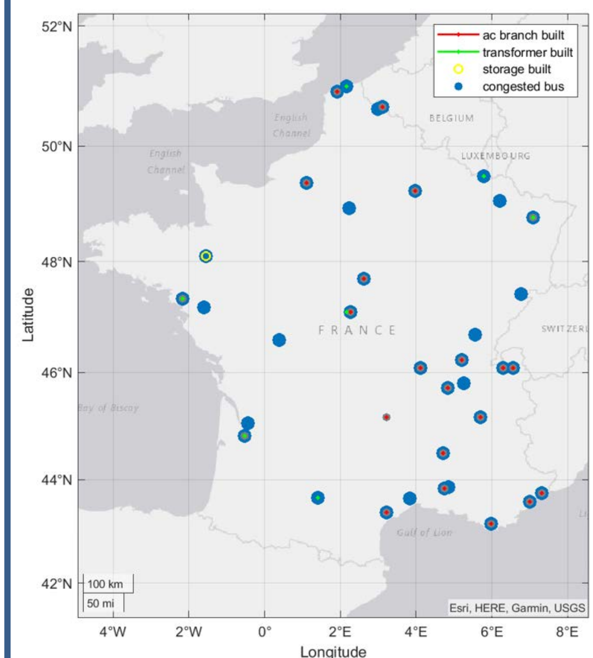
France

Investment decisions

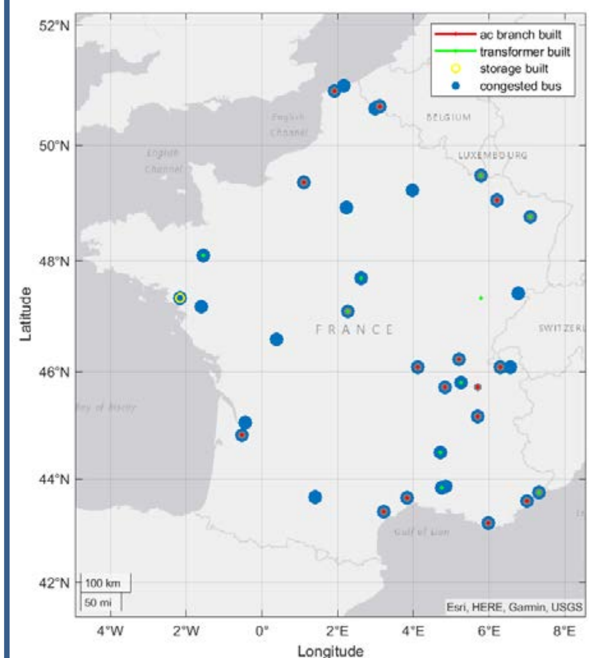
2030



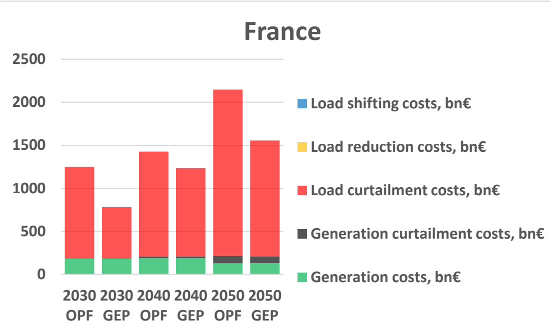
2040



2050

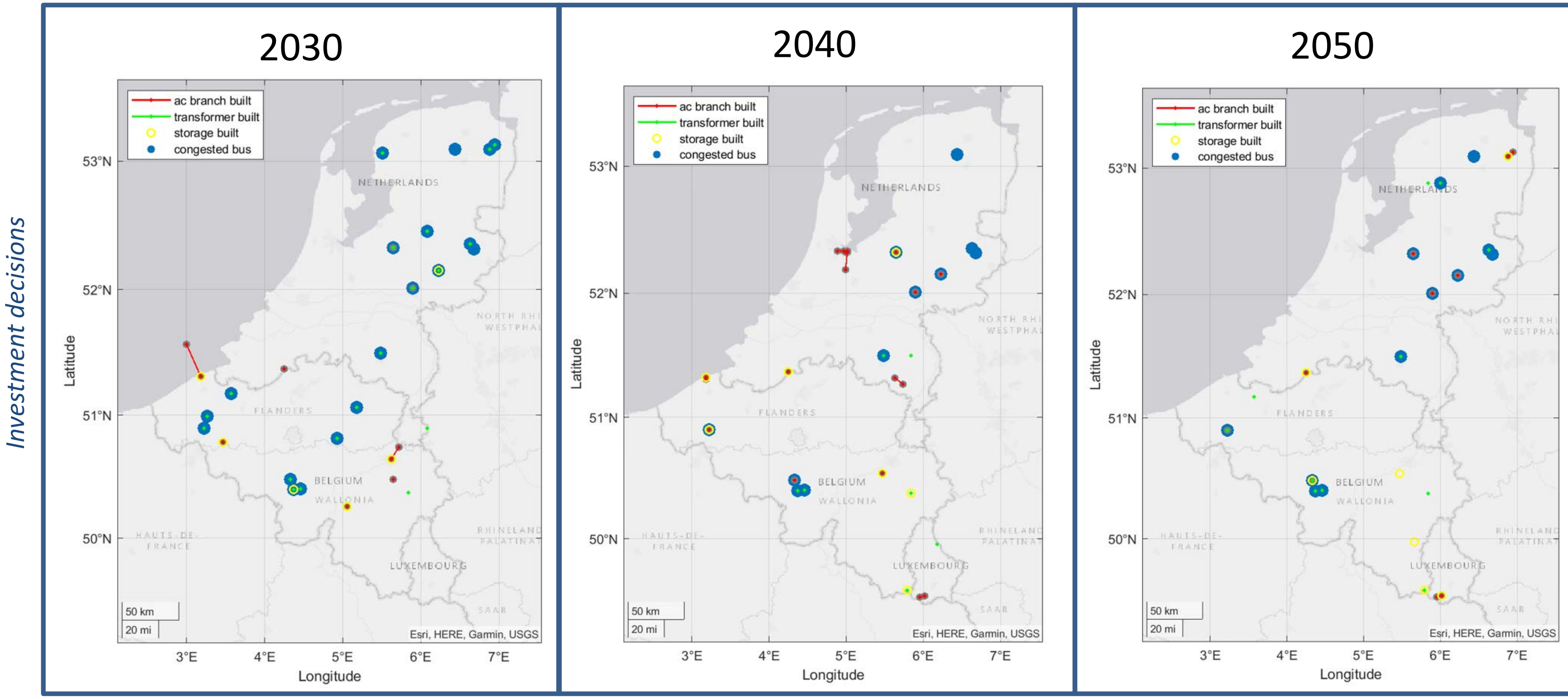


Type	AC Branch			Transformer			Storage			Flexibility load			Total		
	2030	2040	2050	2030	2040	2050	2030	2040	2050	2030	2040	2050	2030	2040	2050
Number of candidates	60	79	67	25	7	19	0	1	2	15	13	12	100	100	100
Investment decisions	6 (T) 38 (D)	0 (T) 42 (D)	0 (T) 39 (D)	0 (T) 25 (D)	0 (T) 7 (D)	0 (T) 19 (D)	0	1	1	9	8	8	72	58	67
Investment rejected	0 (T) 22 (D)	6 (T) 31 (D)	6 (T) 22 (D)	0 (T) 0 (D)	0 (T) 0 (D)	0 (T) 0 (D)	0	0	1	6	5	4	28	42	33

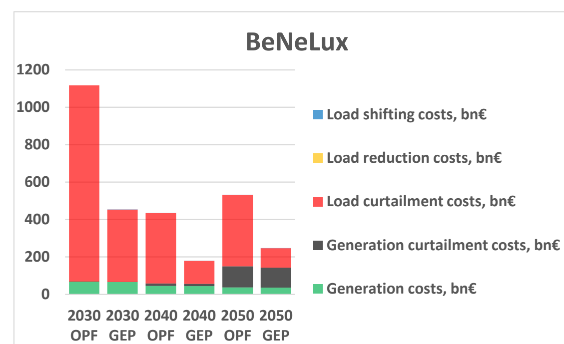


Results of the planning process

BeNeLux

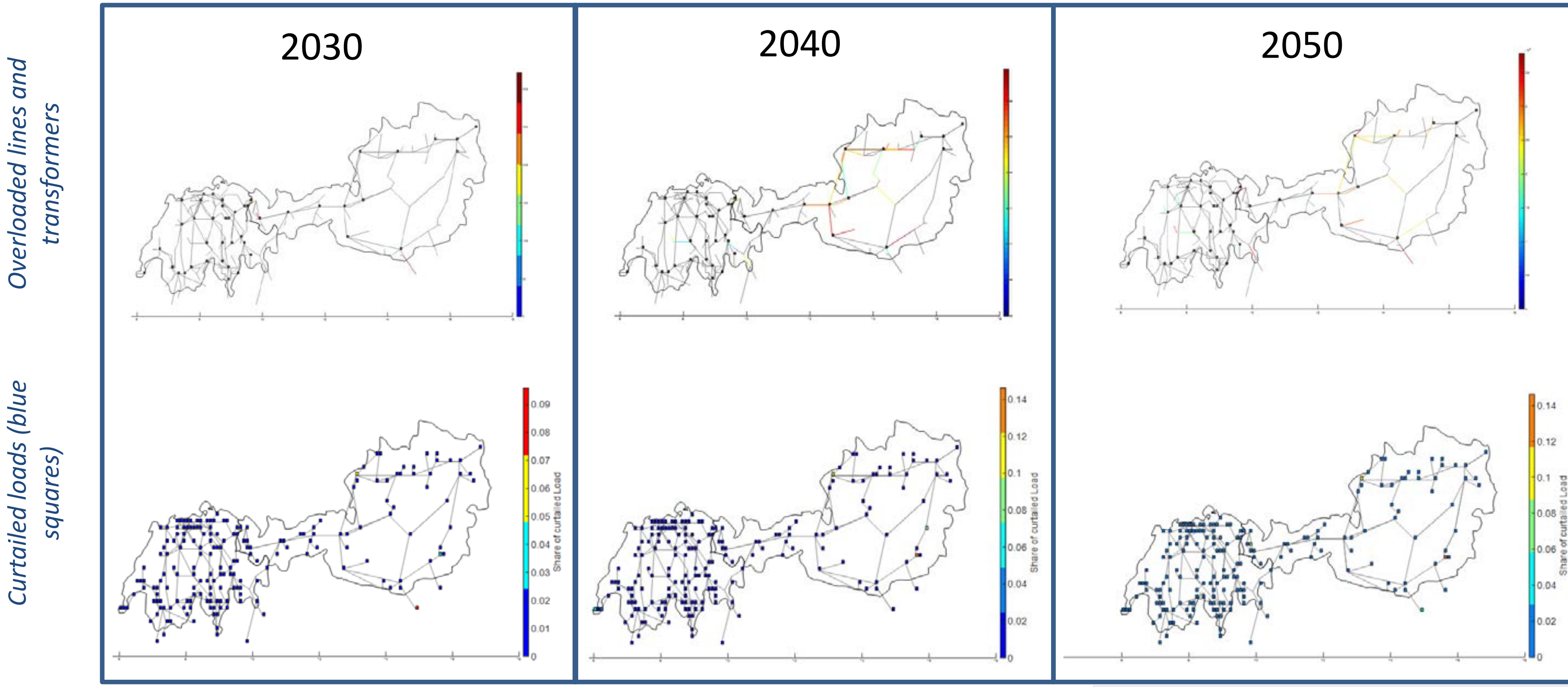


Type	AC Branch			Transformer			Storage			Flexibility load			Total		
	2030	2040	2050	2030	2040	2050	2030	2040	2050	2030	2040	2050	2030	2040	2050
Number of candidates	13	28	33	35	7	18	19	19	20	18	11	14	85	65	85
Investment decisions	6 (T)	7 (T)	3 (T)	4 (T)	4 (T)	4 (T)	12	7	12	1	4	5	57	36	50
	3 (D)	11 (D)	12 (D)	31 (D)	3 (D)	14 (D)									
Investment rejected	0 (T)	2 (T)	7 (T)	0 (T)	0 (T)	0 (T)	7	12	8	17	7	9	28	29	35
	4 (D)	8 (D)	11 (D)	0 (D)	0 (D)	0 (D)									

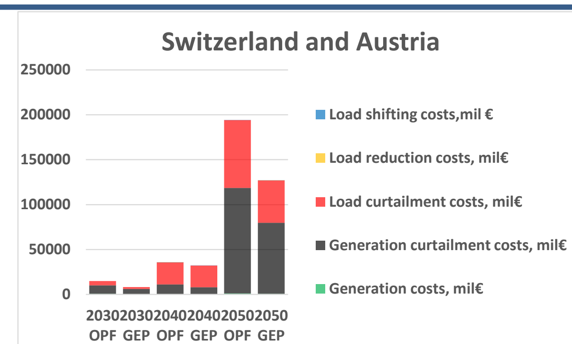


Results of the planning process

Switzerland and Austria



Type	AC Branch			Transformer			Storage			Flexibility load			Total		
	2030	2040	2050	2030	2040	2050	2030	2040	2050	2030	2040	2050	2030	2040	2050
Number of candidates	9	35	20	0	1	0	11	45	20	5	19	19	25	100	59
Investment decisions	4	18	13	0	0	0	1	38	17	5	19	17	10	75	47
Investment rejected	5	17	7	0	1	0	10	7	3	0	0	2	15	25	12

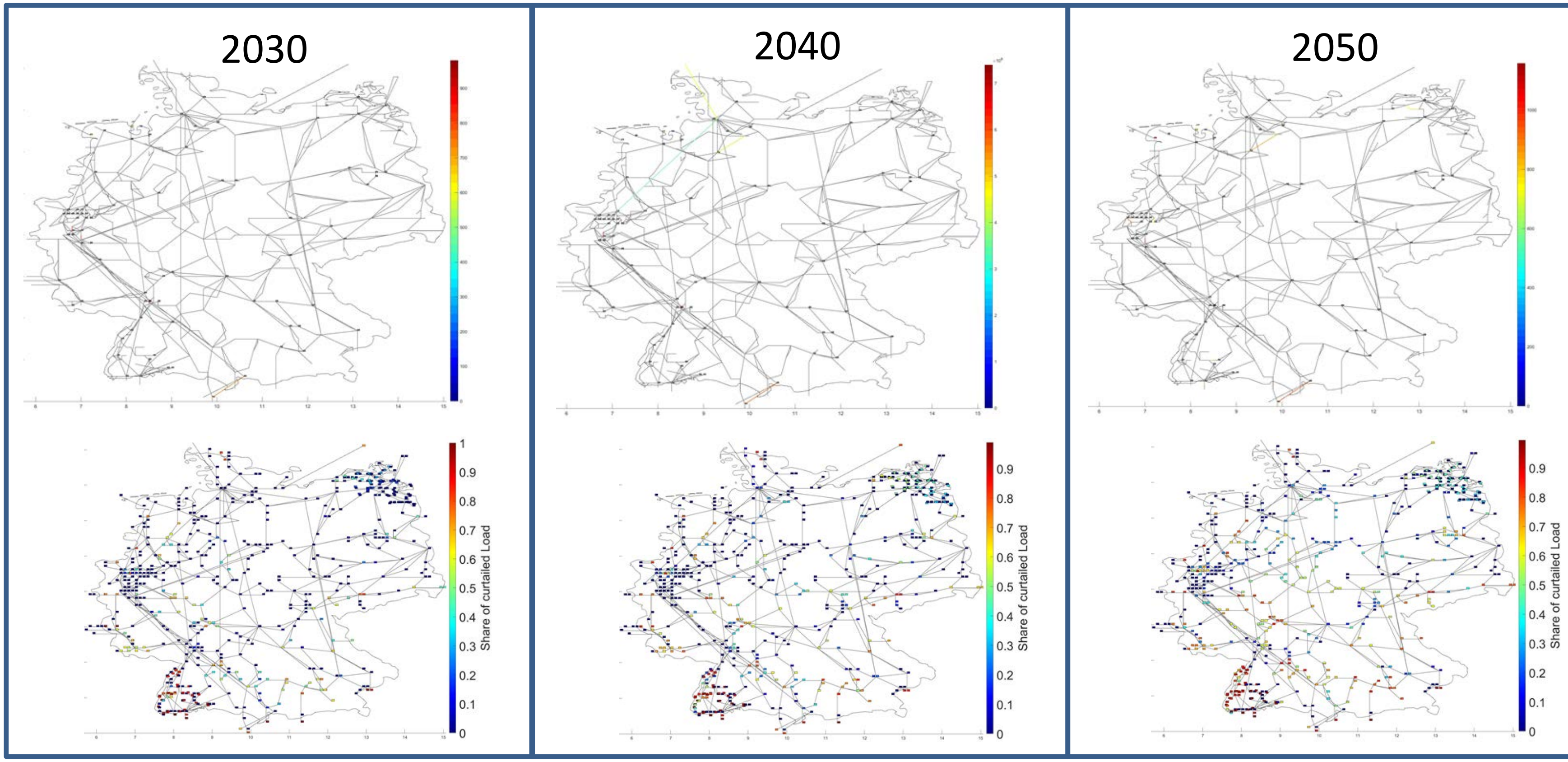


Results of the planning process

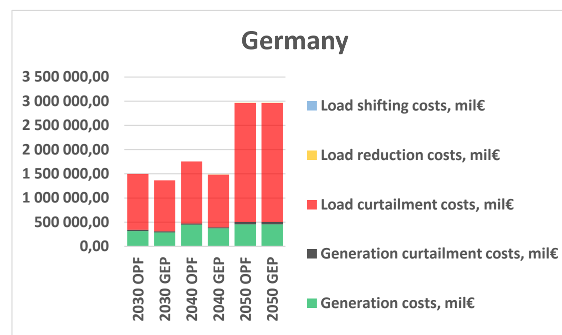
Germany

Overloaded lines and transformers

Curtailed loads (blue squares)



Type	AC Branch			Transformer			Storage			Flexibility load			Total		
	2030	2040	2050	2030	2040	2050	2030	2040	2050	2030	2040	2050	2030	2040	2050
Number of candidates	3	3	3	0	0	0	3	2	3	1	1	2	7	6	8
Investment decisions	3/0/0	0/2/2/3	0	0	0	0	0/0/0	0/1/0/2	0	0/0/0/	0/1/1/0	0	3/0/0	0/3/3/5	0
Investment rejected	0/3/3	3/1/1/0	3	0	0	0	3/3/3	2/1/2/0	3	1/1/1	1/0/0/1	2	4/7/7	6/3/3/1	8

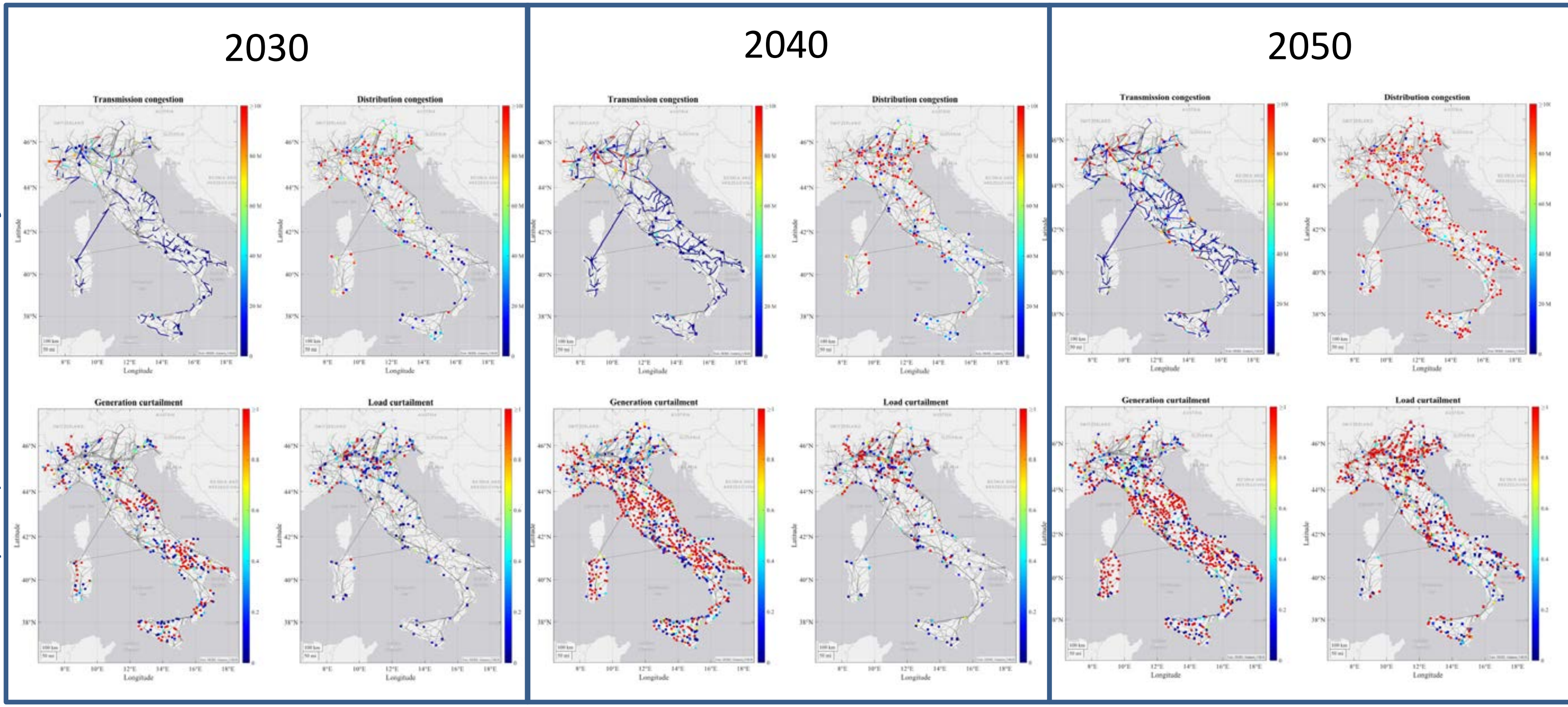


Results of the planning process

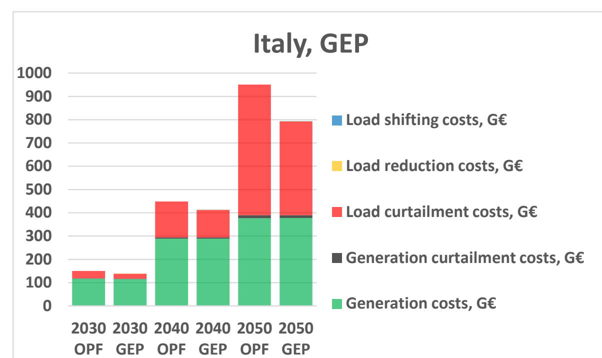
Italy

Overloaded lines and transformers

Curtailed loads (blue squares)



Type	AC Branch			Transformer			Storage			Flexibility load			Total		
	2030	2040	2050	2030	2040	2050	2030	2040	2050	2030	2040	2050	2030	2040	2050
Number of candidates	90	85	92	2	0	9	9	7	5	19	12	1	120	104	107
Investment decisions	7 (T)	12 (T)	6 (T)	1 (T)	0 (T)	4 (T)	6	6	5	5	9	1	59	44	49
	40 (D)	17 (D)	29 (D)	0 (D)	0 (D)	4 (D)									
Investment rejected	6 (T)	4 (T)	4 (T)	1 (T)	0 (T)	1 (T)	3	1	0	14	3	0	61	60	58
	37 (D)	52 (D)	53 (D)	0 (D)	0 (D)	0 (D)									



Results of the planning process

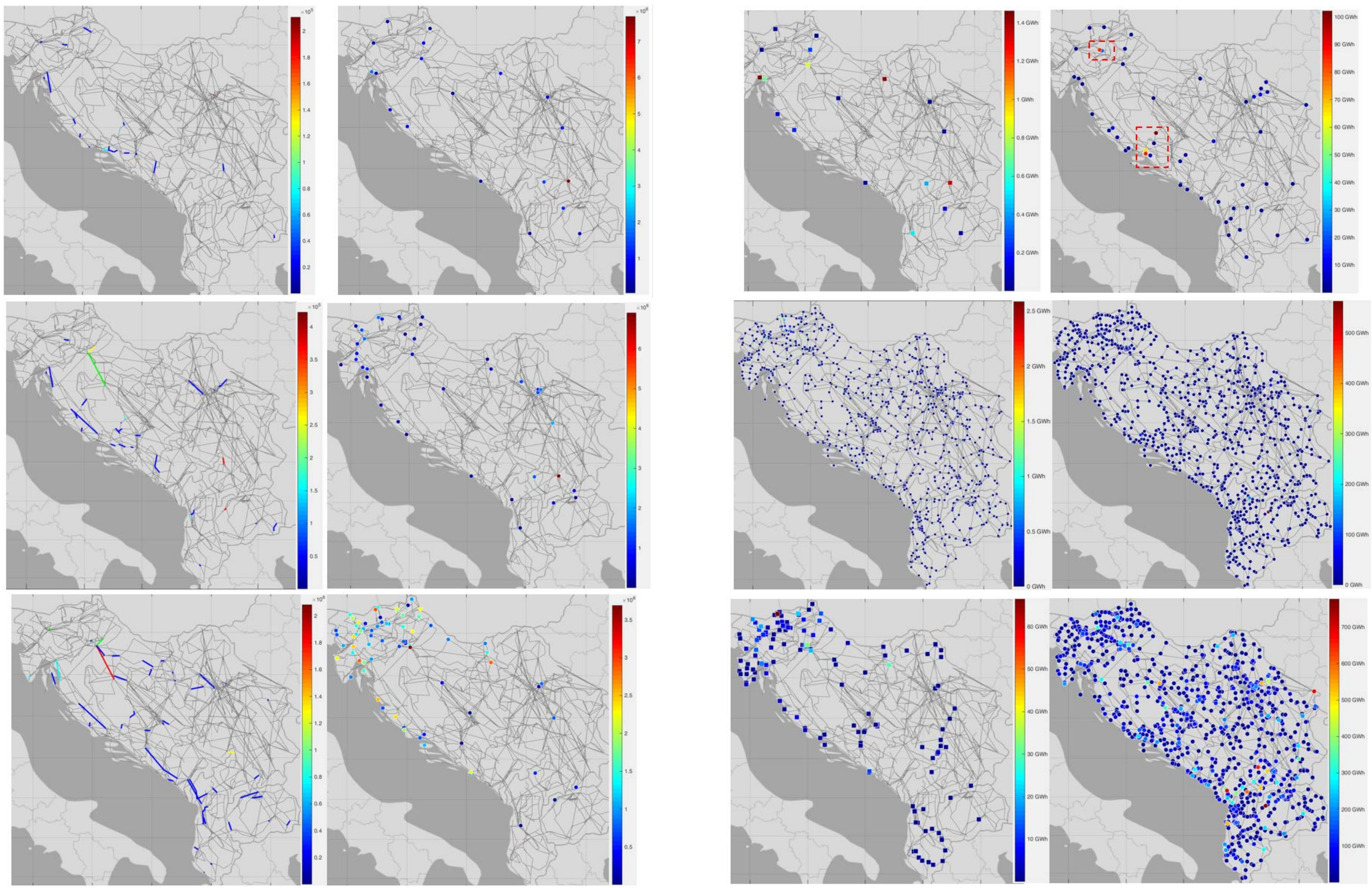
Balkan Region

Overloaded lines and transformers, transmission | *Overloaded lines and transformers, distribution* | *Curtailed generators (circles) and loads (squares), transmission* | *Curtailed generators (circles) and loads (squares), distribution*

2030

2040

2050

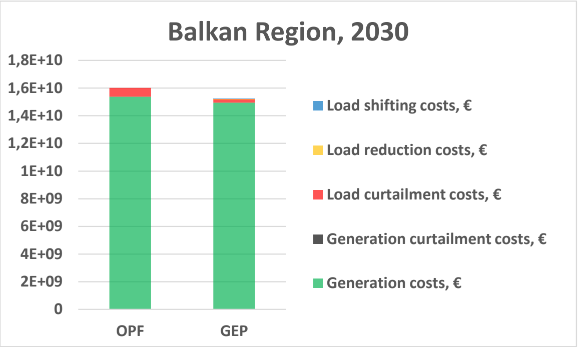


Results of the planning process

Balkan Region

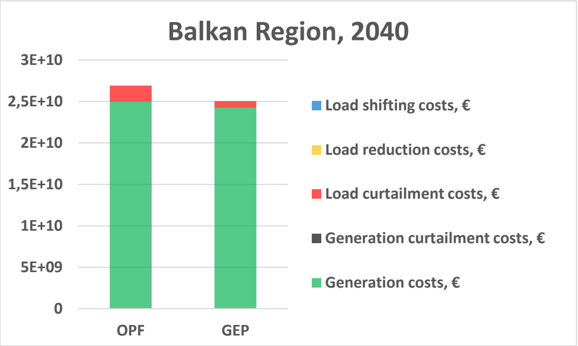
2030

Type	AC Branch	Transformer	Storage	Flexibility load	Total
Number of candidates	37	0	38	25	100
Investment decisions	7 (T)	0 (T)	6	15	38
	10 (D)	0 (D)			
Investment rejected	5 (T)	0 (T)	32	17	62
	15 (D)	0 (D)			



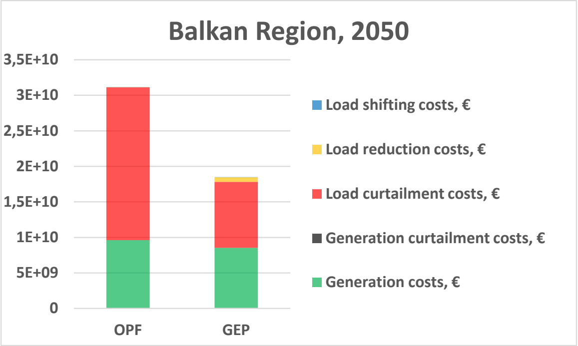
2040

Type	AC Branch	Transformer	Storage	Flexibility load	Total
Number of candidates	40	0	38	22	100
Investment decisions	6 (T)	0 (T)	18	16	51
	11 (D)	0 (D)			
Investment rejected	7 (T)	0 (T)	20	6	49
	16 (D)	0 (D)			



2050

Type	AC Branch	Transformer	Storage	Flexibility load	Total
Number of candidates	44	0	23	33	100
Investment decisions	3 (T)	0 (T)	21	33	79
	22 (D)	0 (D)			
Investment rejected	4 (T)	0 (T)	2	0	21
	15 (D)	0 (D)			



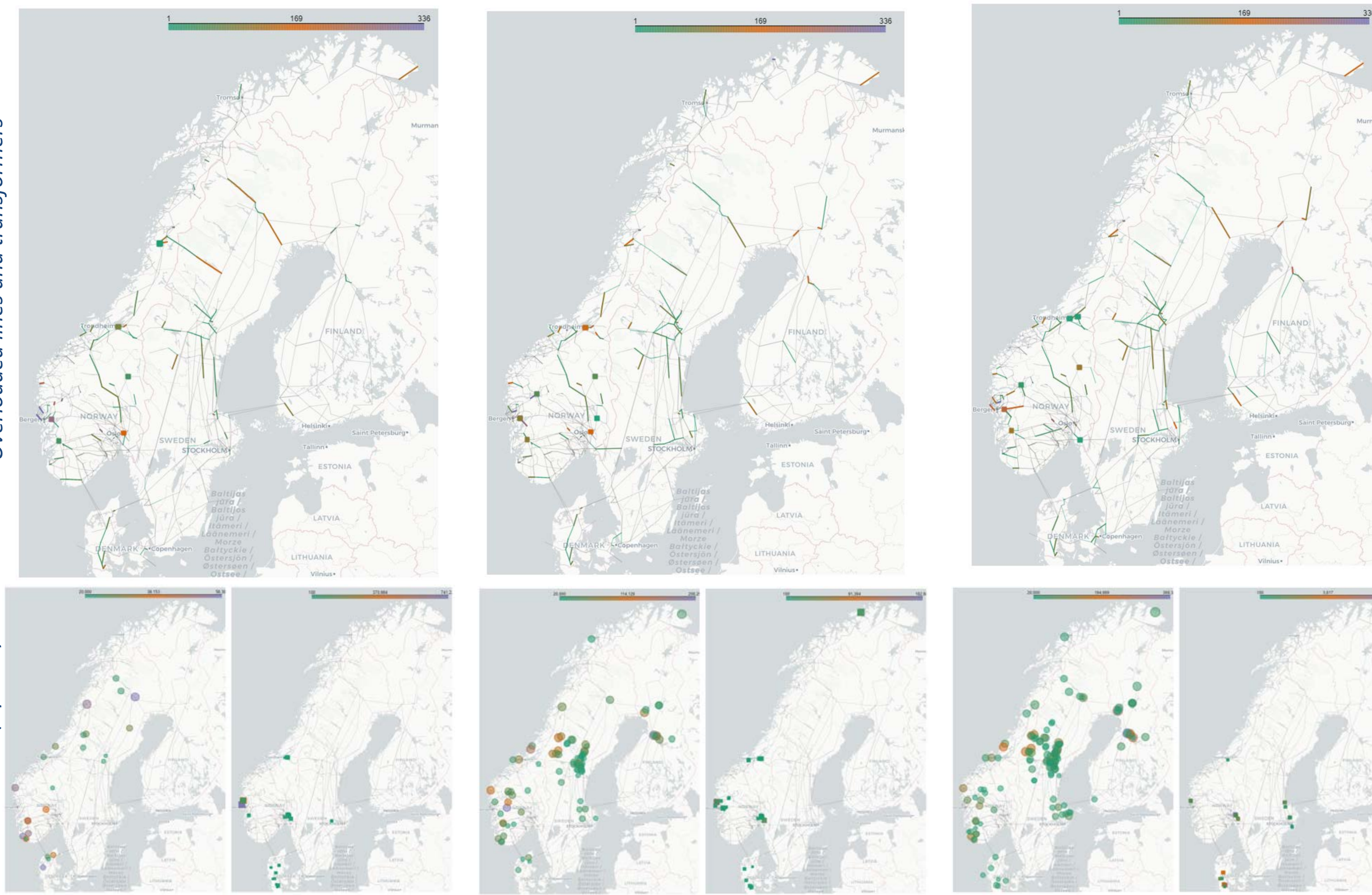
Results of the planning process

Northern Countries

2030 *2040* *2050*

Overloaded lines and transformers

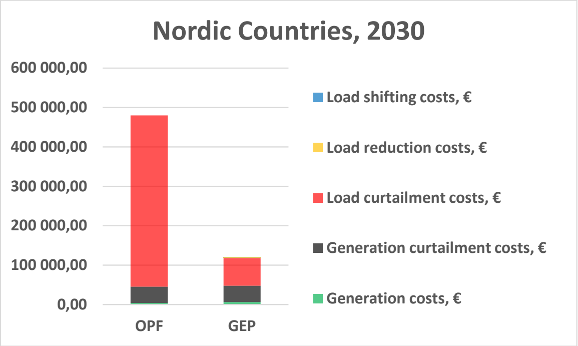
Curtailed generators (circles) and loads (squares)



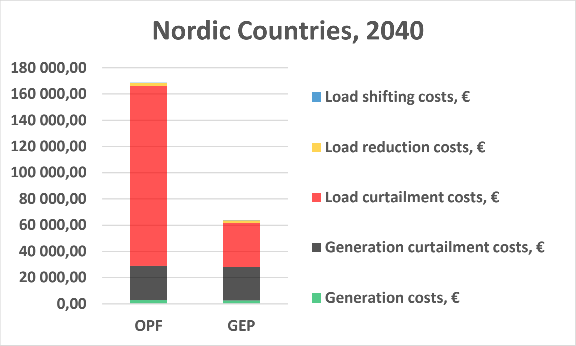
Results of the planning process

Northern Countries

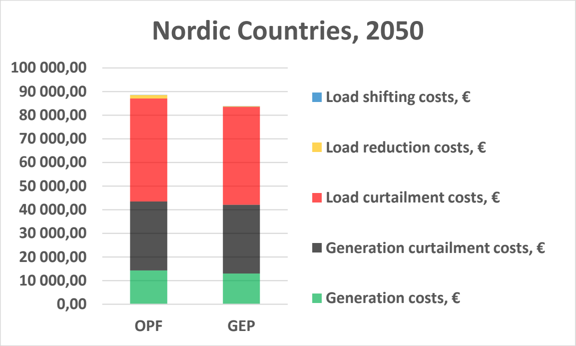
Type	AC Branch	Transformer	Storage	Flexibility load	Total
Number of candidates	108	0	3	3	114
Investment decisions	7 (T)	0 (T)	0	3 (T)	73
	63 (D)	0 (D)		0 (D)	
Investment rejected	6 (T)	0 (T)	3	0 (T)	41
	32 (D)	0 (D)		0 (D)	

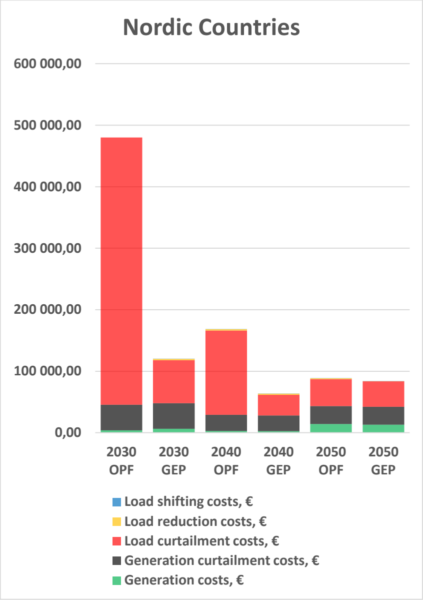


Type	AC Branch	Transformer	Storage	Flexibility load	Total
Number of candidates	89	3	8	0	100
Investment decisions	23 (T)	2 (T)	8	0 (T)	53
	20 (D)	0 (D)		0 (D)	
Investment rejected	3 (T)	1 (T)	0	0 (T)	47
	43 (D)	0 (D)		0 (D)	



Type	AC Branch	Transformer	Storage	Flexibility load	Total
Number of candidates	79	0	2	19	100
Investment decisions	5 (T)	0 (T)	2	0 (T)	32
	12 (D)	0 (D)		13 (D)	
Investment rejected	2 (T)	0 (T)	0	0 (T)	68
	60 (D)	0 (D)		6 (D)	





Results of the planning process

Summary and comparison

- Number of **congestions**:
  - Increased with each time horizon
    - Increasing load and/or generation profiles throughout the years
    - Limiting the number of candidates

- Number and type of **investment decisions**:
  - Conventional grid reinforcement (lines and transformers)
    - Percentage in transmission does not exceed 37.1%
    - Approval rate for transmission candidates does not go below 42.9% (exception – French network with 0% approved)
    - Approval rate decrease or stagnate with each time horizon with the following exceptions:
      - ✓ Italy RC: limiting the number of candidates and increase of load and RES generation
      - ✓ Northern Countries RC: difference in location of congestions
  - Flexibility resources (storages and flexibility loads)
    - Tendency to increase the approval rate with each time horizon for storages
    - Average approval rate of flexibility loads is 64%, the values vary from 6% (BeNeLux 2030) to 100% (in many cases)

- Variations of the **costs** before and after GEP:
  - 4 RC out of 6 – increase of the total costs throughout the years
  - 2 RC out of 6 – total costs of 2030 higher than 2040
    - BeNeLux due to increase in RES generation in 2040, whereas the load profile does not increase so drastically in 2040
    - Nordic RC due to approving candidates in the focus area with high density of congestions and area partially relieved from overloads in 2040

- **Environmental impact** assessment:
  - Carbon footprint plays more significant role
  - Maximum value of carbon footprint is 69.8% (Balkan RC in 2040)

Thank you…

Nicolò Italiano

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Email: nicolo.italiano@rdnester.com

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research and innovation programme under grant agreement N° 863819

FlexPlan

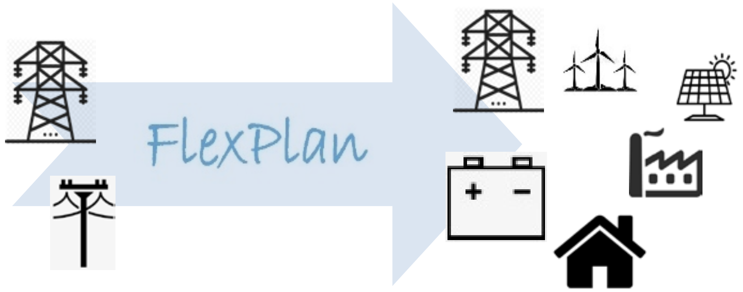
FlexPlan| 07thv March 2023

Regulatory Guidelines

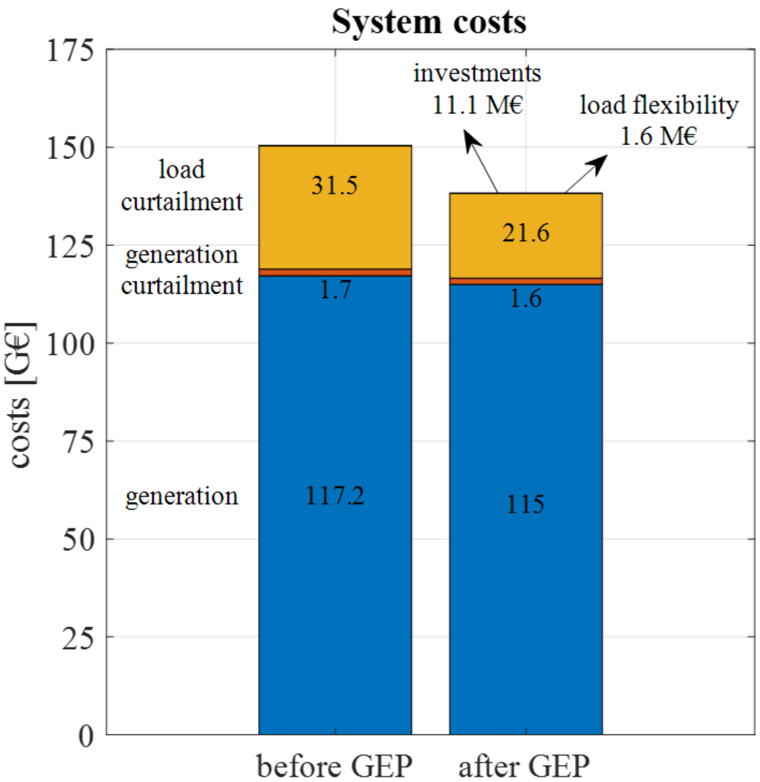
Dario Siface, Giorgia Lattanzio
RSE S.p.A.

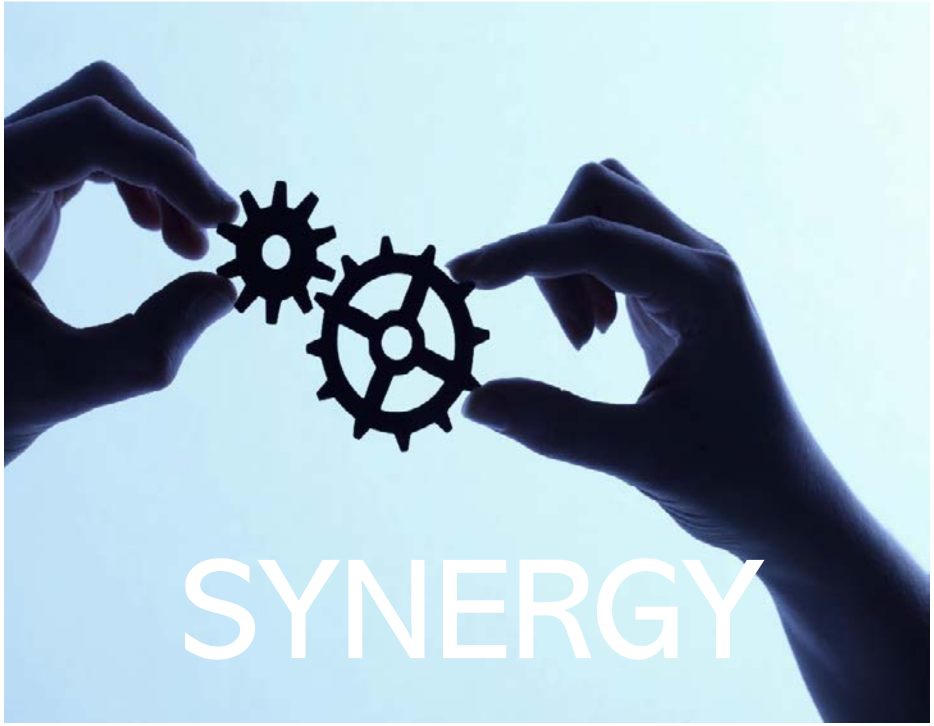
A New Perspective

FlexPlan



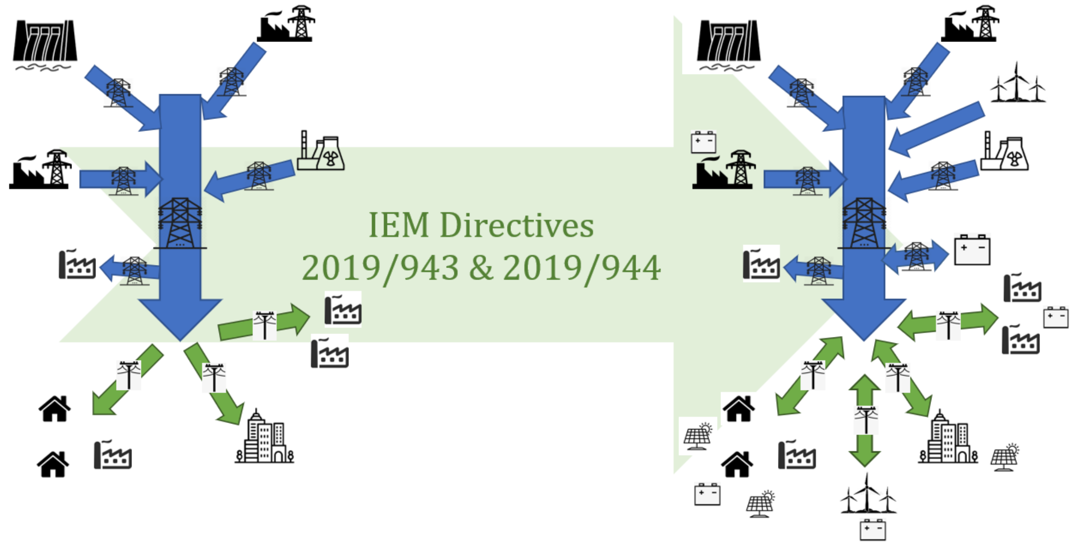
FlexPlan is a research project part of the assessment of the evolution of Power Systems towards a larger involvement of distributed resources.
It asses the possibility to include investments on flexibility resources in **SYNERGY** with investments on networks for long term planning.



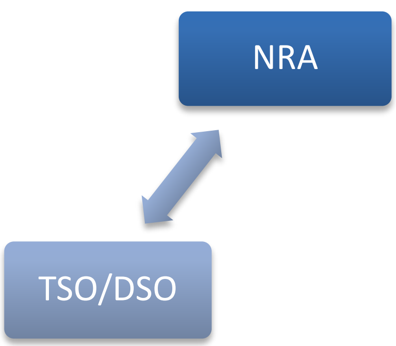


The Present European Regulatory Framework

EU Regulation 943 and EU Directive 944 valorise the role of flexibility as a support to grid planning in synergy with network investments.



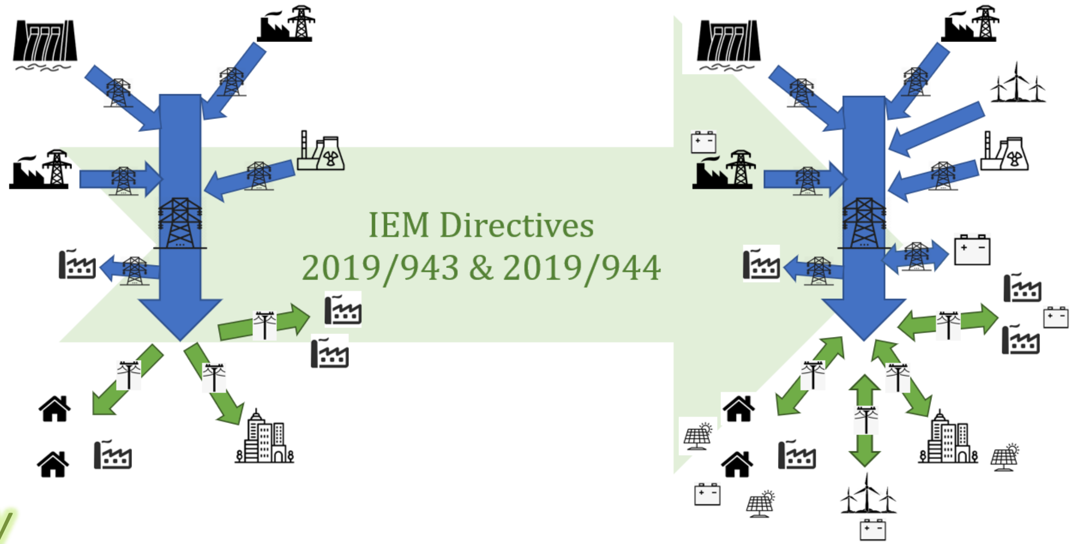
TRADITIONAL SCHEME

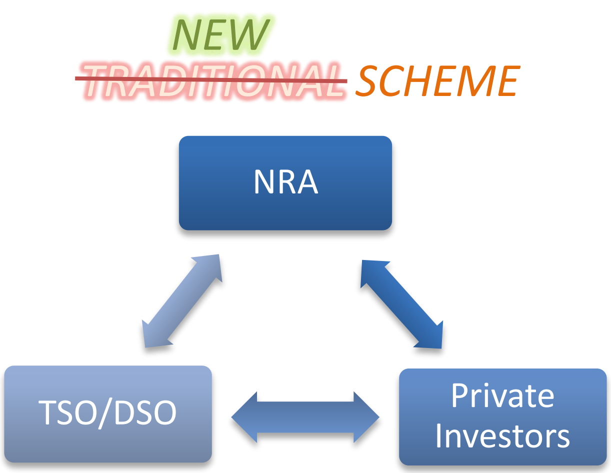


In the traditional schemes, grid investments – under the control of NRAs – were only in charge to SOs.

The Present European Regulatory Framework

EU Regulation 943 and EU Directive 944 valorise the role of flexibility as a support to grid planning in synergy with network investments.





In the traditional schemes, grid investments – under the control of NRAs – were only in charge to SOs.

The desired future configurations will, instead, include also private investors – which will become flexibility owners.

Therefore, a new player is introduced which will interact with SOs – to meet the real needs of the Power System – and with NRAs – to assess the goodness of the investments.

Preliminary thoughts for regulatory guidelines

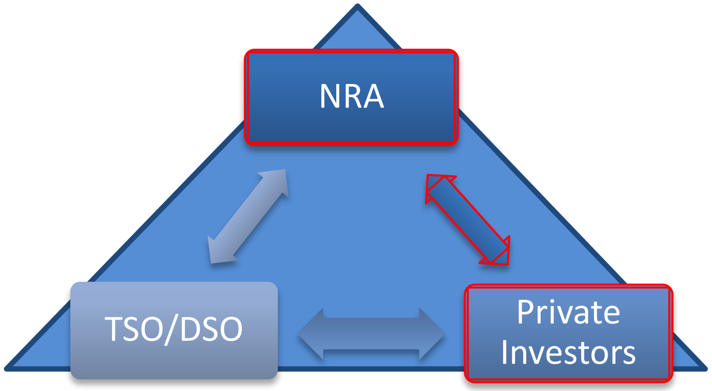
FlexPlan

FlexPlan proposes to analyse the regulatory guidelines considering 10 main topics:

- Incentives for settling new flexibility resources
- Storage Ownership
- Responsibilities and data exchange between TSO and DSO in planning
- Regulation on aggregators and possibility to include flexibility in their basket
- Services that can be provided by flexibility resources
- Markets flexibility resources can participate in
- Products tailored for flexibility resources in RT-markets
- How proposed market reforms could affect flexibility remuneration
- Interactions with capacity markets
- CBA update and internalization of environmental costs

Preliminary thoughts for regulatory guidelines

FlexPlan



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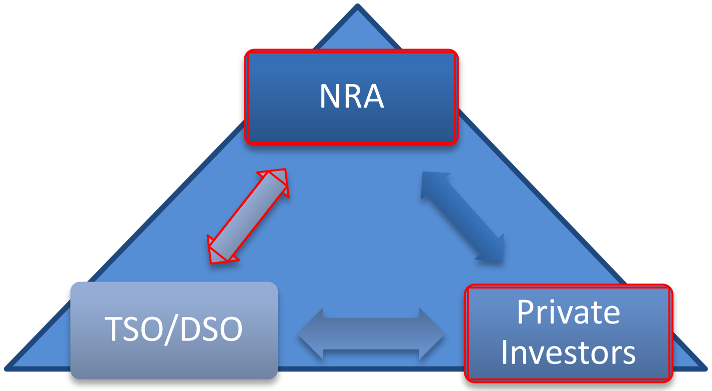
Preliminary thoughts for regulatory guidelines

FlexPlan



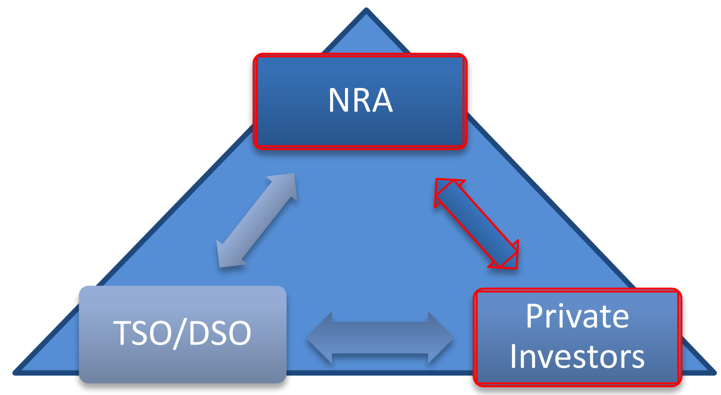
Storage Ownership

SOs are not allowed to own storage facilities according to IEM Directives.

To avoid conflict of interests and market distortion, private investors should be found.
Also “must-run” operation could be considered.
SOs ownership should be allowed only if strictly necessary (e.g. to prevent exercise of market power).

Preliminary thoughts for regulatory guidelines

FlexPlan



Incentives for settling new flexibility resources

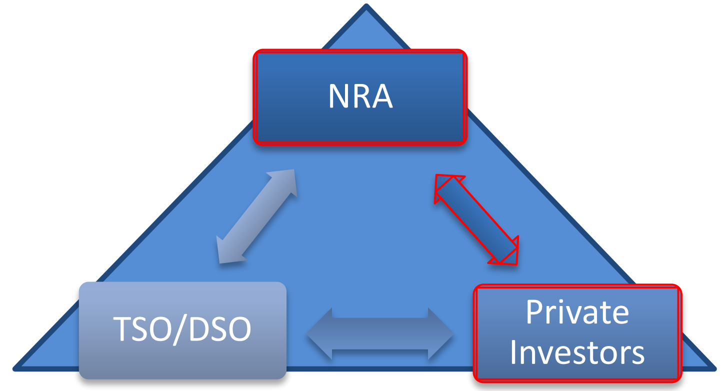
Storage Ownership

According to IEM Directives, flexibility should be valorised as a support to T&D grid planning.

Local economic signals would foster an optimal deployment of the new resources, while ensuring a proper remuneration of the new flexibility assets.

Preliminary thoughts for regulatory guidelines

FlexPlan



Incentives for settling new flexibility resources

Storage Ownership

Services that can be provided by flexibility resources

Markets flexibility resources can participate in

Products tailored for flexibility resources in RT-markets

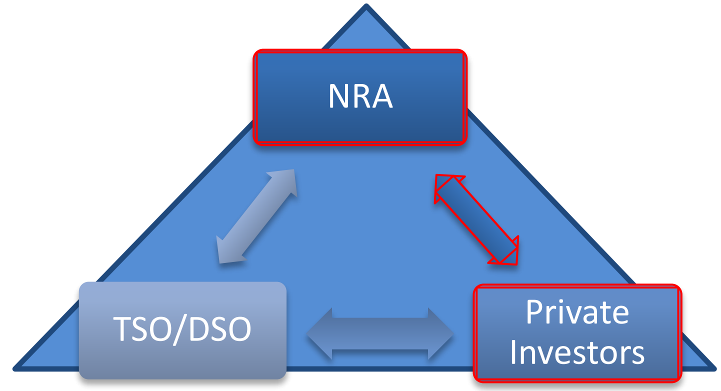
A good exploitation of flexibility resources requires to establish how flexibility should participate to grid management. Market-based mechanisms are suggested by IEM Directives.

The market chain architecture should be reviewed to promote participation of DER. New guidelines are needed to promote deployment of all kind of flexibility (e.g. demand response).

A set of specific products should be created in order to allow and enhance the use of flexibility resources in real time markets.

Preliminary thoughts for regulatory guidelines

Aggregators represent a great potential for flexibility deployment.
New rules must be defined to increase the attractiveness of flexibility service provision by these participants.



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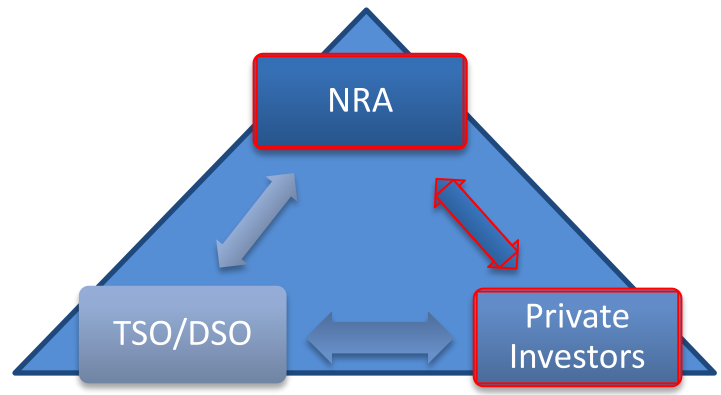
Preliminary thoughts for regulatory guidelines

FlexPlan



Incentives for settling new flexibility resources

Storage Ownership

Regulation on aggregators and possibility to include flexibility in their basket

Services that can be provided by flexibility resources

Markets flexibility resources can participate in

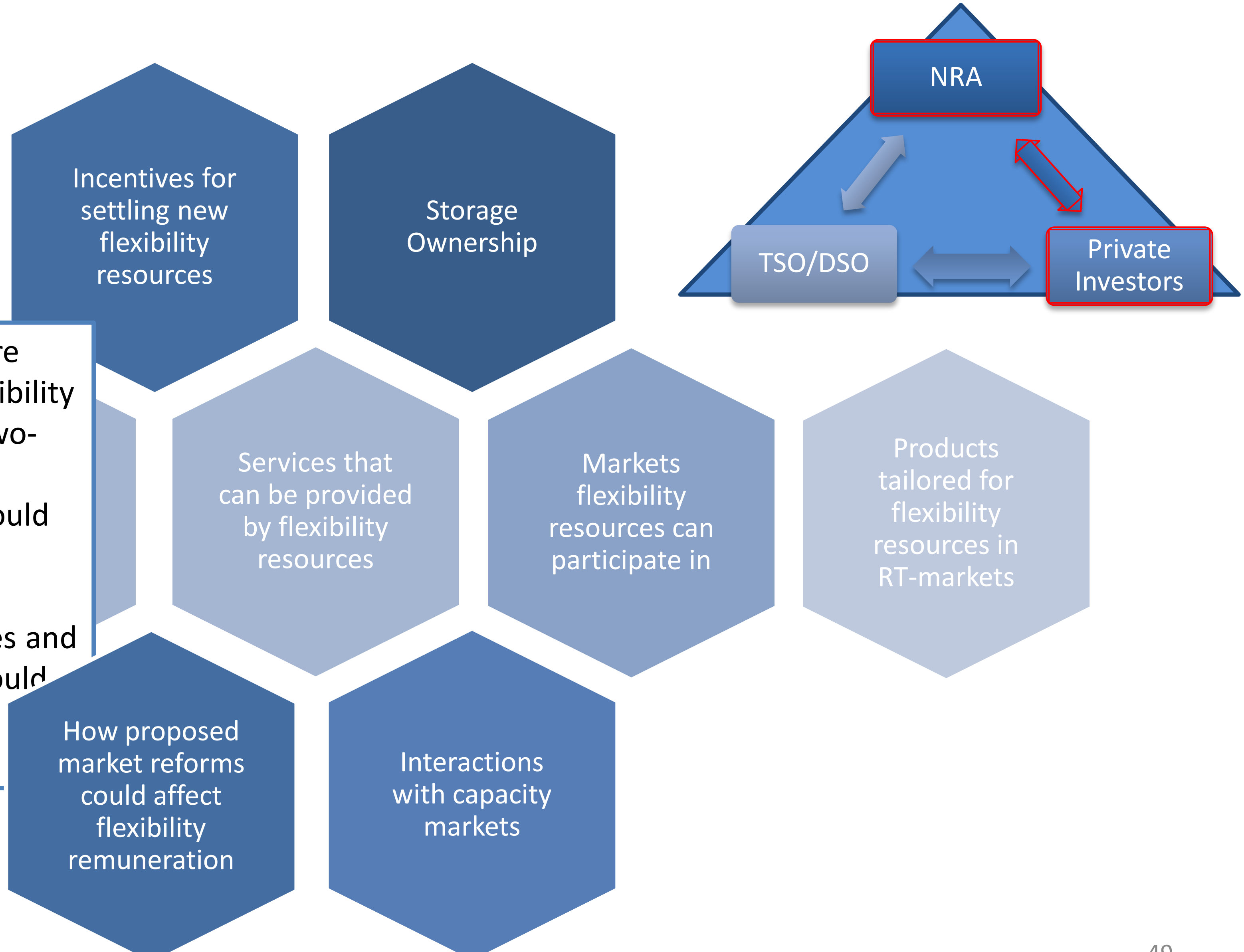
Products tailored for flexibility resources in RT-markets

Interactions with capacity markets

Capacity markets (or, more broadly speaking, local economic signals) should be provided to optimize flexibility investments.

Preliminary thoughts for regulatory guidelines

FlexPlan



Market reforms are investigated (possibility of price-caps or two-stage markets). These reforms should consider the deployment of flexibility resources and how their role should be remunerated.

Preliminary thoughts for regulatory guidelines

FlexPlan

NRA

⇒ National Regulatory Authorities should translate the suitability of **deploying new storage or flexibility in strategic network locations** into **opportune incentivization tools** for potential investors.

locational element (e.g. by setting up locational capacity markets) able to drive potential investors to **foster investments in critical nodes** (identified by SOs).

Preliminary thoughts for regulatory guidelines

FlexPlan

⇒ National Regulatory Authorities should translate the suitability of **deploying new storage or flexibility in strategic network locations** into **opportune incentivization tools** for potential investors.

locational element (e.g. by setting up locational capacity markets) able to drive potential investors to **foster investments in critical nodes** (identified by SOs).

Possible drawback: regions with high potential for the exercise of market power.

Possible solutions

→ combine market-based mechanisms for the procurement of flexibility with long-term contracts with a pre-established strike price, to disincentivize aggressive strategies

→ establish a cap on bid prices

→ SO bids the asset on behalf of the owner – "must-run" configuration (only extreme situations)

Preliminary thoughts for regulatory guidelines

FlexPlan

NRA

⇒ National Regulatory Authorities should translate the suitability of **deploying new storage or flexibility in** strategic network locations into **opportune incentivization tools** for potential investors.

⇒ Real time market should be reformed by **defining products that allow "flexibility" providers to compete with traditional resources on a "level playing field" basis**. Operative constrains of storage and demand side management should be fully considered.

⇒ A clarification on the nature of the services provided by these subjects could also **help the process of market reform** that is going on now, since it cannot be neglected that storage and DSM will be major players in the future provision of ancillary services to the System

Preliminary thoughts for regulatory guidelines

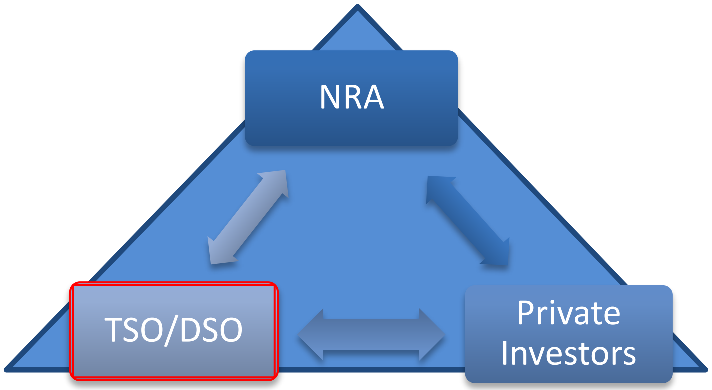
FlexPlan

⇒ **Active use of Demand Response** – indicated by 2019/944 Directive – still shows a **lack of a comprehensive regulatory framework**. There are significative expectations from the forthcoming Network Code for Demand Response, since the ACER’s Framework Guideline for the Code creates, among the other things, a logical connection between network development planning as described in Art.32 and demand response, as an alternative to system expansion.

⇒ The role and responsibilities of **aggregators** should be accurately designed within the redefinition of real-time market architectures. By the FlexPlan “vision”, they **should act by compensating positions with opposite risk exposures among the aggregated resources**, thus favouring real-time markets operation. However, there should be **solid business opportunities** for this figure, without which no real subject, even in presence of a specific regulation, will ever volunteer to take such responsibility.

Preliminary thoughts for regulatory guidelines

FlexPlan



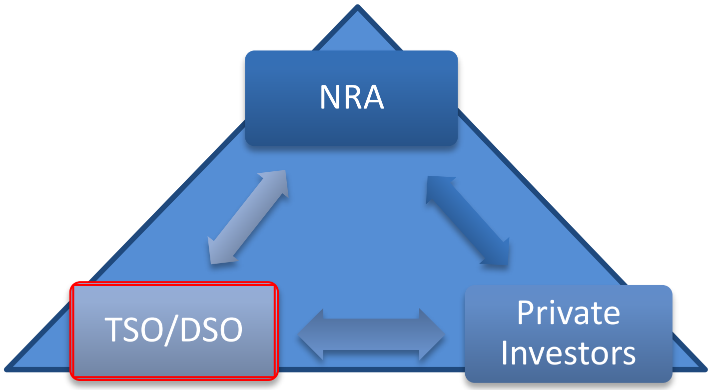
Responsibilities and data exchange between TSO and DSO in planning

Cooperation between TSO and DSO must be strengthened.

Planning procedures should be modified to favor the deployment of flexibility resources, also keeping in mind TSO-DSO cooperation for acquiring resources from distribution.

Preliminary thoughts for regulatory guidelines

FlexPlan



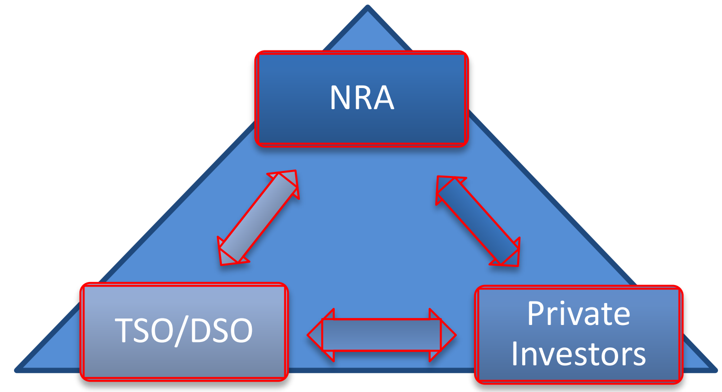
Responsibilities and data exchange between TSO and DSO in planning

⇒ **A fully integrated T&D planning, it is not reasonable** due to the numerical complexity of the optimization problem and the legal implications of a complete data sharing, even between SOs

⇒ **Coordinated approach** by means of an **exchange of data at the border** between different systems, **allowing DSOs**, in case advantageous for the system, **to oversize their network to get fit to provide services to transmission**.

T&D decomposition approach proposed by FlexPlan can be a good starting

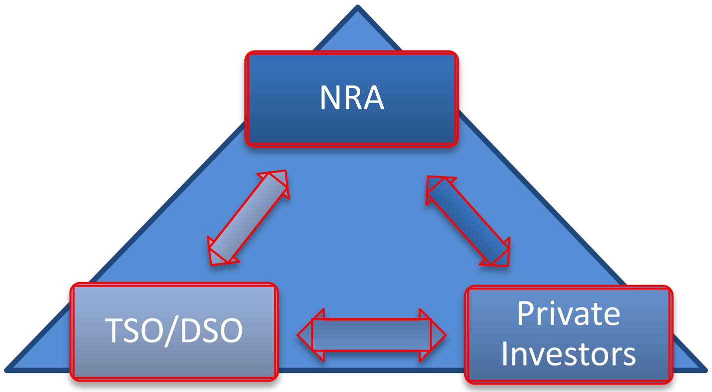
Preliminary thoughts for regulatory guidelines



Cost-benefit analysis must take into account positive effects of flexibility resources (monetized and not-monetized effects). Importance must be given to GHG and other pollutant reduction.

CBA update and internalization of environmental costs

Preliminary thoughts for regulatory guidelines



⇒ Cost-benefit analysis must take into account positive effects of flexibility resources. Key importance must be attributed to GHG and other pollutant reduction. **Environmental aspects should be put in monetary terms so that they can be co-evaluated with more traditional ones (social welfare, etc).**

CBA update and internalization of environmental costs

Thank you…

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FlexPlan

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