Long-term transmission capacity planning in a scenario with high share variable renewable energies

Presenter: Stéphane Allard, G2Elab, Univ. Grenoble Alpes, France

Authors: Stéphane Allard, Silvana Mima, Vincent Debusschere,
Tuan Quoc Tran, Patrick Criqui and Nouredine Hadj-Saïd

Plan

I. Context
II. State of the art modeling
III. EUTGRID, a new transmission capacity planning module
IV. Conclusions & perspectives

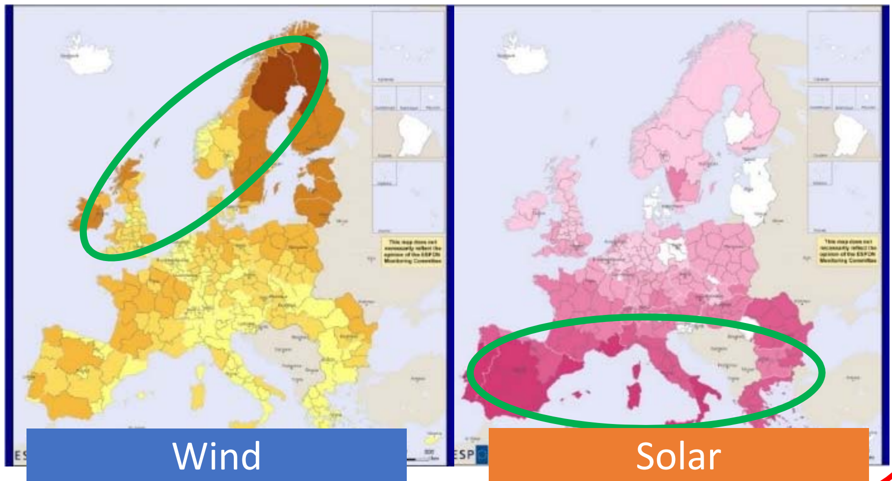
I. Context– Problematics (1/2)

Fight against global warming → Climate-energy policies (CO_2 reduction)

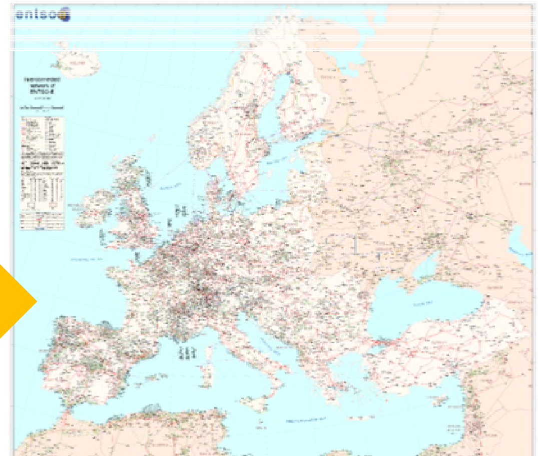
Need prospective studies : long-term energy models

PARIS2015
UN CLIMATE CHANGE CONFERENCE
COP21·CMP11

- Large scale integration of renewable energy production (solar/wind)
- Energy potential is **unevenly** located



Climate-energy policies
VREs integration



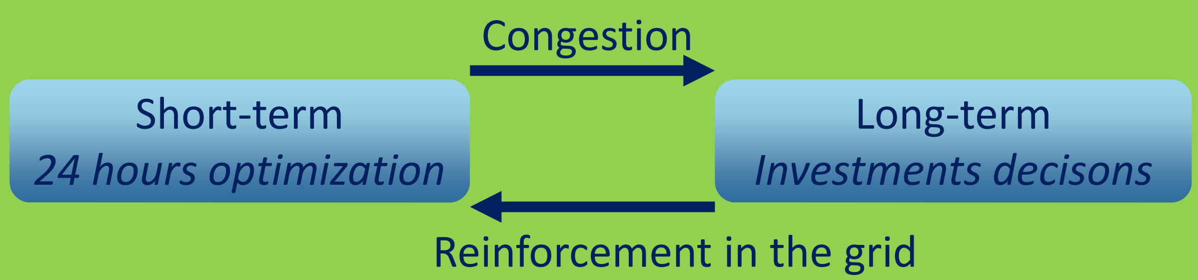
Potential effect : congestion
- ➢ Investments needed (reinforcements)

I. Context – Problematics (2/2)

- **Electrical grid must obey one fundamental law:**
  - **Production = Consumption** *all the time*
- **Short-term management** (an hour):
  - Equalizes demand and supply facing accidents and local infrastructure
- **Long-term planning** (4 to 10 years):
  - Locates future bottlenecks at European level

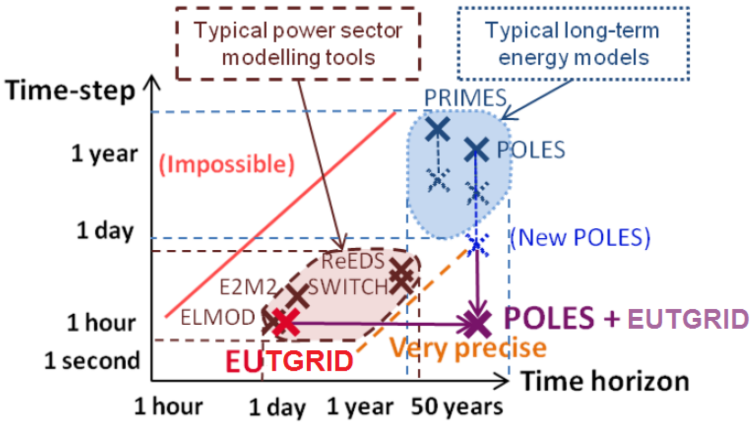
Objective : Optimal interactions between different time-steps :

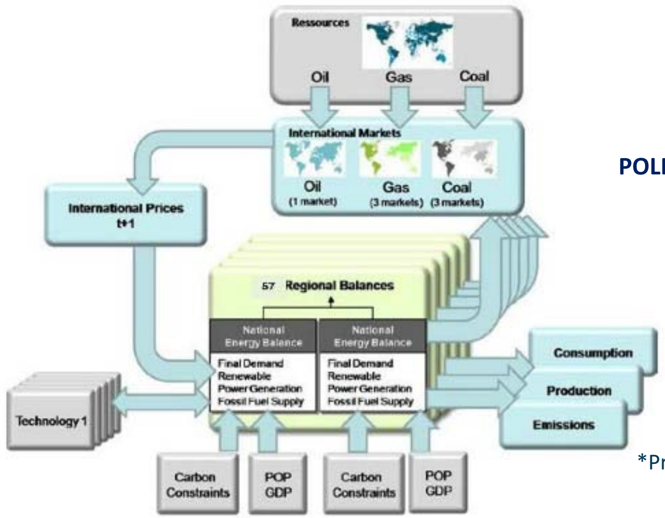
- Our focus



➢ **Insure investments in long-term will help short-term management**

II. State of the art modeling





POLES* (developped since 1990)

- Used by European Union, Enerdata
- Global (57 countries/regions)
- Up to 2100
- Many different energies (electricity, gas, oil, etc)
- Bottom-up (45 explicit technologies)

*Prospective Outlook Long-term Energy Systems

- **Engineering models:**
  - Short-term management (ex: DIgSILENT)
  - Long-term planning: (ex: ANTARES (RTE) - Monte-Carlo or ELMOD - social welfare)
- **Long-term energy models:**
  - Few implement a power sector module
  - Ex: PRIMES (34 nodes, DC load flow, grid investments with NTC)
    TIMES (35 nodes, DC load flow, grid investments with NTC)
  - POLES has been improved with EUCAD (24 nodes, transport model)

III. EUTGRID, a new transmission capacity planning module

Grenoble Applied Economics Lab

- **EUTGRID : EUropean Transmission GRid Investment and Dispatch**

  → optimizes total operating costs of the system taking into account constraints

  1. Increases spatial division (more nodes per country [86 nodes – 24 countries])
  2. Implementing loadflow (Grid characteristics)
  3. Grid investment mechanism based on nodal prices

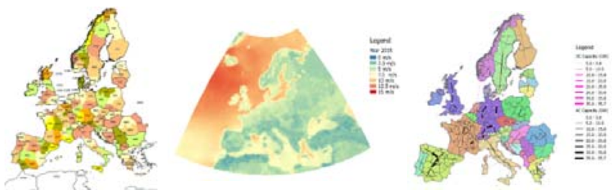
POLES YEAR N-1 → **POLES YEAR N** → POLES YEAR N+1

POLES YEAR N
- State of the power system
- EUTGRID inputs
- Demand evolution
- Costs evolution
- Technical evolution
- EUTGRID outputs

(Demand evolution, Costs evolution, Technical evolution, EUTGRID outputs) → Investments decisions

EUTGRID inputs:
Demand
Operation Costs
Installed Capacities
Interconnections capacities
Dispatchable consumptions

EUTGRID

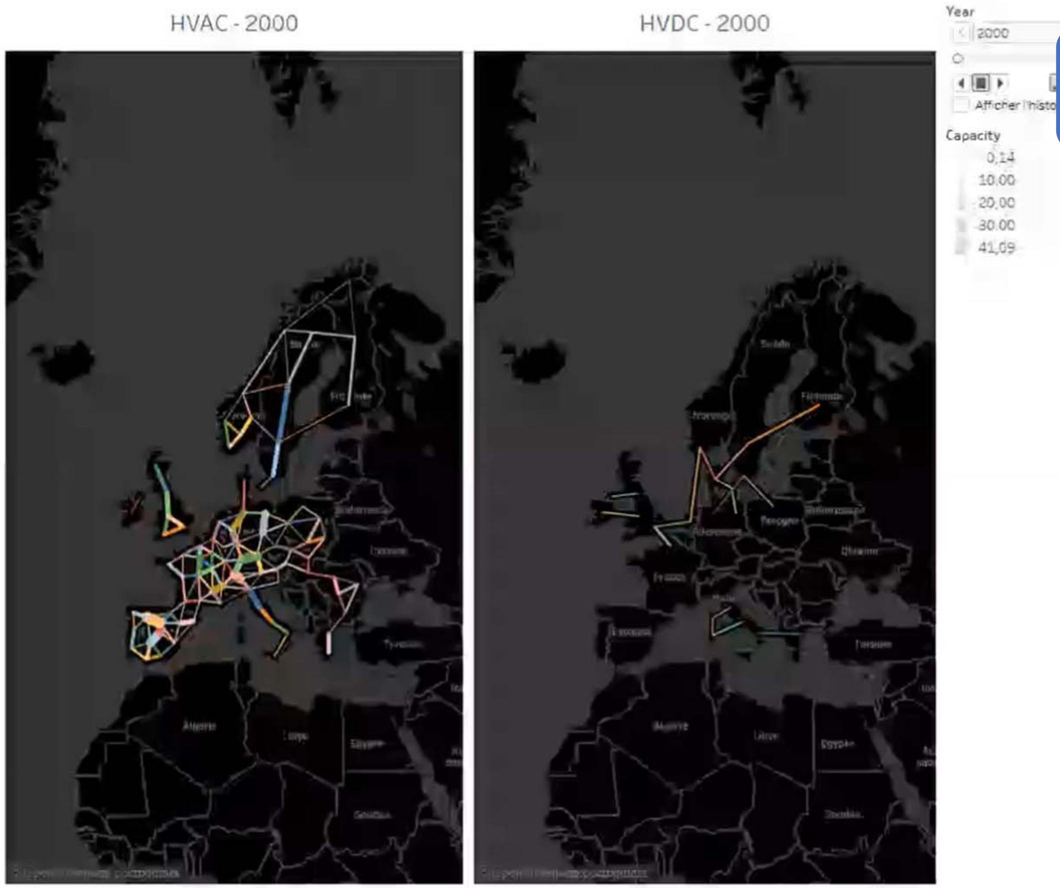


Congestion : Decisons taken every 5 years
(Grid investment mechanism)

EUTGRID outputs:
Hourly production
Hourly storage
Hourly imports/exports
Production curtailment
Unserved load
Interconnections (reinforcement / new)

III. EUTGRID - Results

- « 2°C scenario » was performed: Dynamic investment in HVAC and HVDC (Europe)



Initial grid - 2010

		2010
Transmission grid	Total budget [b€]	0
	Grid [TWkm]	382.2
	HVAC [GW]	1071.8
	HVDC [GW]	12.2
	Line length [000km]	73.1

Additionnal grid investments – 2010 up to 2080

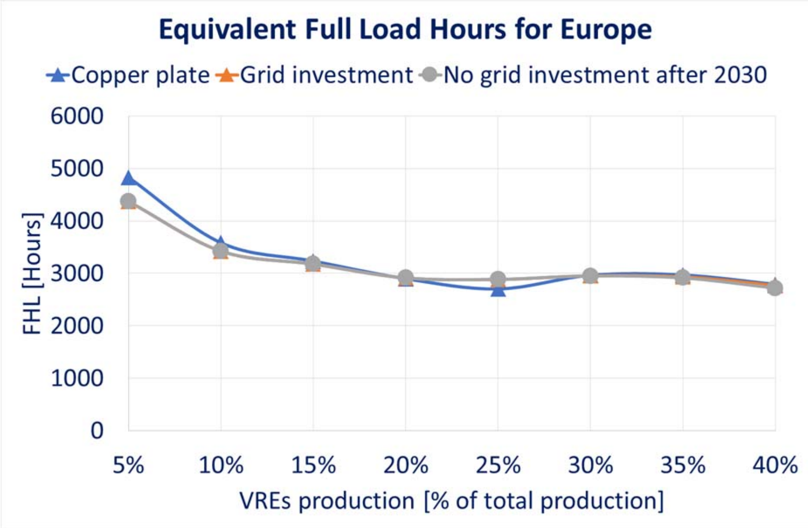
		2010 - 2030	2030 - 2050	2050 - 2080
Transmission grid	Total budget [b$]	179.6	136.1	138.9
	Grid added [TWkm]	96.7	72.1	77
	HVAC added [GW]	201.9	68	91.8
	HVDC added [GW]	41.8	69.7	52.7
	Line length added [000km]	60.5	36.7	40.6

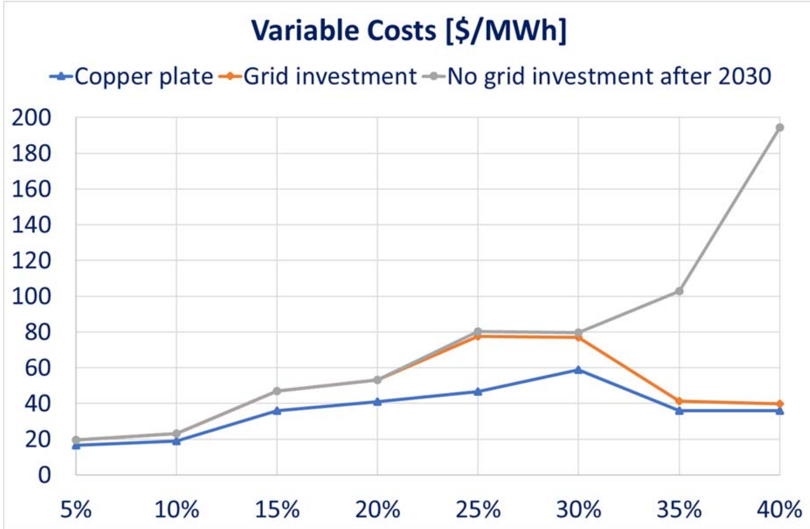
III. EUTGRID - Results

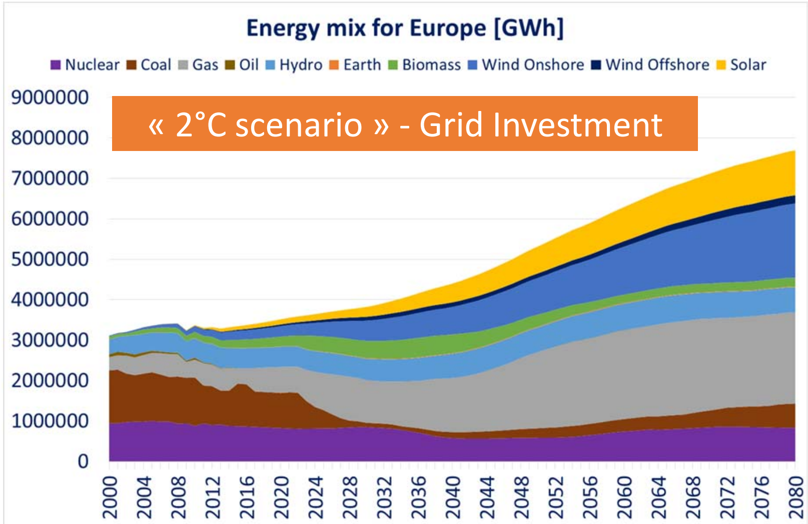
- « 2°C scenario » : 3 different sub-cases
  1. Copper plate
  2. Grid investment mechanism implemented
  3. No grid investment after 2030
     - transmission grid investments from TYNDP 2014 (ENTSO-E) are assumed to be done

- Analysis of different indicators

III. EUTGRID - Results

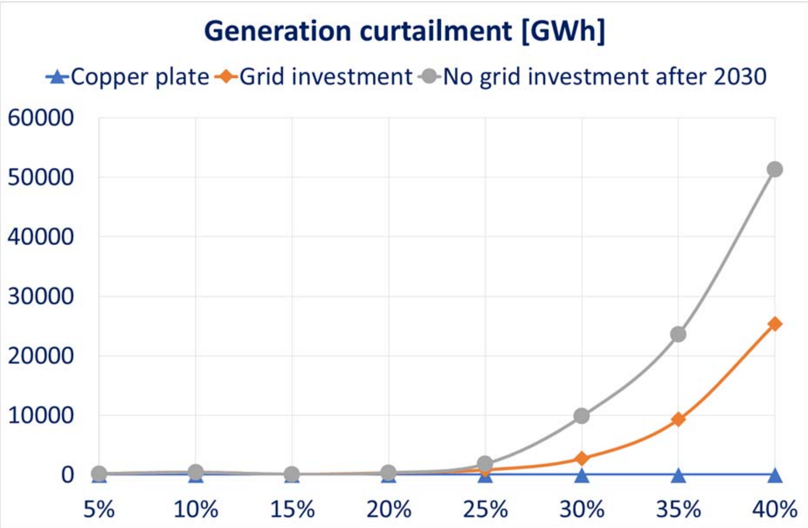


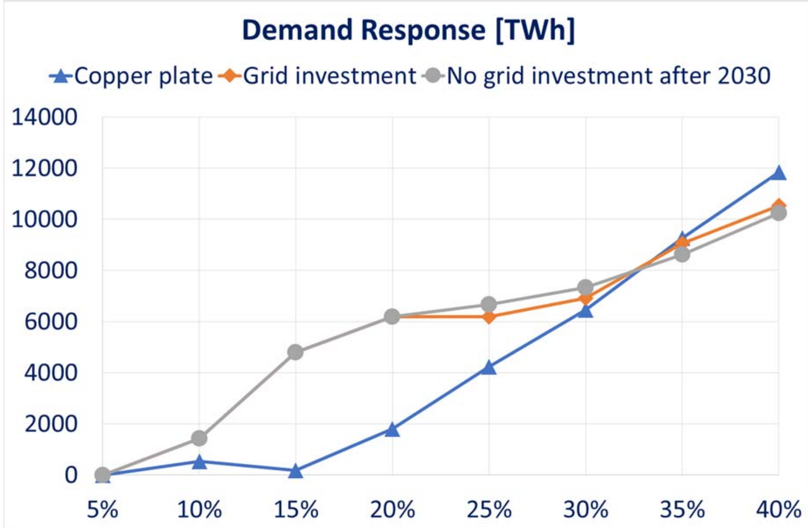


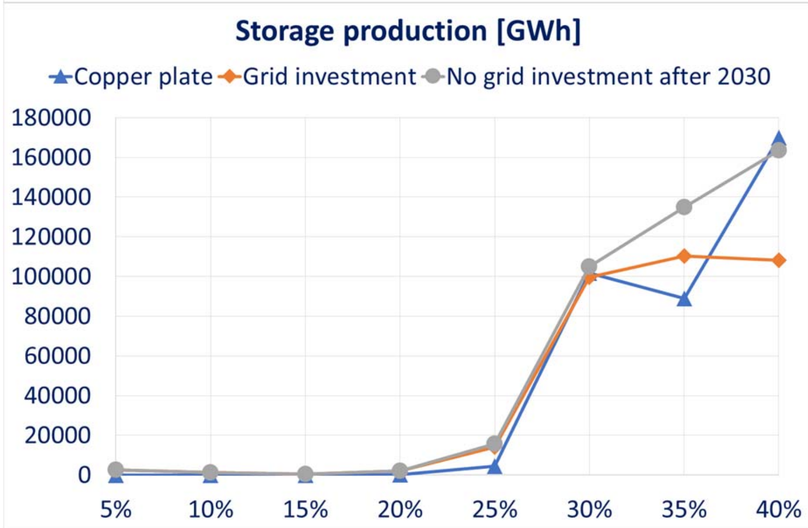


- VREs integration reduces FLH of the system
  - Share from from gas increases in the energy mix
- Transmission grid helps to reduce total variable costs
  - *Energy Not Distributed* appears with no investment after 2030

III. EUTGRID - Results







- With VREs integration, Curtailment, Storage and Demand Response increase
- Transmission Grid helps to reduce their use

IV. Conclusions & Perspectives

- **Realisations**: EUTGRID coupled with POLES
  - Increases spatial division (VREs unevenly located)
  - Implementing loadflow (realistic power flows)
  - Grid investment mechanism (realistic decisions to reinforce the grid HVAC/HVDC)

- **Results:** “2°C scenario” was performed
  - VREs integration reduces equivalent FLH for the system
  - Transmission grid helps to reduce operating costs
  - Transmission grid investment helps to reduce VREs curtailment
  - Storage & DR are needed in all sub-scenarios

- **Perspectives**:
  - A sensitivity analysis should be performed on different parameters (such as costs HVAC/HVDC, costs of batteries, ROI)
  - Analysis of movements of VREs decentralization in the sub-transmission and distribution grids

Thank you for your attention!

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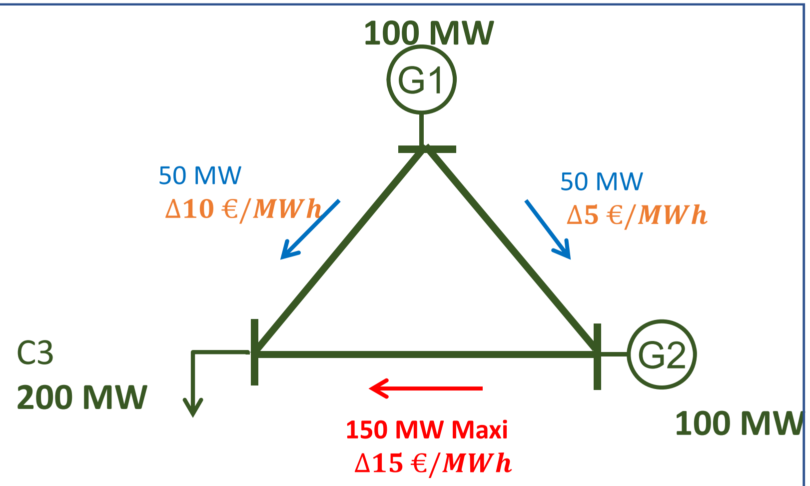
Annex 1

Grid Investment mechanism

Initialization:
- Run a loadflow
- Save total costs

List for all lines:
- Transmission costs between nodes
- Costs of investments for HVAC/HVDC

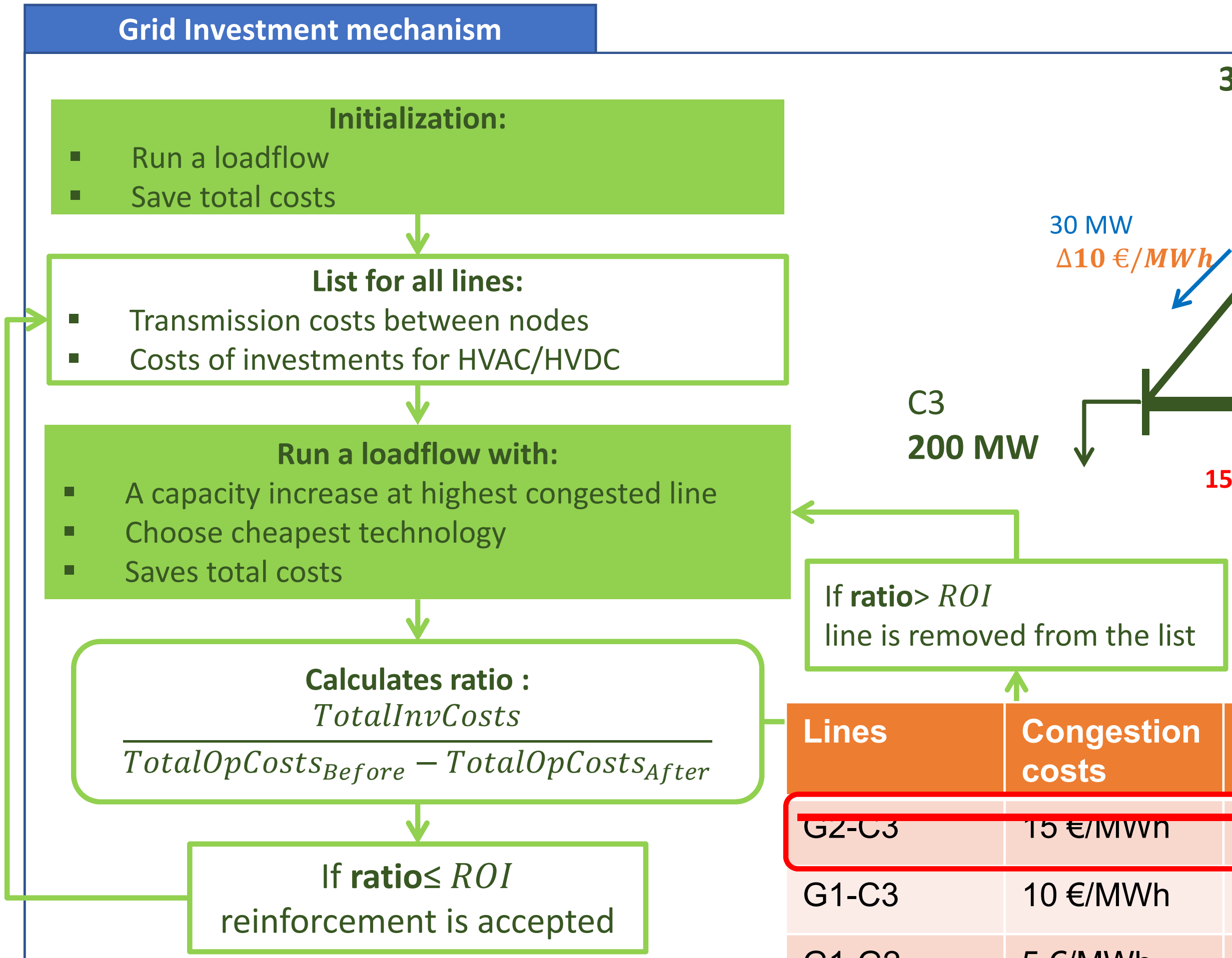
Run a loadflow with:
- A capacity increase at highest congested line
- Choose cheapest technology
- Saves total costs

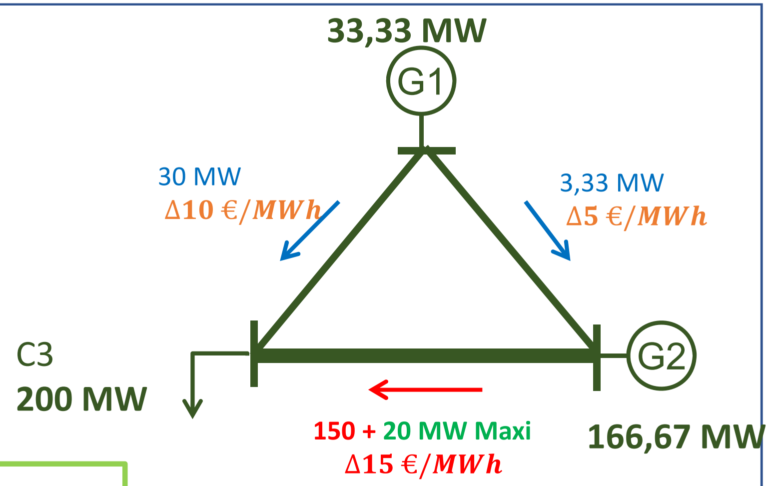


$$TotalCosts_{Before} = 45000€$$

Lines	Congestion costs	HVAC investment	HVDC investment
G2-C3	15 €/MWh	€€	€€€
G1-C3	10 €/MWh	€€	€€€
G1-G2	5 €/MWh	€€	€€€

Annex 1





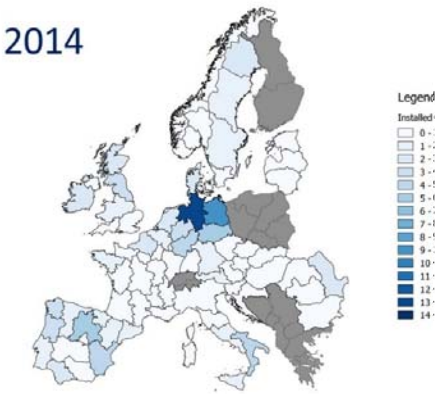
$TotalCosts_{Before} = 45000$€

$TotalCosts_{After} = 4166,67$€

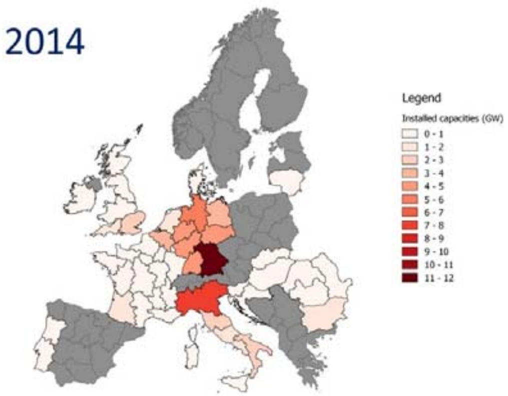
Lines	Congestion costs	HVAC investment	HVDC investment
~~G2-C3~~	~~15 €/MWh~~	~~€€~~	~~€€€~~
G1-C3	10 €/MWh	€€	€€€
G1-G2	5 €/MWh	€€	€€€

Drivers for VREs installation

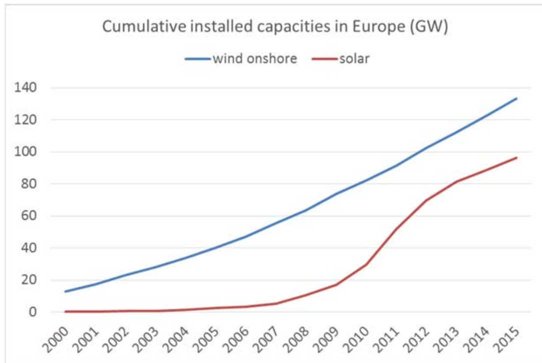
Historic installed capacities (2000 – 2015)



Wind on-shore



Solar

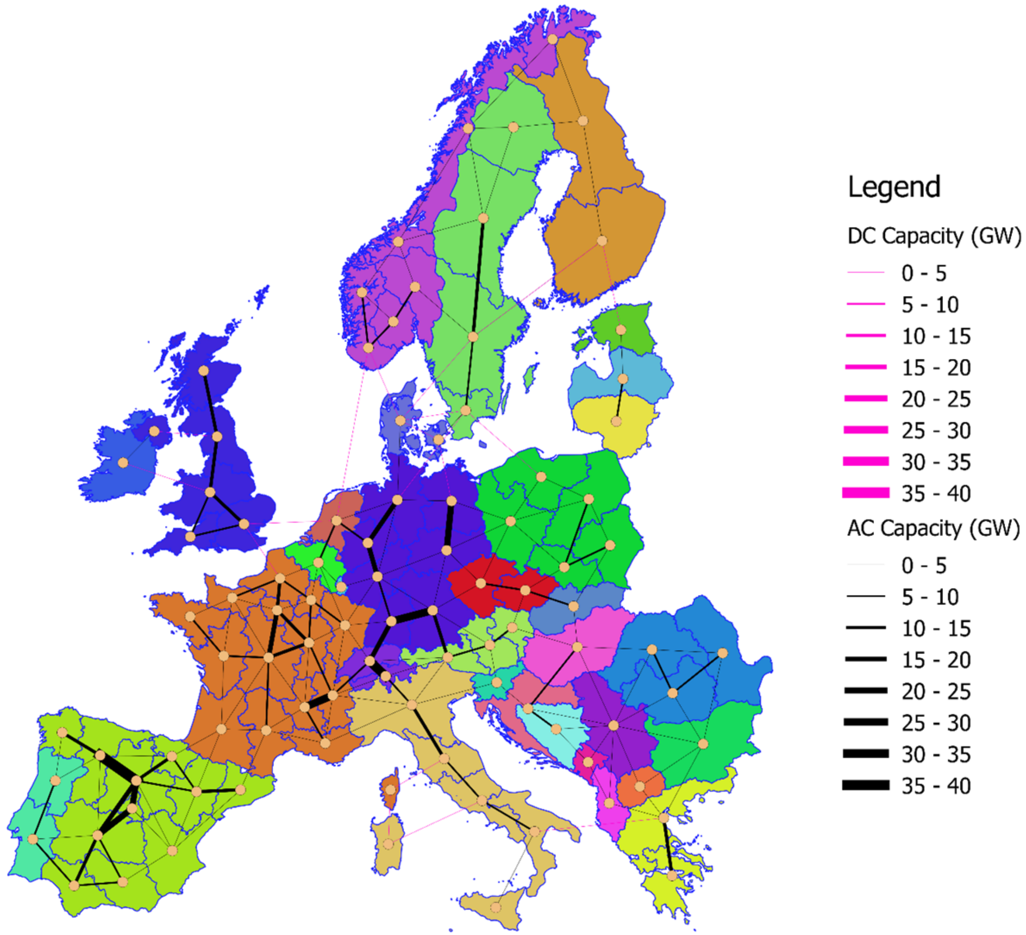


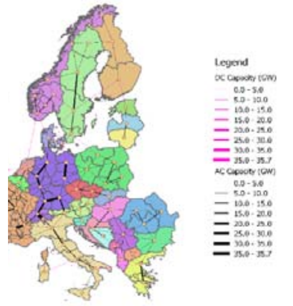
- Precise spatial location and historical data are missing
- Potential does not seem to be the 1st driver for installation :
  - ➢ Potential (Available Surface, Energetic)
  - ➢ Population density
  - ➢ Exclusion zones (ie protected areas)

EUTGRID model description

Increases spatial divisi

- POLES data are
  - Distributio to distribut
    - Linea
  - Grid conne
  - New VREs t





ssion grid (HVAC & HVDC) in 2012

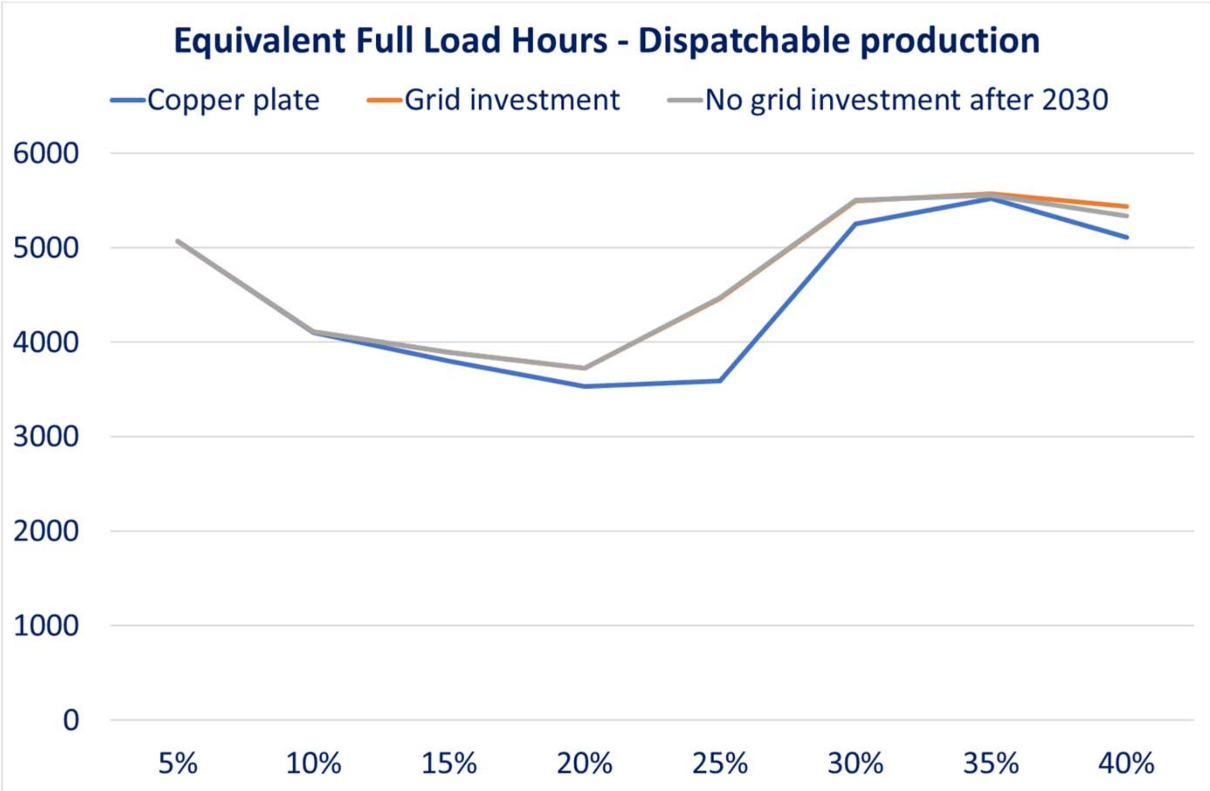
Mean wind speed (m/s) at 100m in 2015

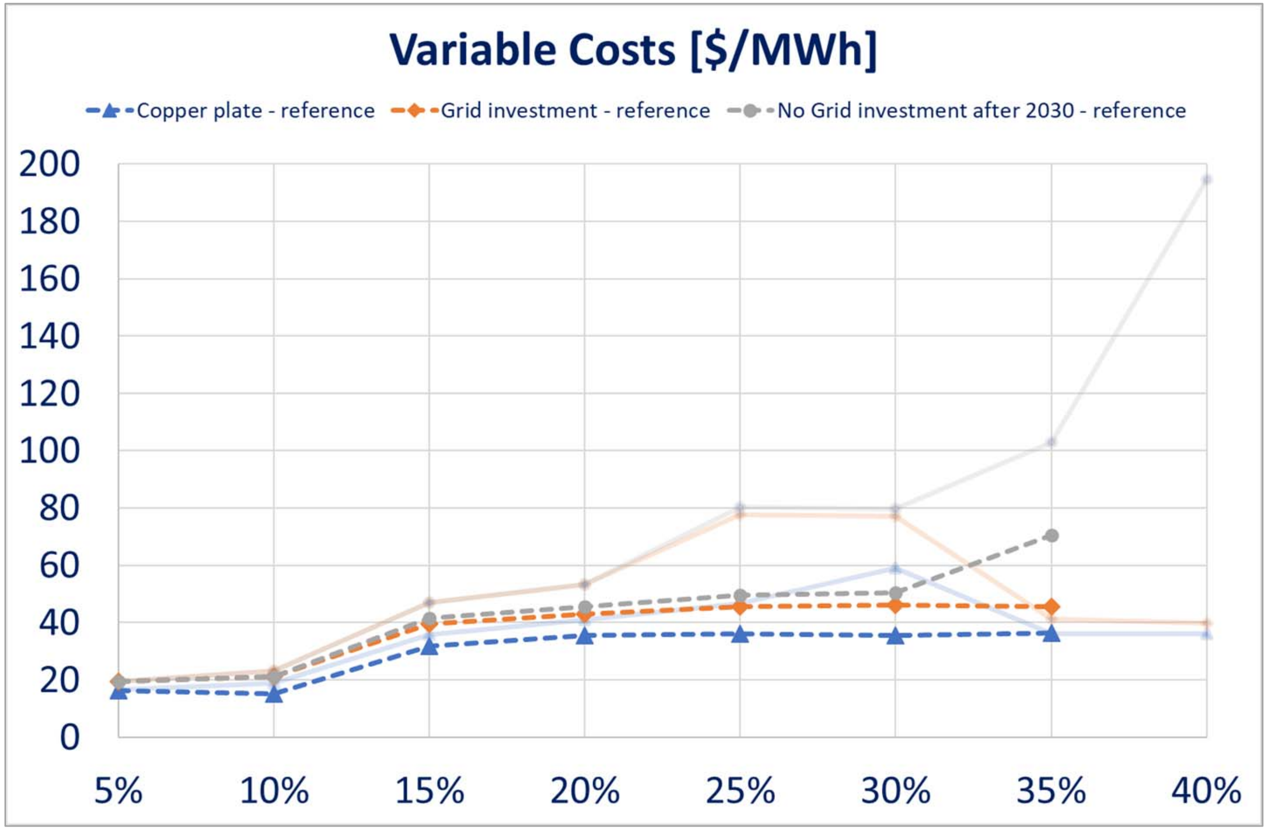
HVAC/HVDC costs

$$C_{line} = PowerUnit * Inv_{transf\ or\ Conv} + Coef_{typology} * (InvCosts * dist_{line} + CapCosts * PowerUnit * dist_{line})$$

	HVAC	HVDC
$PowerUnit$[MW]	1700	1700
Transformer/Converter [k€/MW] $Inv_{transf\ or\ Conv}$	15	110
Investments costs [k€/km] $InvCosts$	1300	1300
Capacity costs [k€/(km*MW)] $CapCosts$	0,5	0,75

	Rural	Urban	Mountain
$Coef_{typology}$	1	1,38	2,05


Equivalent Full Load Hours - Dispatchable production
Copper plate
Grid investment
No grid investment after 2030
6000
5000
4000
3000
2000
1000
0
5%
10%
15%
20%
25%
30%
35%
40%



Variable Costs [$/MWh]
Copper plate - reference
Grid investment - reference
No Grid investment after 2030 - reference
200
180
160
140
120
100
80
60
40
20
0
5%
10%
15%
20%
25%
30%
35%
40%