



# **INTEGRATING ELECTRICITY AND NATURAL GAS PLANNING: LINKING MODELS AND ASSESSMENT OF RECIPROCAL EFFECTS**

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# Outline

1. Background and motivation: gas-electricity links
2. Objectives and Research questions
3. Electricity and Natural Gas planning models
4. Models linkage, interaction and implementation
5. Results and insights
6. Conclusions and future work

# Link: Gas to electricity

- Amount of gas used to generate electricity
  - Demand for gas: long-term contracts and short-term nominal (daily) intakes
- Gas supply infrastructure based on geographical location
  - Infrastructure (production fields and pipeline network) to deliver gas at certain nodes
  - Gas power units dependency on gas transmission infrastructure
- Gas market prices influence the investments in the electricity generation mix
  - Gas price hikes could push-up the marginal cost of gas units

# Link: Electricity to Gas

- Compressors electricity consumption (power for compressors)
  - E.g. Compressors at Kollnes Gas processing plant consumed 1TWh/y
- Short term demand (wind/solar variable output) for gas may trigger gas network issues and limit gas flexible generation
  - Might constraint the gas transmission network ability to rout gas effectively
- Expansion of the power system & location of new gas power plants
- Electricity prices (gas revenue sales) and gas contracts (long-term)
  - Might influence investment decisions on the gas network design

# Literature on Electricity-Gas nexus

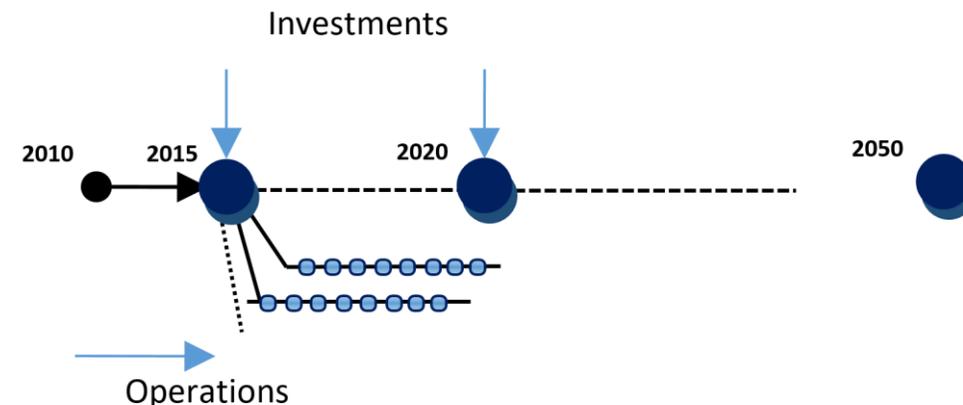
- Overall: various papers dealing with modeling the two systems together for short-term operations. Few consider a joint long term perspective
- Most papers focused on the security of electricity supply (gas-electricity dependency under a risk/reliability perspective)
- Integrated gas-electricity models showed reduced costs compared to individual models. But the difference is around 1% better, not much.
- Linkage: mainly on gas supply limits to gas-fired power plants and the location of the plants (effects on gas network design)

# Objectives and research questions

- How investments on the gas infrastructure affects the evolution of the electricity sector and vice-versa?
  - Study gas-electricity sector coupling
- Could gas power plants compensate RES fluctuations without creating instability in the gas transmission network?
  - Effects of short-term effects on long-term investment decisions
  - Coping with gas maximal demand vs. level of utilization

# Gas planning model: RAMONA

- Mixed integer Optimization – maximizing social surplus
- 2010-2050 time horizon, 5 year granularity
- 40 nodes "countries", 34 European and aggregated regions for the rest of the world (e.g. Russia, Asia, etc)



## Maximize social surplus

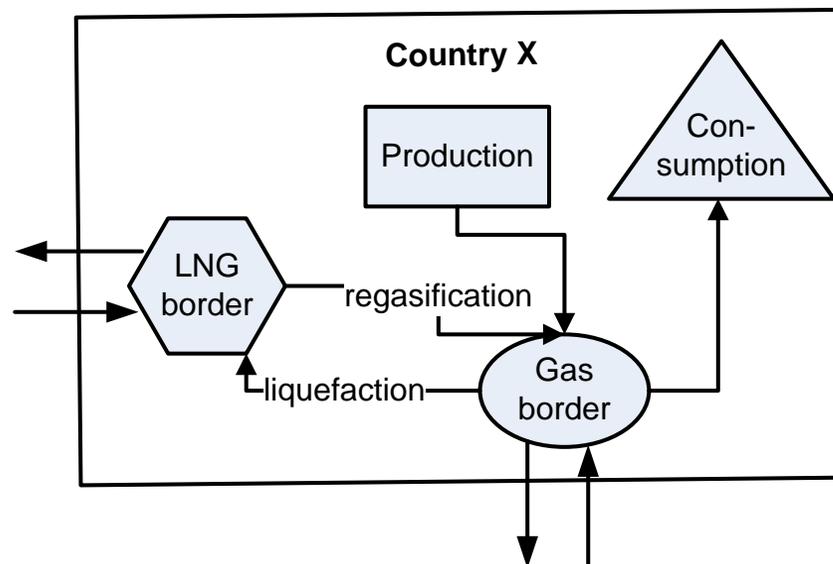
Market price \* volume sold

Less Investment costs

Less Operational costs

### Subject to:

- Production & flow limits
- Market demand
- Mass balance
- Investment enables capacity
- Etc...



## Model Output:

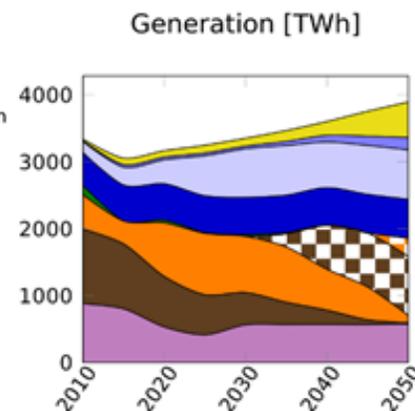
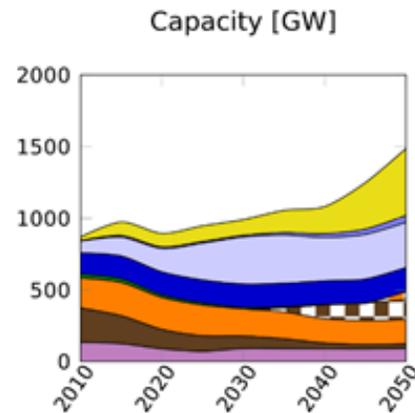
- Pipeline investments
- LNG investments
- Production
- Gas Flow

# Electricity investment model: EMPIRE

European **M**odel for **P**ower system **I**nvestment with (high shares of) **R**enewable **E**nergy

- Central planner viewpoint: minimizing net present value of investment & operational cost
- Investments in generation and cross-border transmission capacity

*EMPIRE model spatial detail*

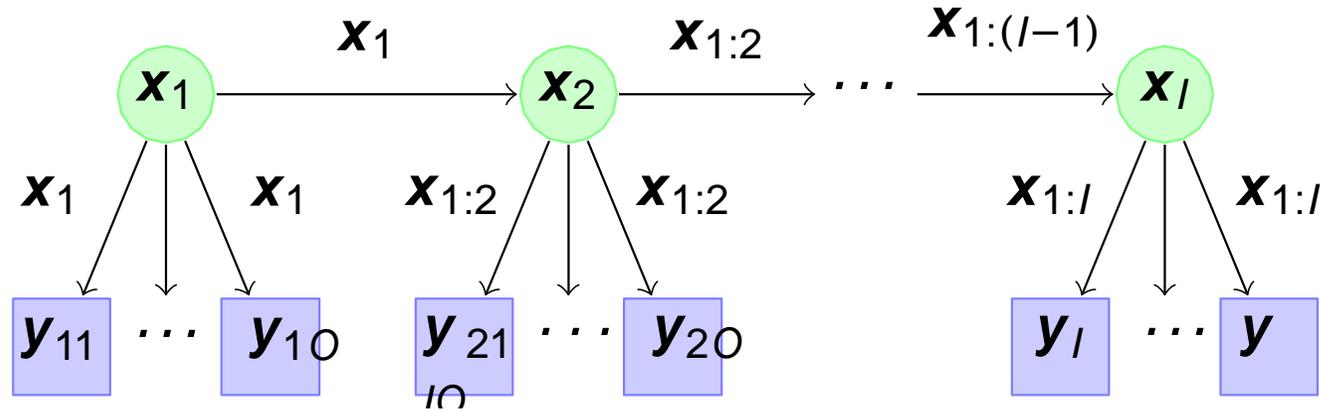


## Modeling assumptions

- Perfect competition (system cost minimization formulation)
- Inelastic demand
- Generation capacity aggregated per technology (i.e. do not model individual plants)
- Investments are continuous
- Lines are independent (i.e. transportation network)
- Perfect foresight about fuel prices, carbon price, and load development.

# Multi-horizon Stochastic programming framework

Investment (strategic) decisions ●  
Operational decisions ■



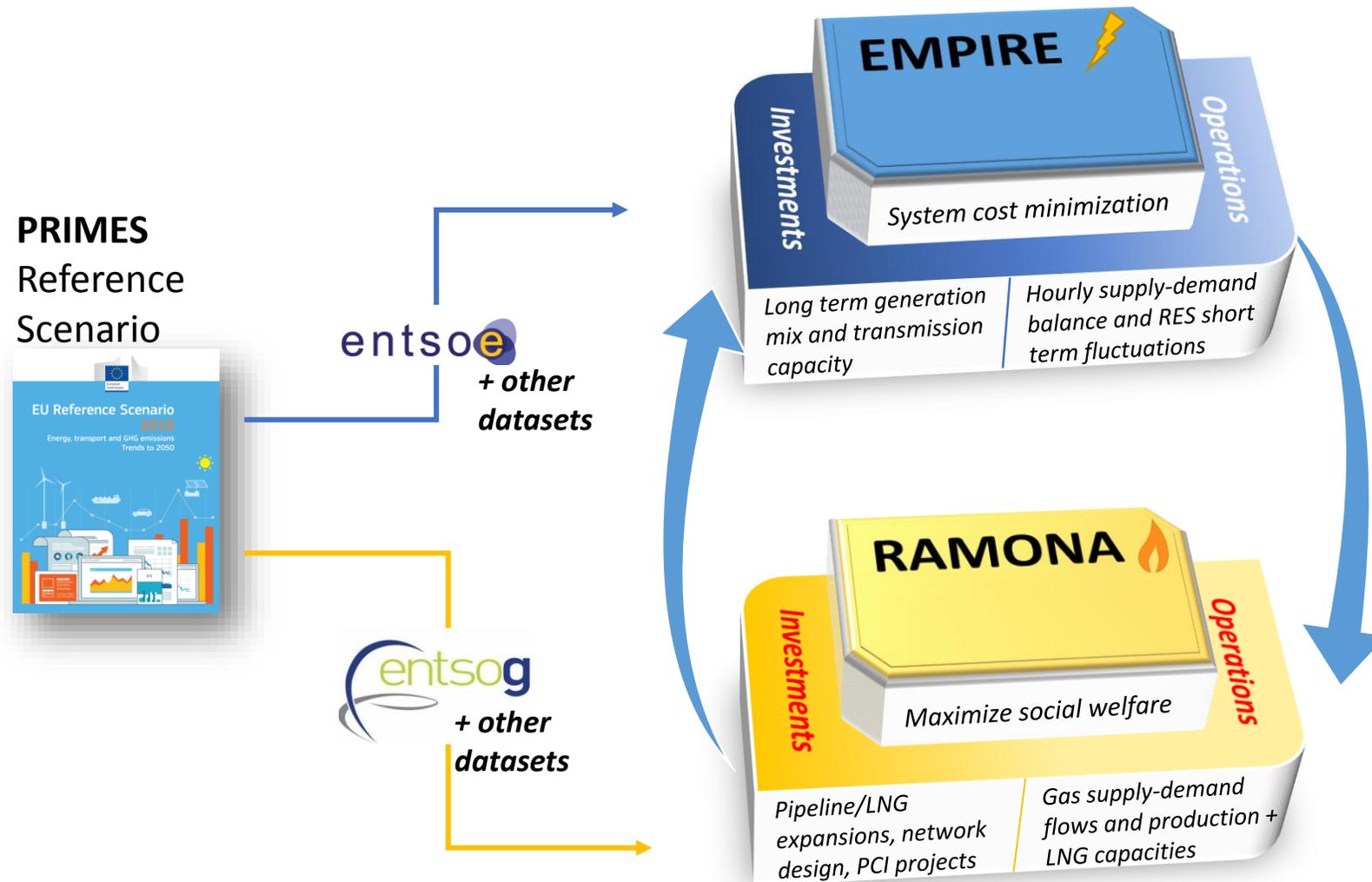
- $x_i$ : investments in period  $i$  (2015, 2020, ..., 2050)
- $y_{i\omega}$ : Operational variables (dispatch, flows, etc.) period  $i$ , stochastic scenario  $\omega$

- Long term investments vs short term dynamics (operations) under uncertainty
  - formulated as a sequenced two-stage stochastic program
- Perfect foresight in the long-term
  - Fit to analyze the energy system transition for a pathway scenario

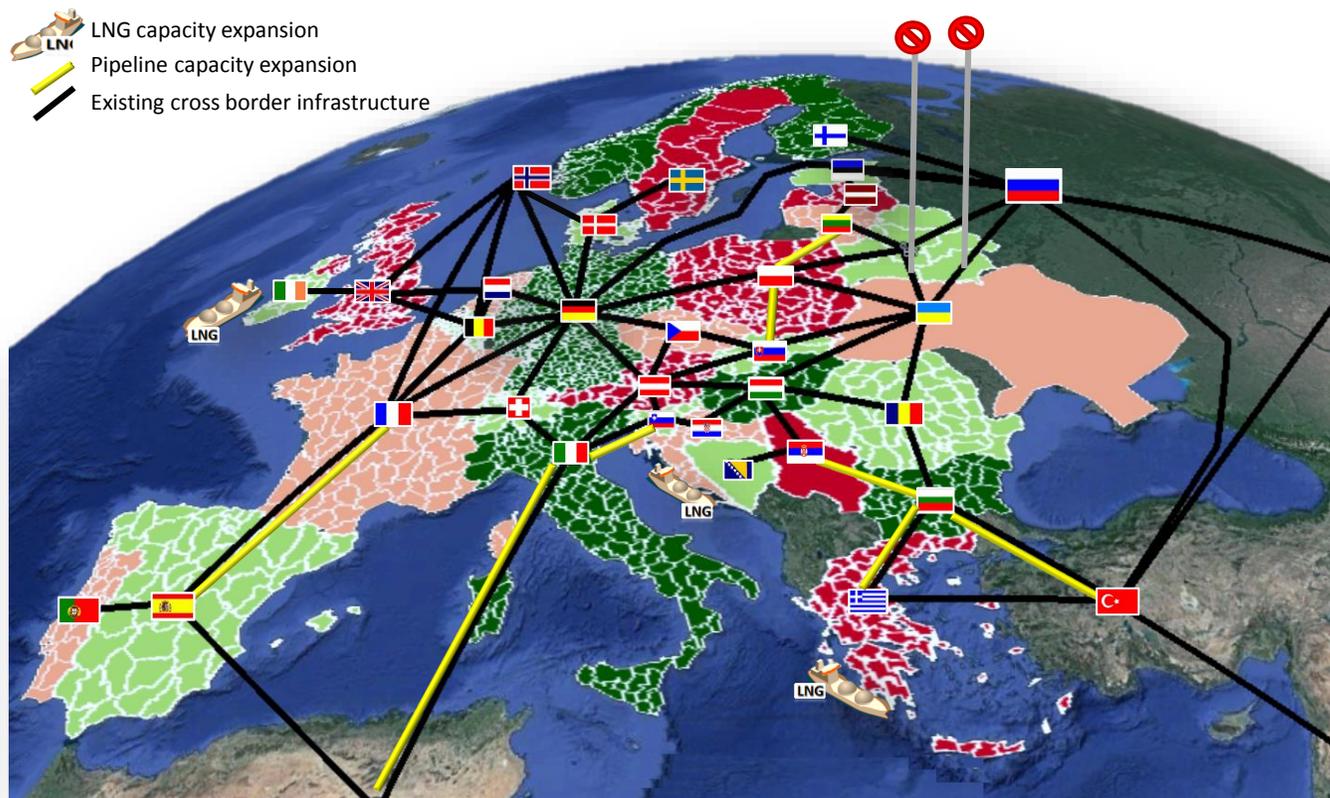
# EU case study setup

- Gas infrastructure planning:
  - ENTSOG PCI projects selected for 2020-2035, which ones to prioritize?
  - Follow decarbonisation targets (PRIMES reference case)
  - Follow PRIMES and ENTSOG gas demand & productions outlooks
  - RAMONA outputs: Pipeline and LNG capacity expansion
- Electricity infrastructure planning:
  - Follow decarbonisation targets (PRIMES reference case)
  - Inputs from IEA reports and outlooks (e.g. long-term fuel prices)
  - Assumption: CCS development in 2040-2050 and open to “high” transmission expansion
  - EMPIRE outputs: Investments in electricity generation and transmission; Gas expansion; and capacity factor of Gas units

# Implementation

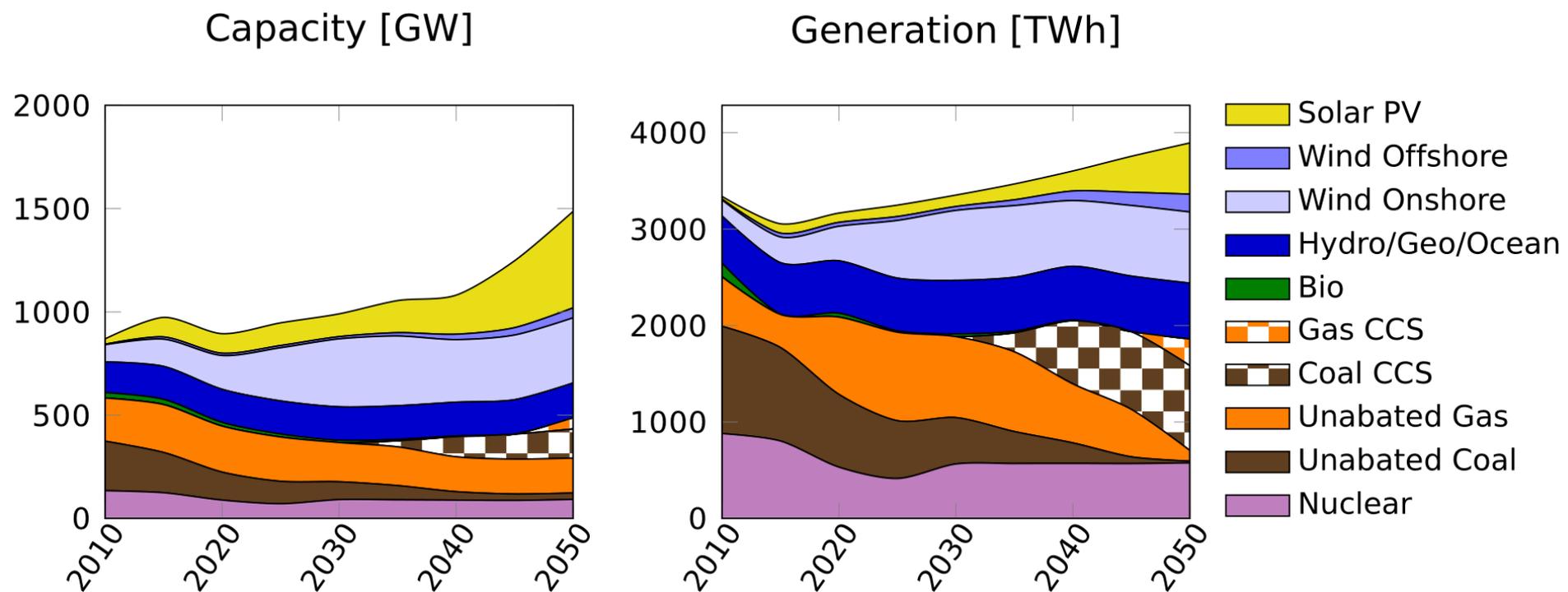


# Gas planning model results



- Russia-Ukraine gas constraints
- Prioritize gas intake from Africa
- LNG expansion: Greece and Croatia
- New 2020-2025 suggested cross-border connections:
  - Bulgaria: GR-BG, BG-RS, and BG-TR
  - Poland corridor and Baltic countries
- Other investments: LNG Ireland and Spain-France connection
- In short, total new investments:
  - New Cross border capacity: 2900 GWh/day
  - New LNG Capacity: 385 GWh/day
  - Total Investments: 6,4 billion euros

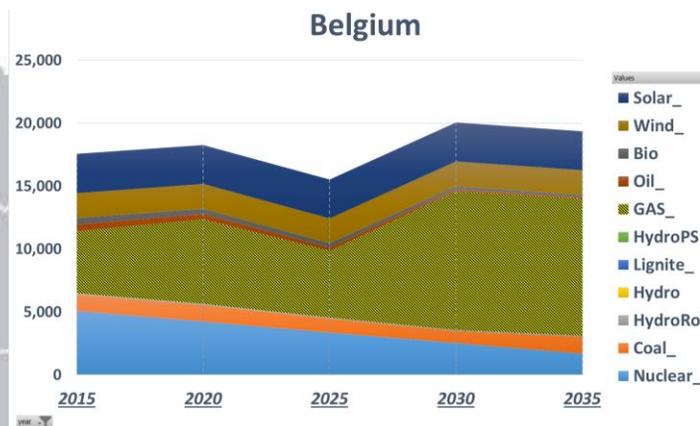
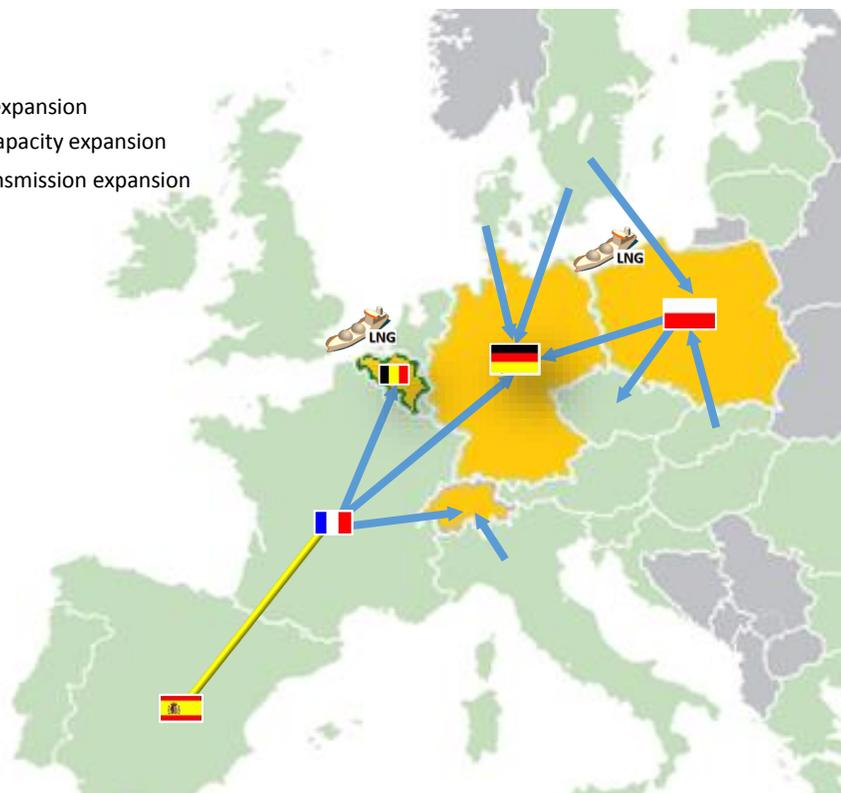
# EMPIRE results



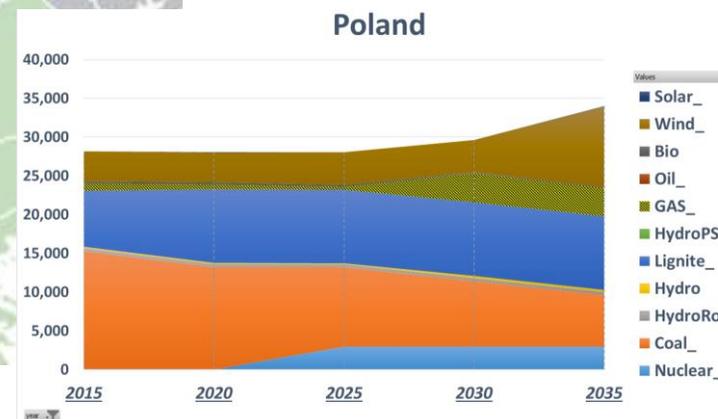
# Gas-Electricity reciprocal effects

- Gas capacity expansion: Switzerland, Poland, Belgium, Germany

-  LNG capacity expansion
-  Gas Pipeline capacity expansion
-  Electricity Transmission expansion



**Belgium & Germany**  
- Mainly used for baseload operation (high utilization)



**Switzerland & Poland**  
- low utilization, frequent cycling, steep ramping

# Conclusions and Future (ongoing) work

- 2025-2030 critical years for the EU energy transition
  - The decarbonization analysis shows that natural gas plays an important role as a bridging fuel for possible CCS development and RES integration
- Further sensitivity analysis on the importance of gas PCI projects and include other potential projects not considered by ENTSO-G
- Multi-horizon stochastic programming provides a useful framework for modelling uncertainties at different scales: Strategic & operational
- Future work
  - Develop a common Electricity-Gas optimization framework
  - Implement a finer time resolution for RAMONA. Also implement some capacity mechanism incentives to trigger (realistic) investments
  - Test new decarbonization pathways: Restriction on electricity transmission expansion

# Thank you :)



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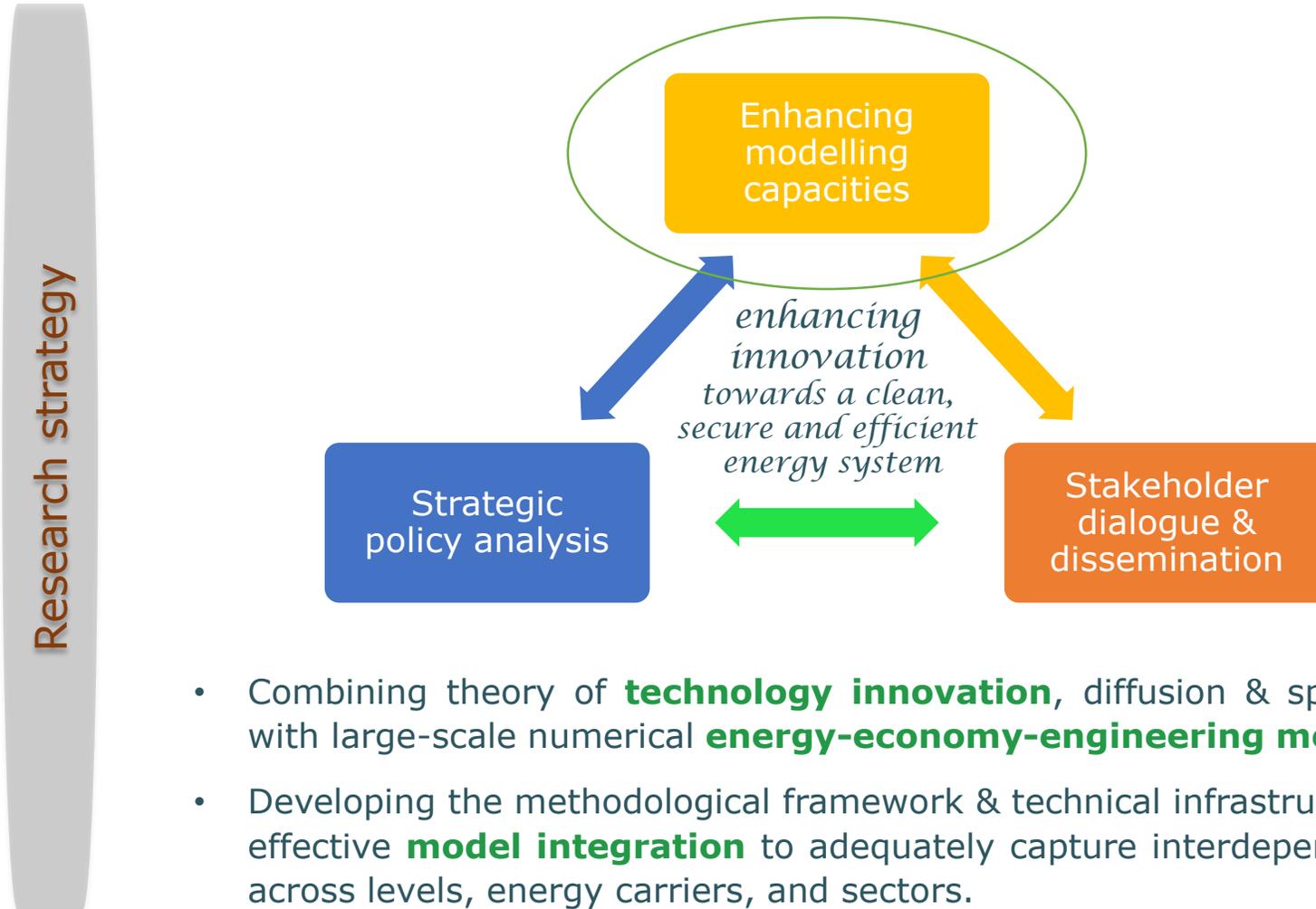
Twitter: [@PedroCDG](https://twitter.com/PedroCDG)

More about the **SET-Nav** project: <http://www.set-nav.eu/>

# Project partners

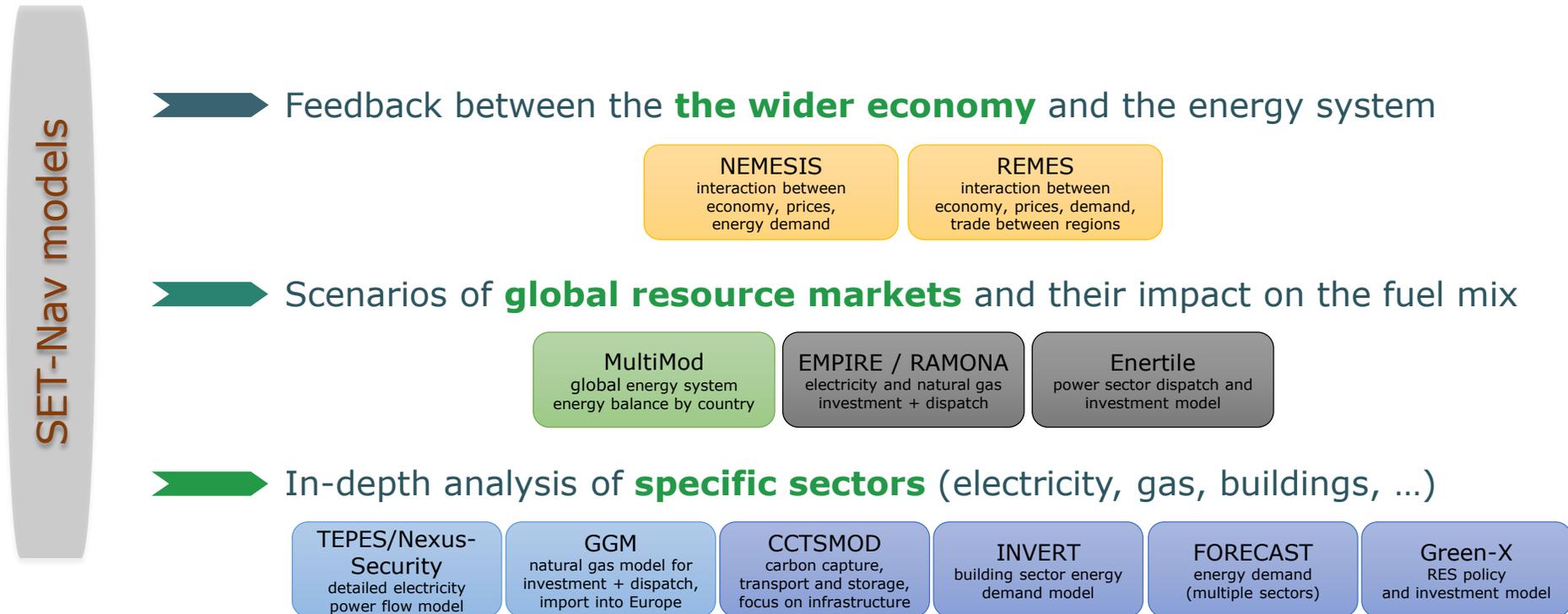


# SET-NAV THREE PILLARS



# FROM MACRO TO THE SYSTEM

SET-Nav integrates a wide variety of models across different levels, sectors, and spatial/temporal disaggregation



The methodological research question:

How to link across **multiple models**, ensuring consistency of model results and numerical convergence...