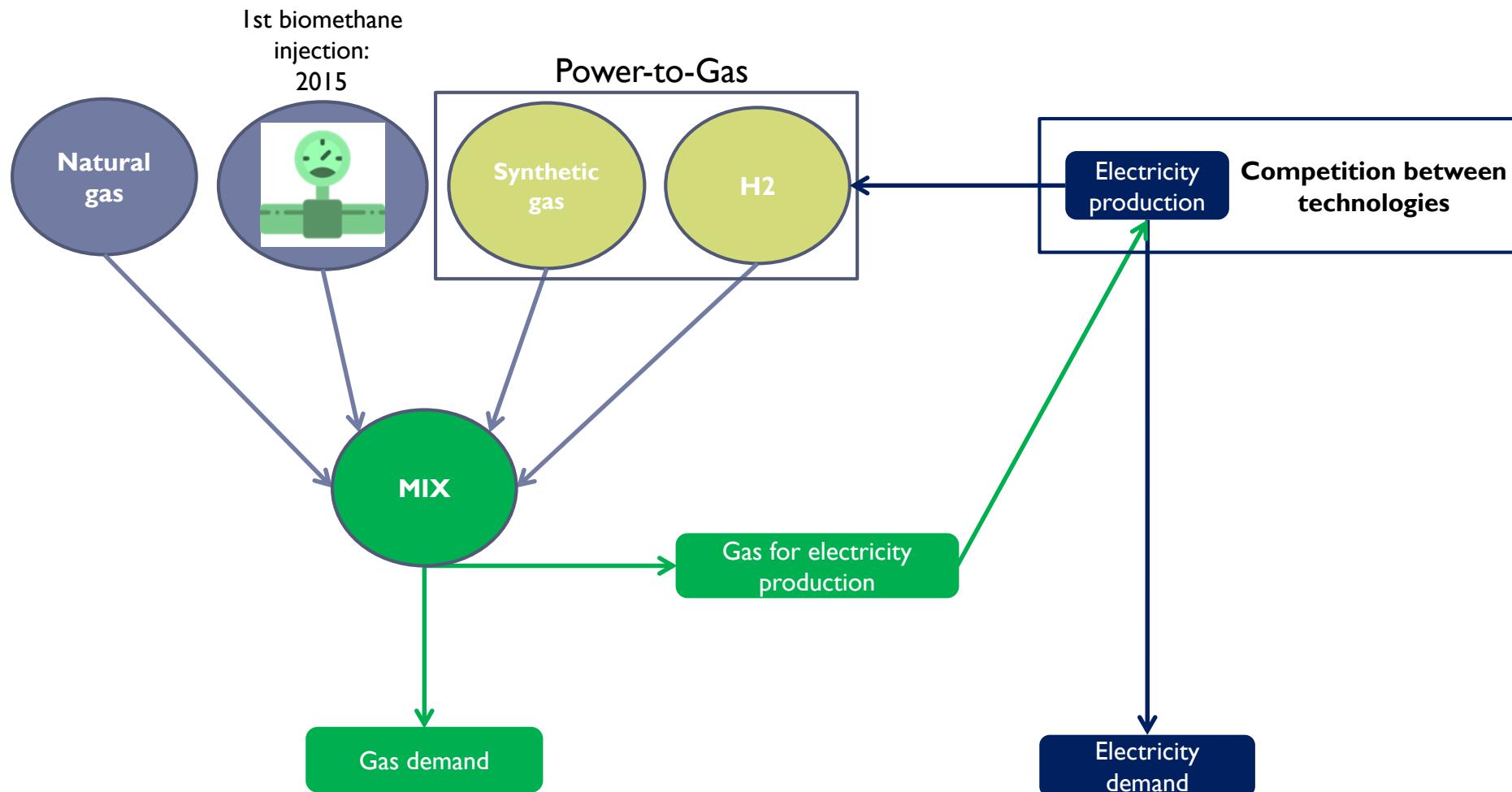




Modeling long term interactions between energy vectors: a case study for gas and electricity systems in France

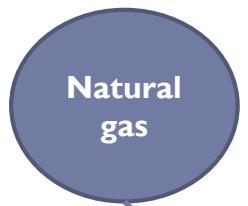
Rémy Doudard – Jérôme Gutierrez – Edi Assoumou
Monday, July 10th, 2017

Topology of gas/electricity systems interactions



Topology of gas/electricity systems interactions

~ 450 TWh/ year
Similar to final electricity demand



1st biomethane injection:
2015



MIX

~ 9% of total installed capacity in the power sector

Gas for electricity production

Gas demand

Electricity demand

Electricity production

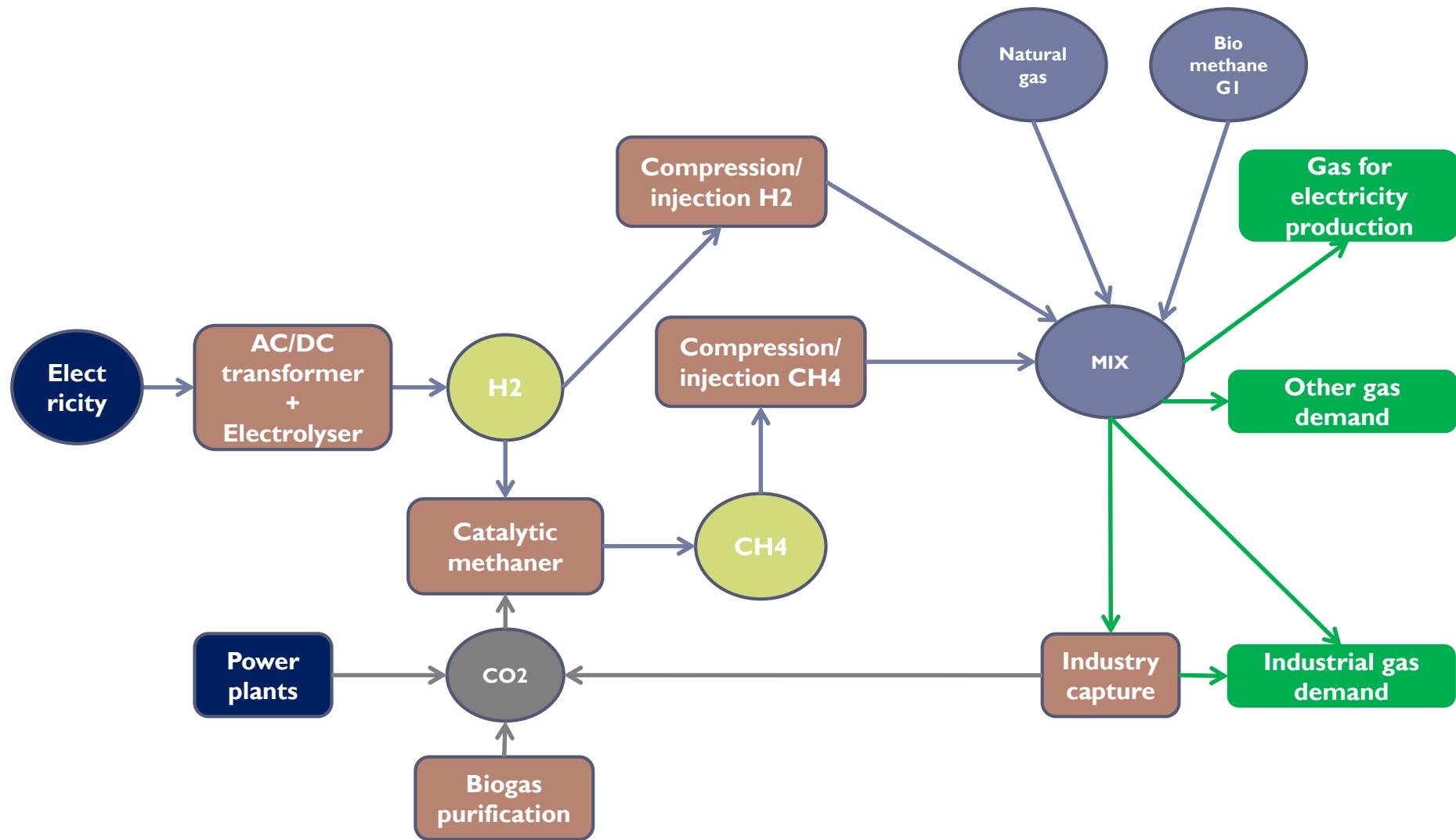
Competition between technologies

Prospective approach in order to assess...

- ▶ **Technological choices**
 - ▶ Gas system (hydrogen, gas from methanation, biomethane)
 - ▶ Electricity system (gas-to-power...)

- ▶ **System operation**
 - ▶ Hourly gas and electricity mix variation

Understanding systems topology and operation: focus on the Power-to-Gas chain



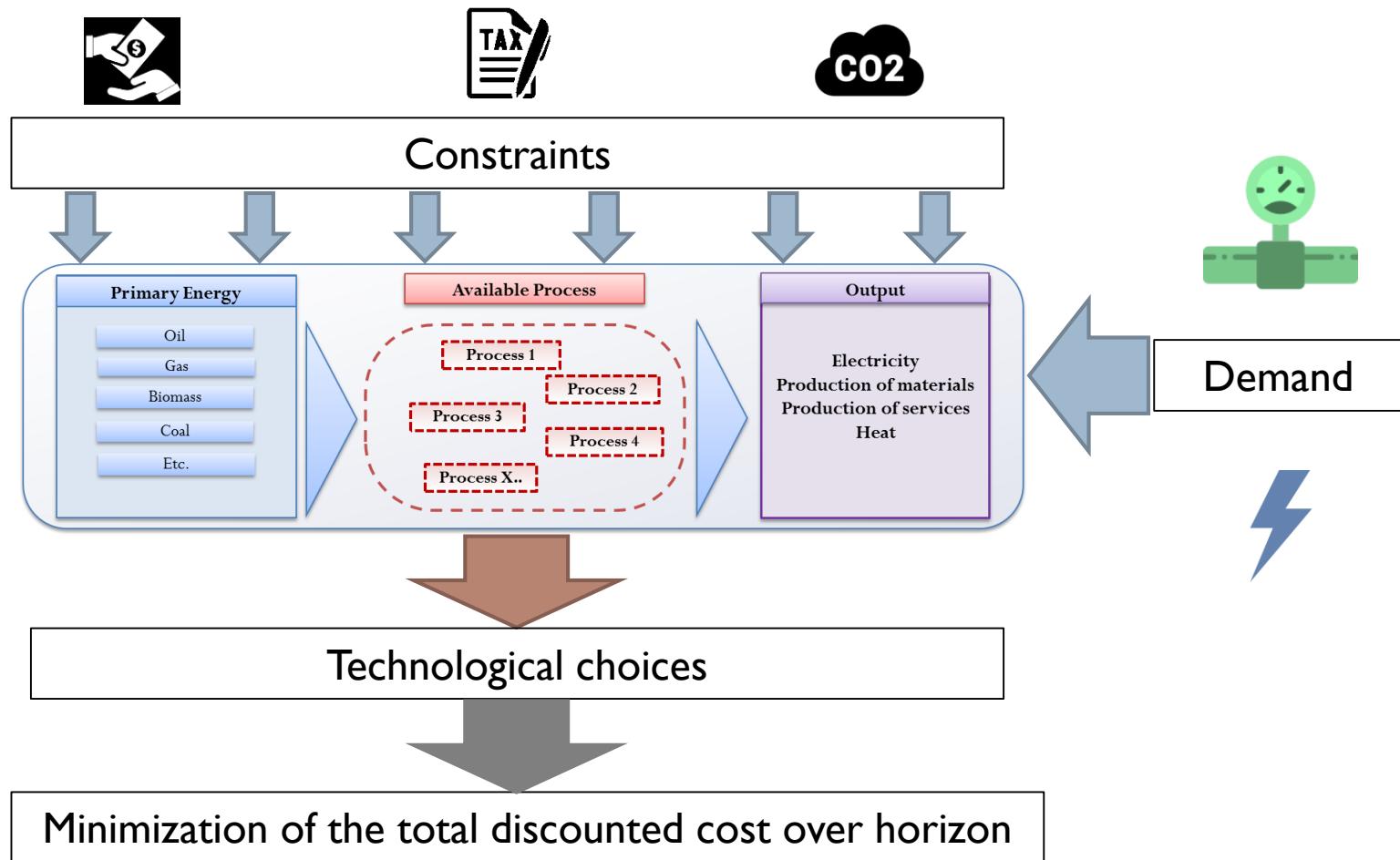
Modeling challenges

- ▶ **Embed system complexity:**
 - ▶ Various technological pathways, from primary resources to final demand
- ▶ **Determine the best configuration given various hypothesis:**
 - ▶ Demand assumption,
 - ▶ Energy prices,
 - ▶ Emissions constraints,
 - ▶ ...



Optimal paradigm

Our choice : TIMES model generator



TIMES_FR_GazElec: french gas/electricity system joint optimisation model

Joint work between two PhD students:

- Jérôme Gutierrez (CMA)
- Rémy Doudard (CMA/GRTgaz)

Electricity system modeling (electricity final demand)

Gas system modeling (gas final demand)

Power-to-gas chain modeling

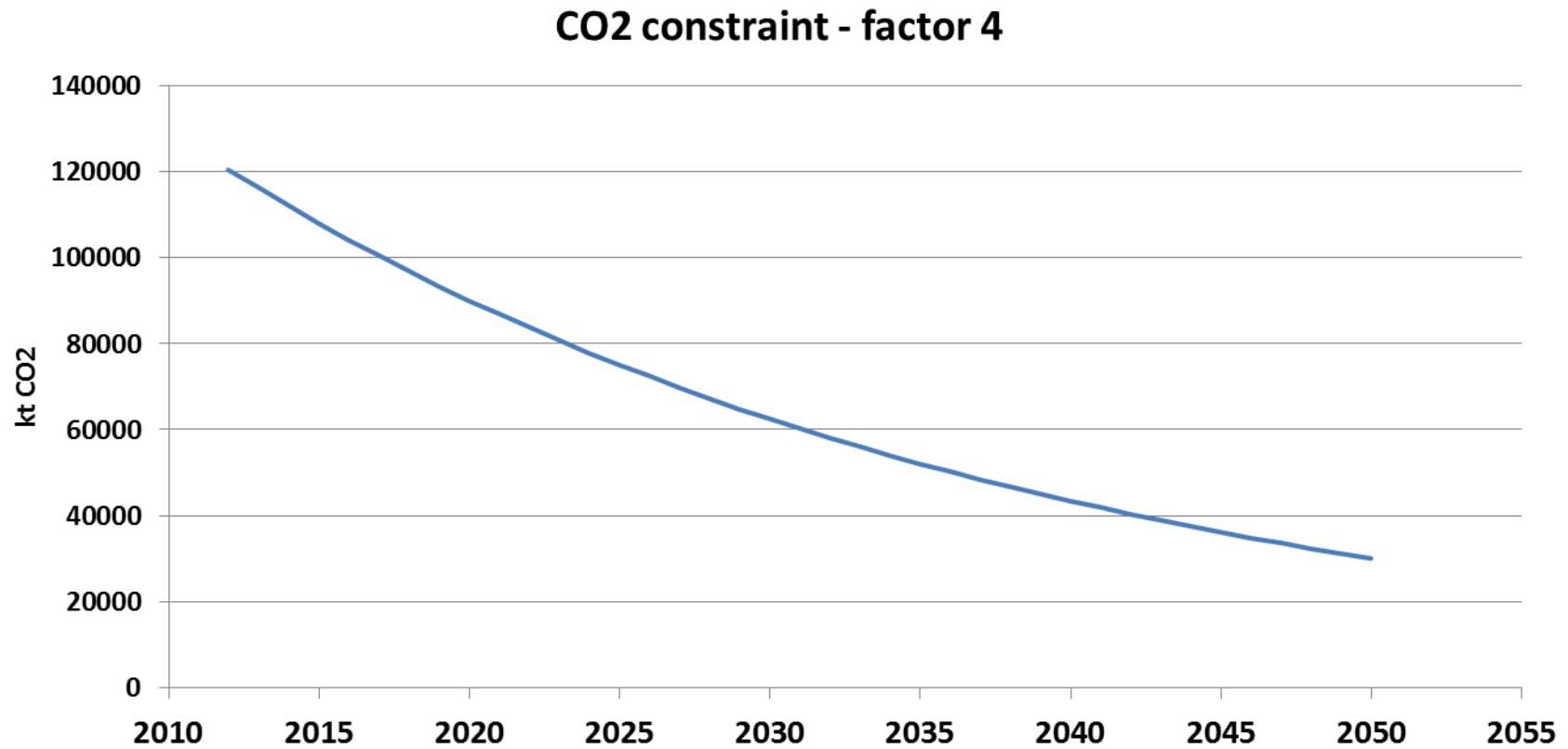
Detailed representation of power plants

TIMES_FR_GazElec
**12 months, 2 representative days (Sem/We), 24h
(576 timeslices)**

Definition of long-term constraints

Case study	Final energy demand scenario	Constraints	Associated scenario
BASE	« Basis » scenarios of French electricity & gas TSOs	No CO2 increase from the electricity system Share of nuclear power limited to 50% from 2025 to 2050	BASE
CO2 constraint		Factor 4 /2012	F4

A first decarbonization pathway



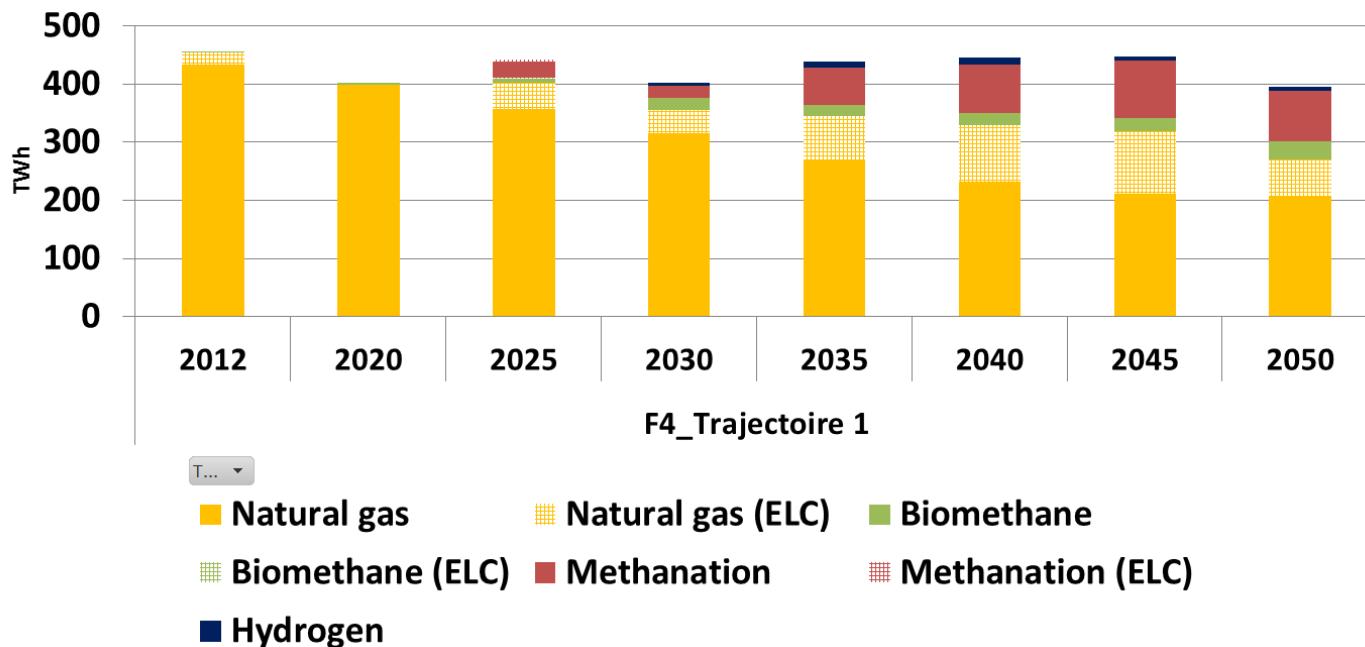


Results – « factor 4 » scenario



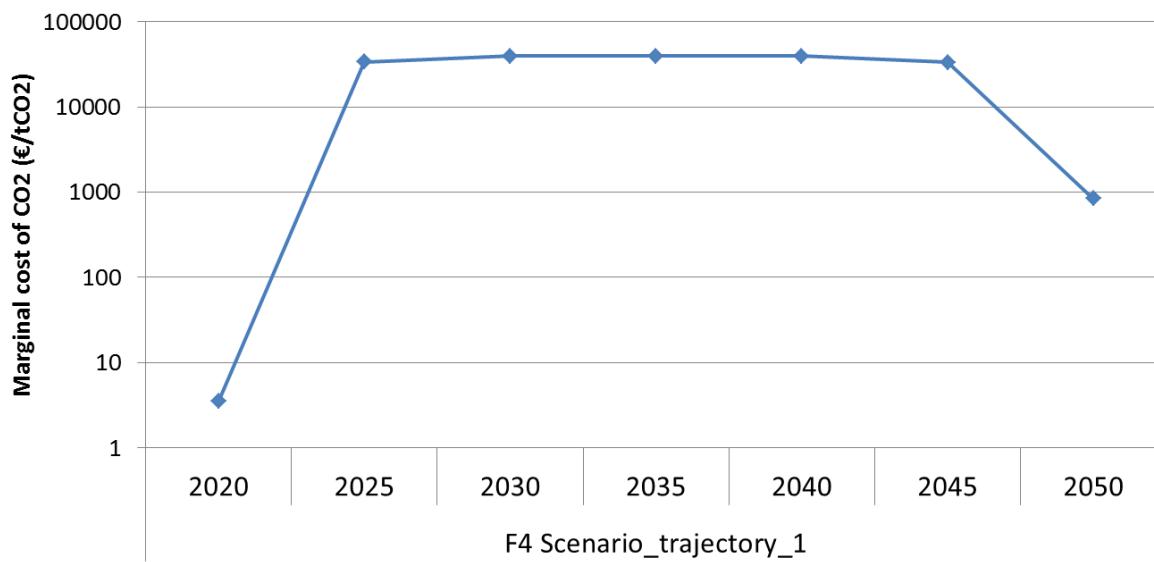
Use of methanation from 2025 to 2050...

- ▶ Use of hydrogen and synthetic gas → « stress » on electricity and CO₂ supply

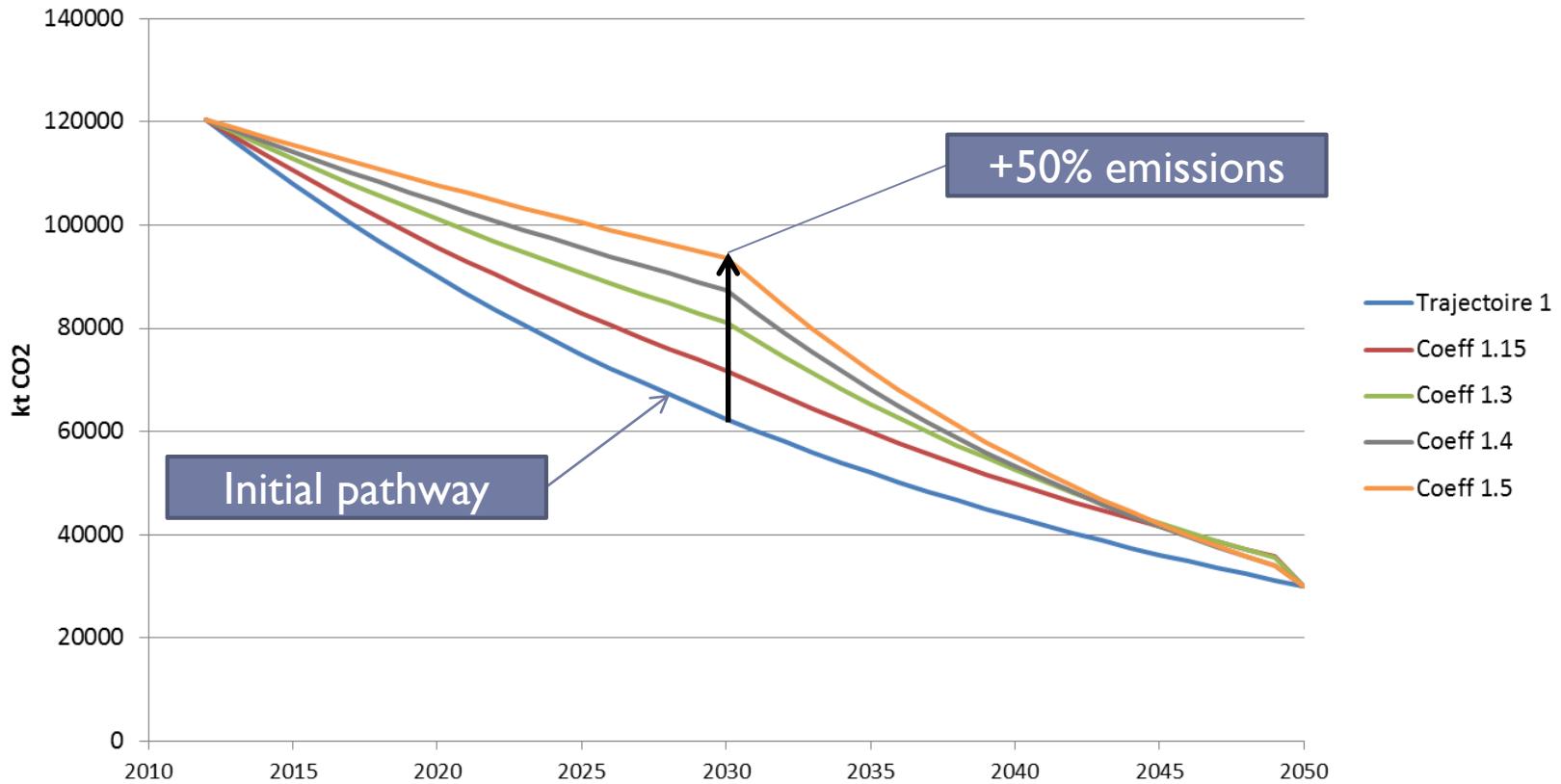


...but the CO2 trajectory makes the system « overconstrained »

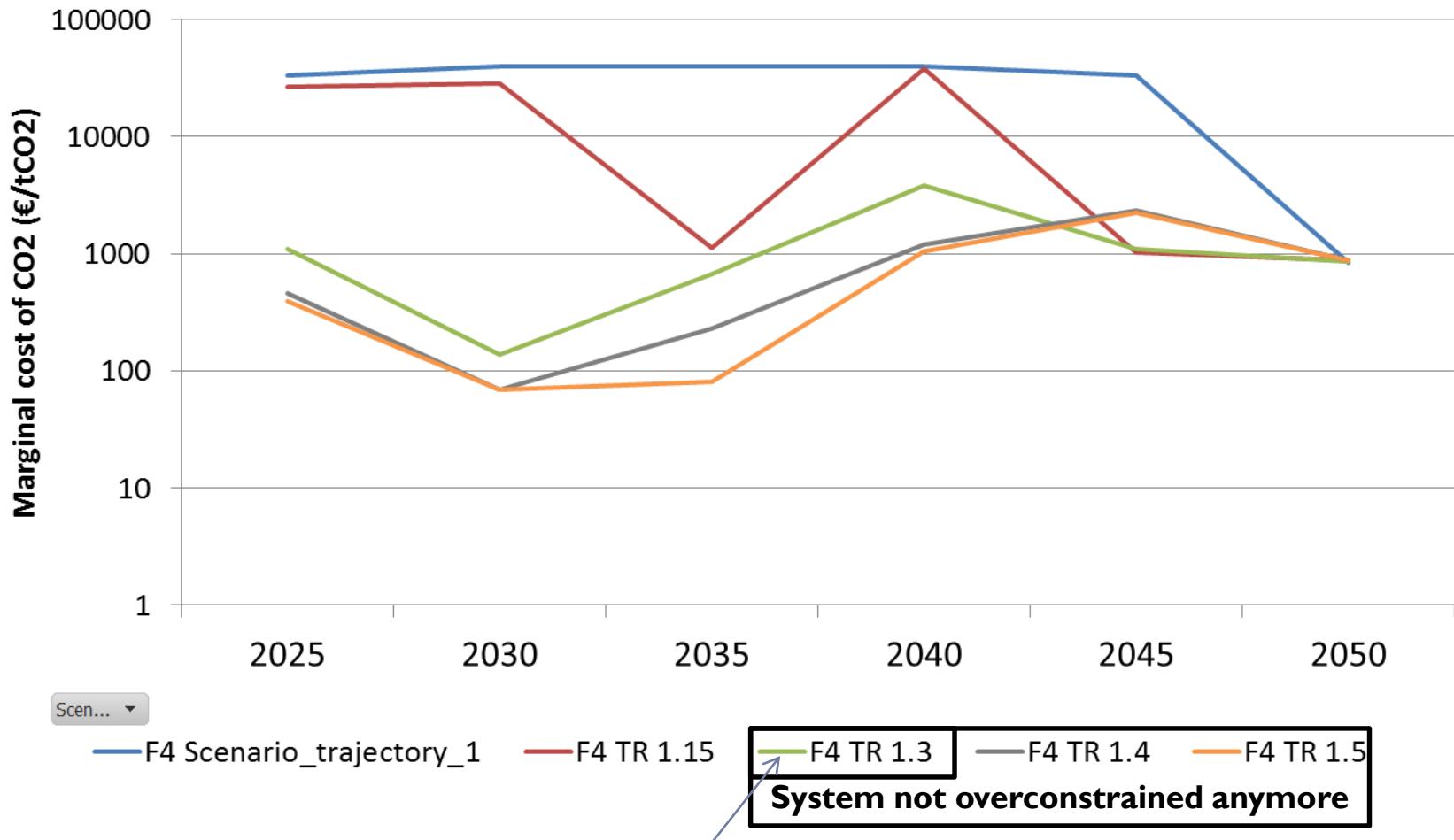
- ▶ Hydrogen and synthetic gas are « imported » by the model with a very high cost
- ▶ Marginal cost of CO2 : cost change in the objective function if we decrease CO2 emissions by one unit



What happens when we modify the decarbonization pathway ?

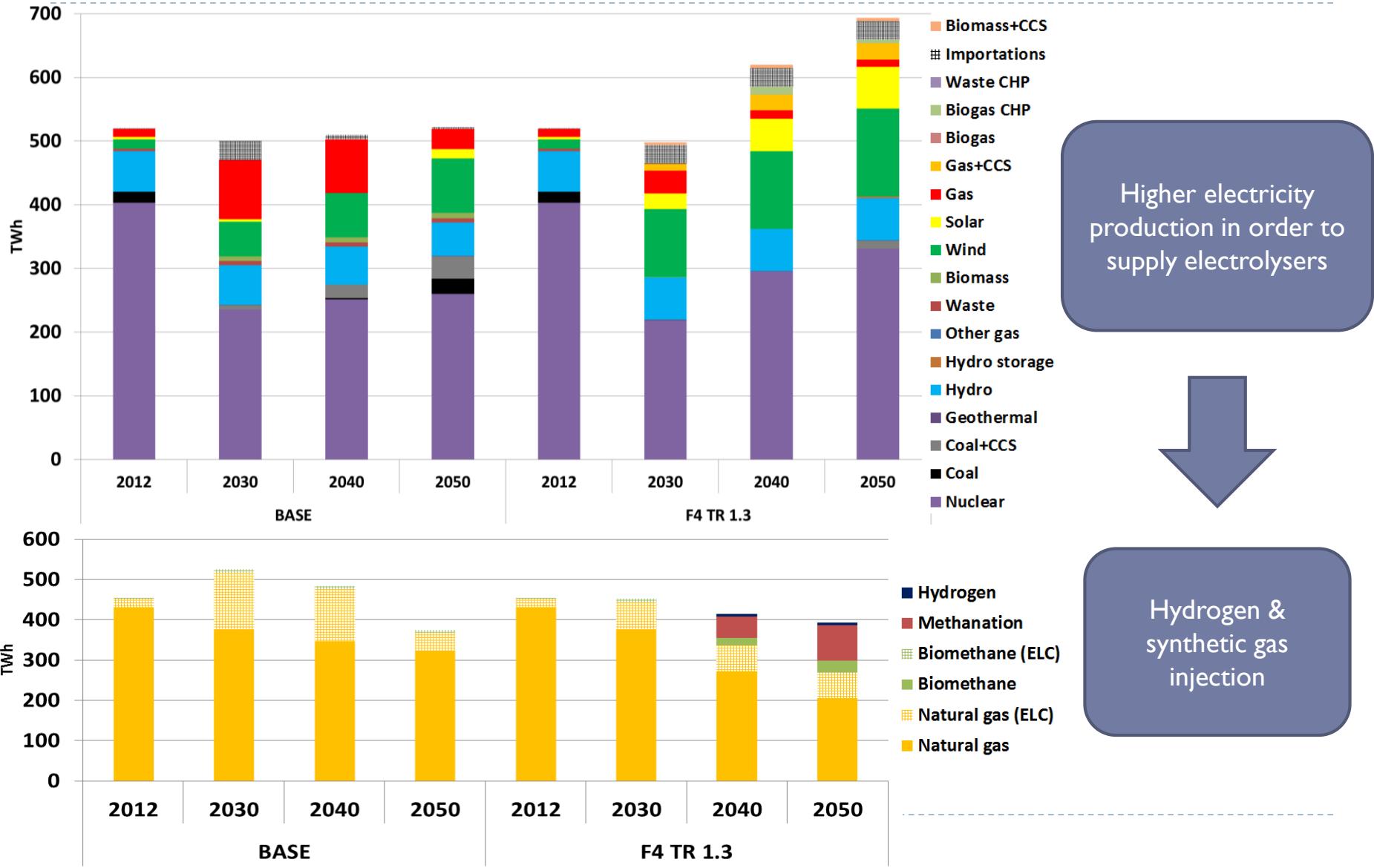


Comparison of CO2 marginal costs



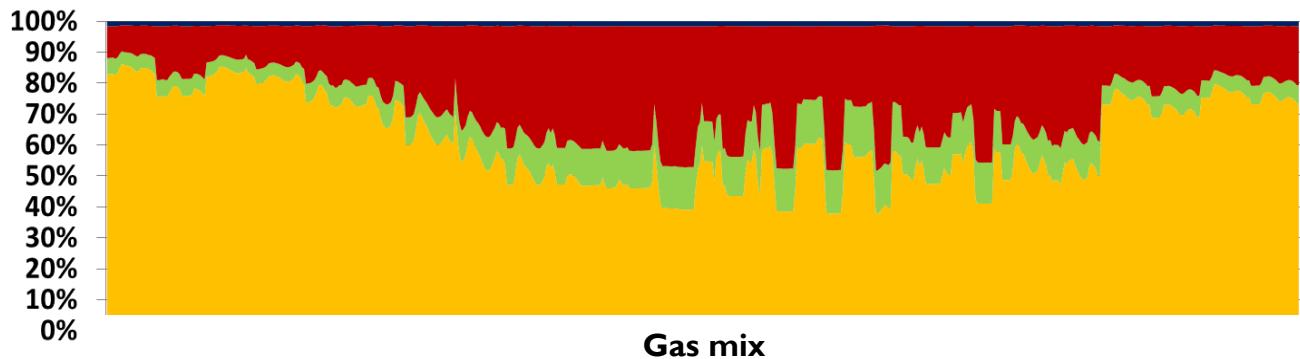
Comparison with basis scenario for following slides

Electricity & gas mix cross-analysis

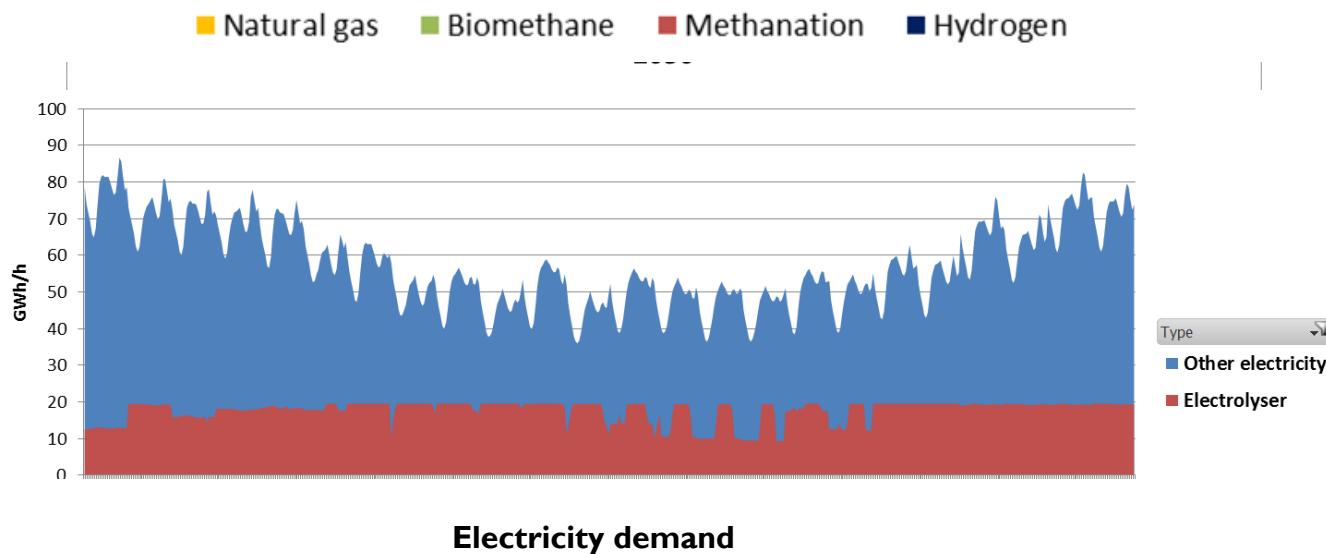


Gas consumption in 2050 : analysis for all timeslices

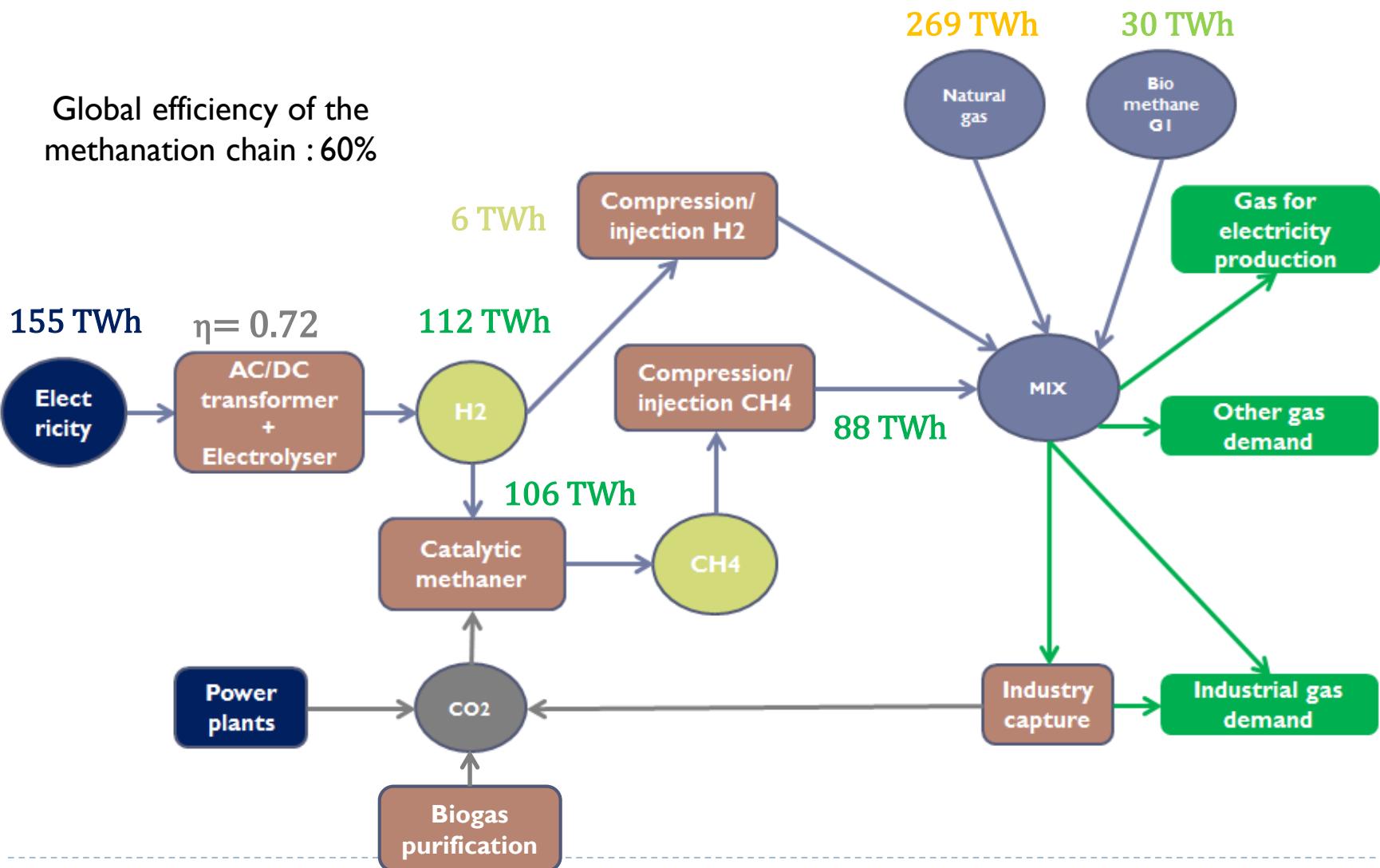
Analysis for all timeslices
(1 weekday and 1
weekend per month)



The activity of the electrolyser is lower at annual peak demand (january) and also at low availability of intermittent renewable energy



Energy flow for gas system in 2050

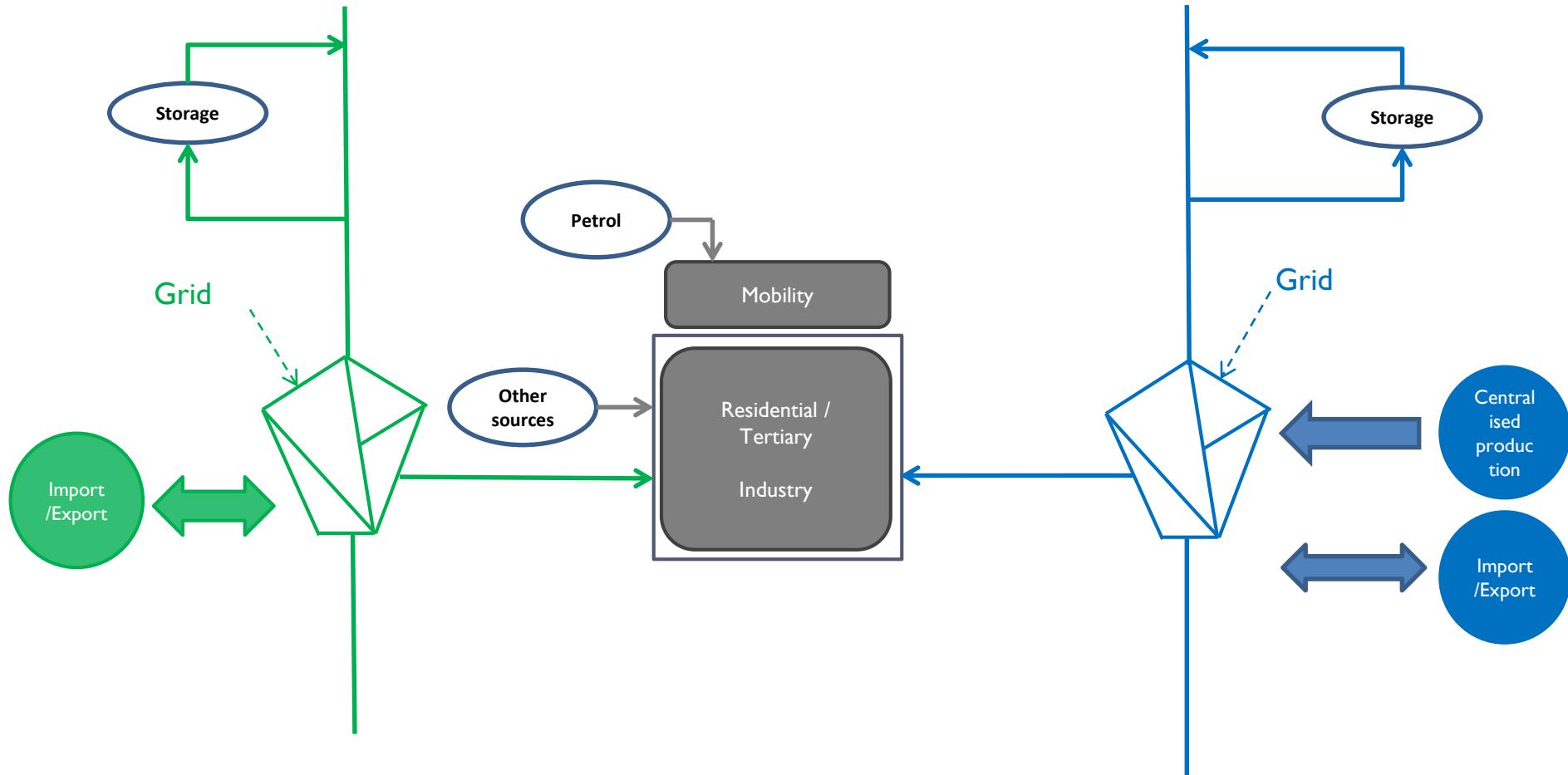


Conclusion

- ▶ Prospective approach in order to investigate interactions between gas and electricity systems in France
- ▶ A bottom-up approach is necessary in order to understand and quantify these long-term interactions
- ▶ Two combined effects influence the level of interactions:
 - ▶ «Timing» of CO₂ constraint
 - ▶ Availability of technologies

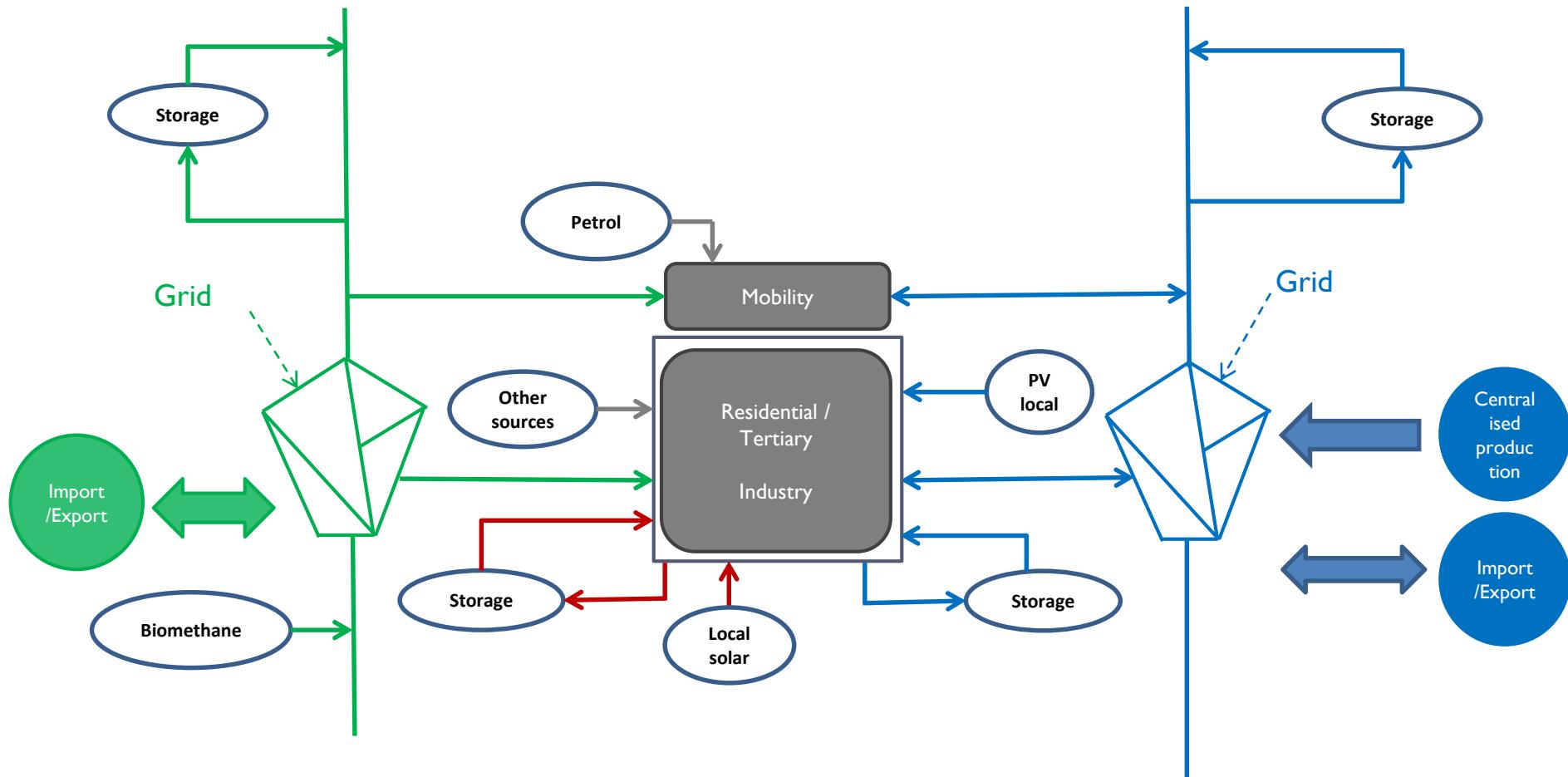
Further work : flexibility of multi-energy systems, prospective approach

Gas **Hydrogen** **Electricity** **Heat**

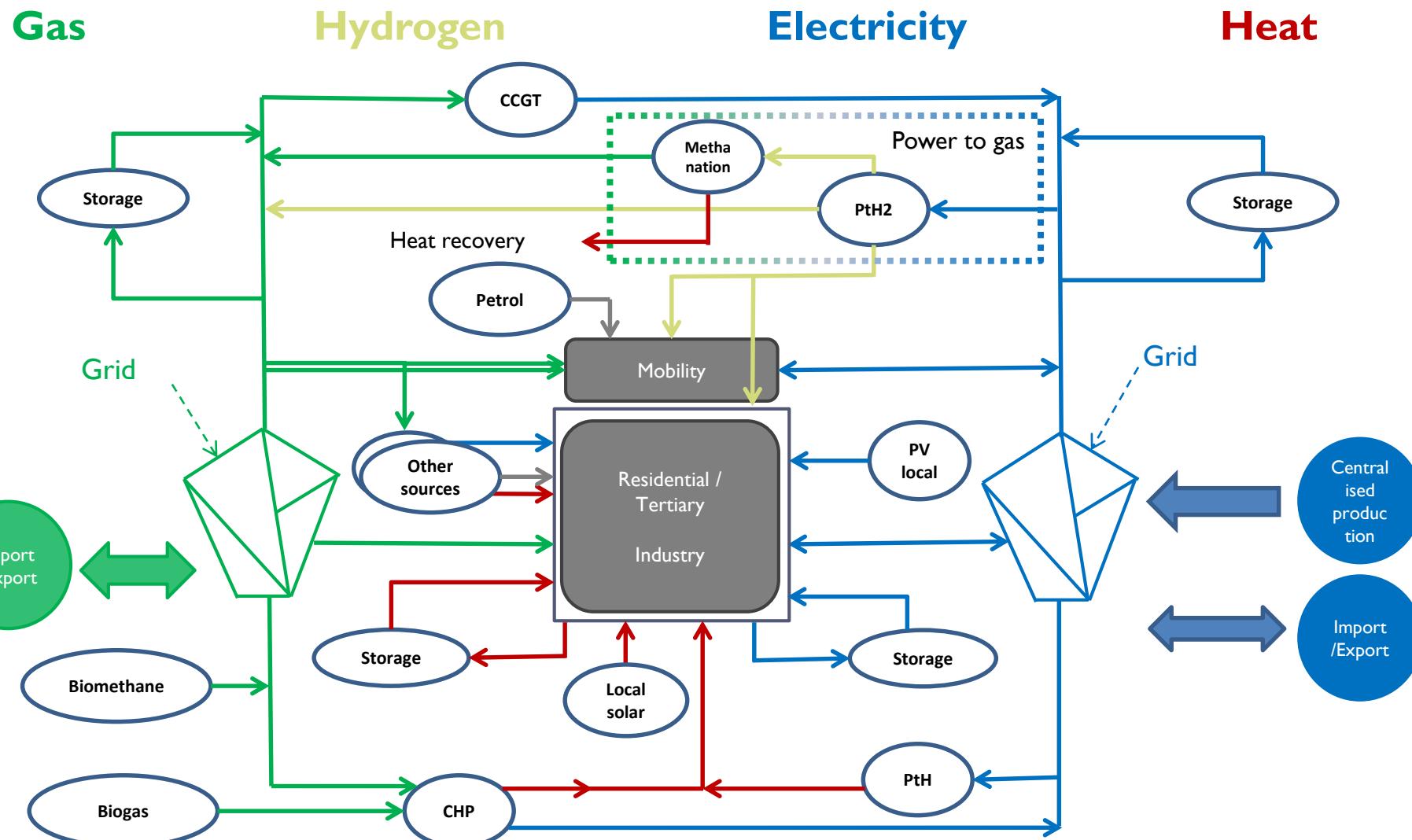


Further work : flexibility of multi-energy systems, prospective approach

Gas **Hydrogen** **Electricity** **Heat**



Further work : flexibility of multi-energy systems, prospective approach



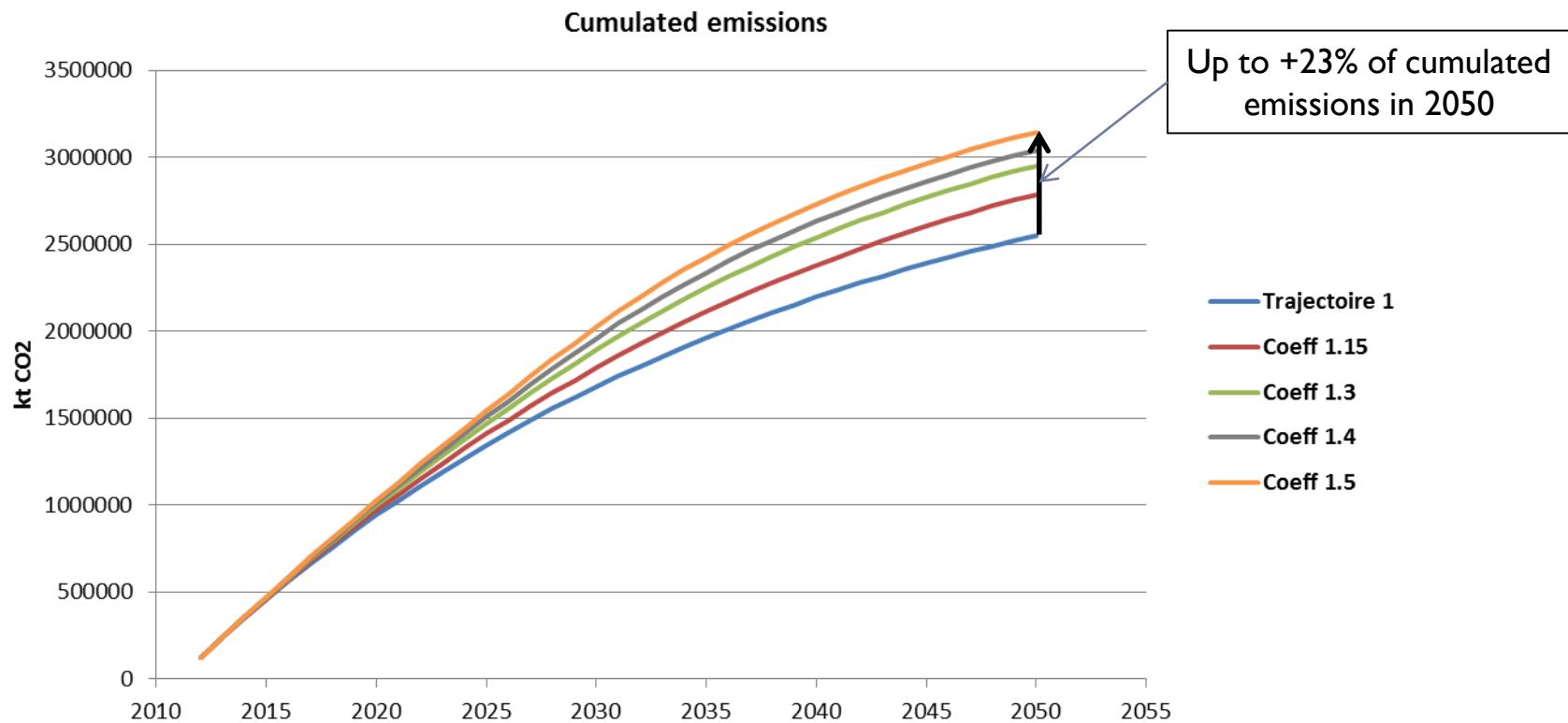


Thank you for your attention !

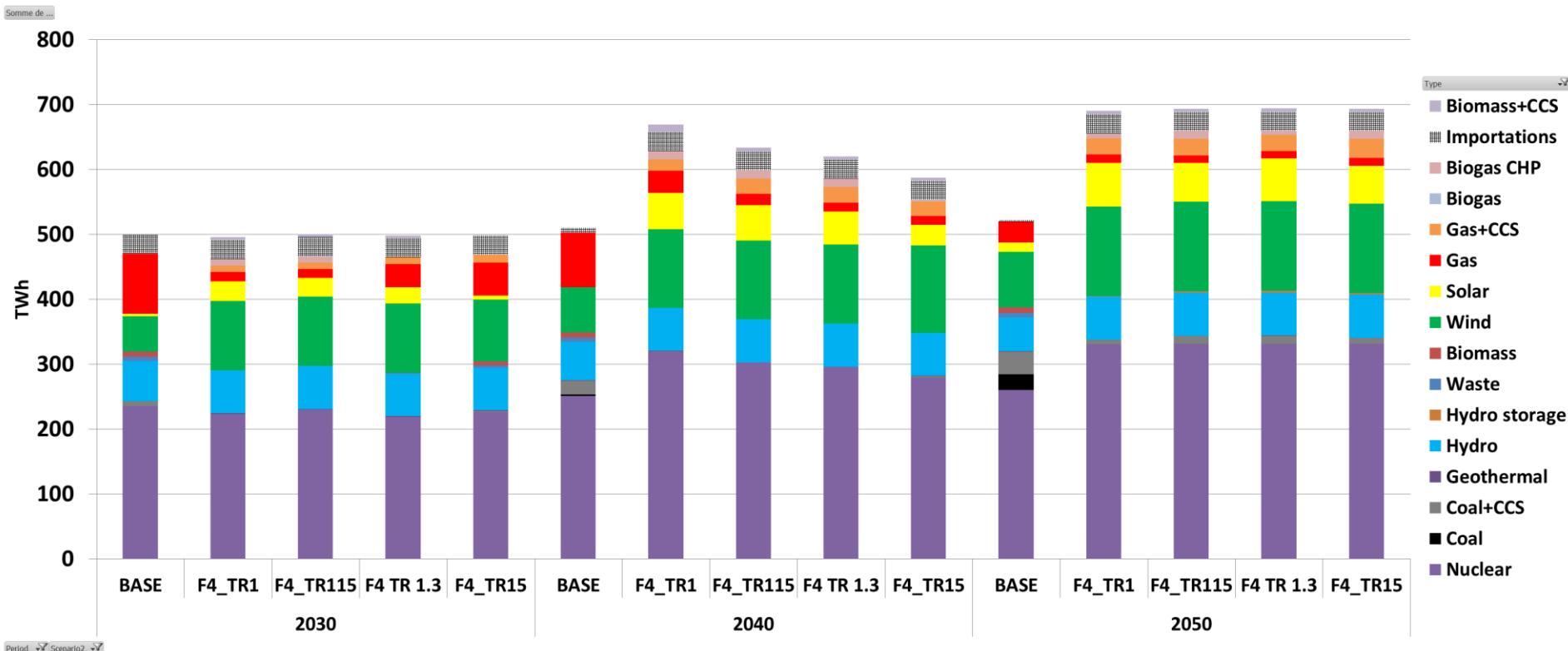
remy.doudard@mines-paristech.fr

Appendices

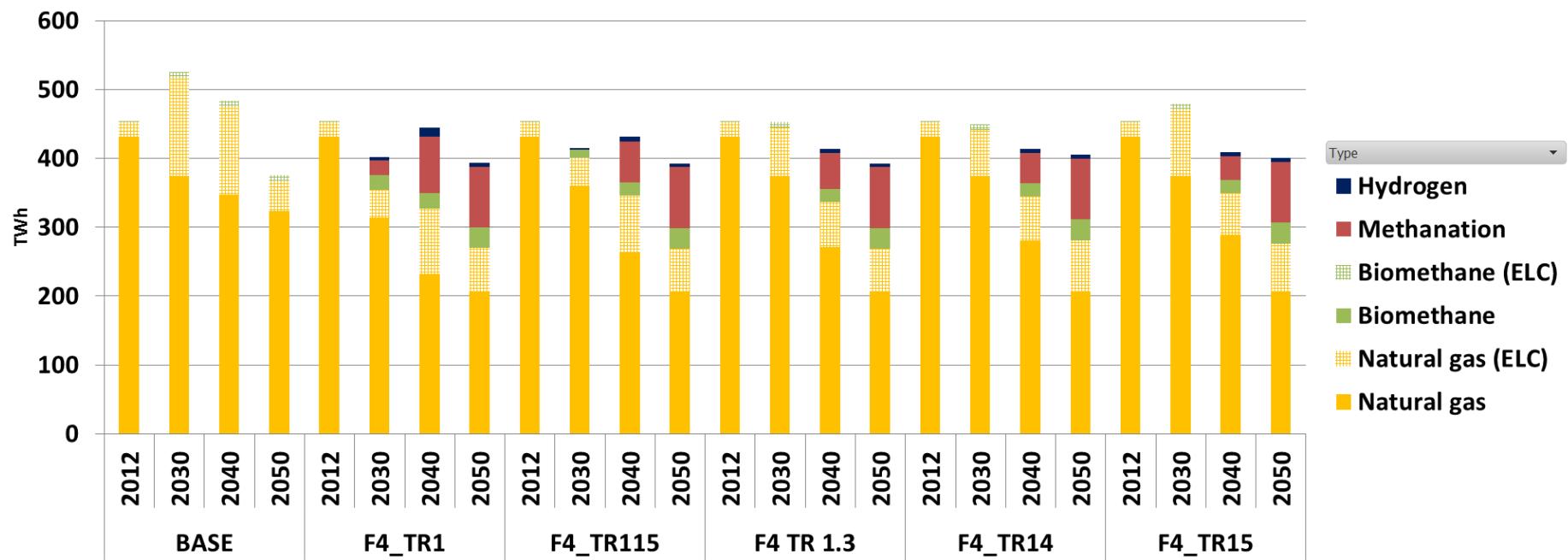
Cumulated emissions



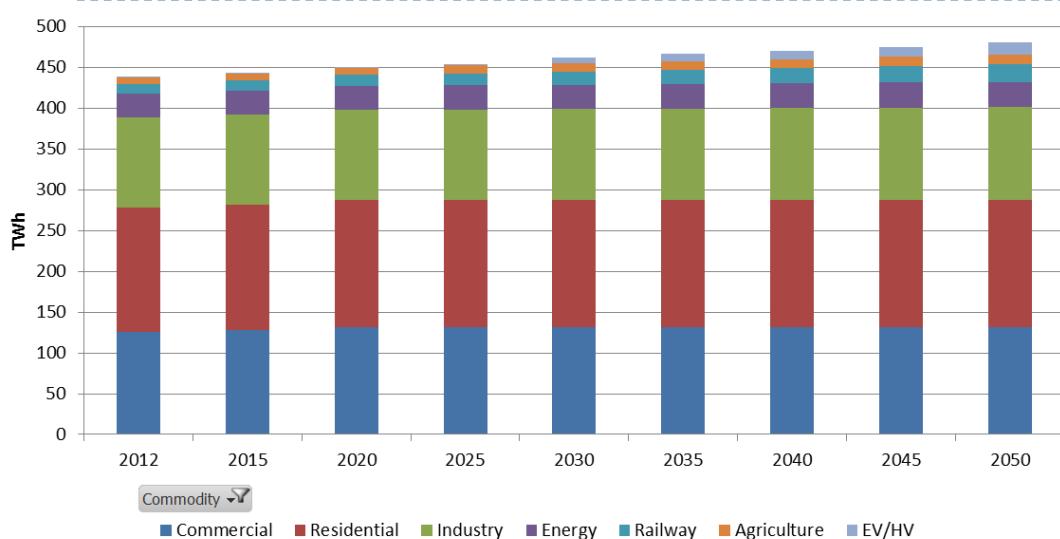
Electricity mix



Gas mix

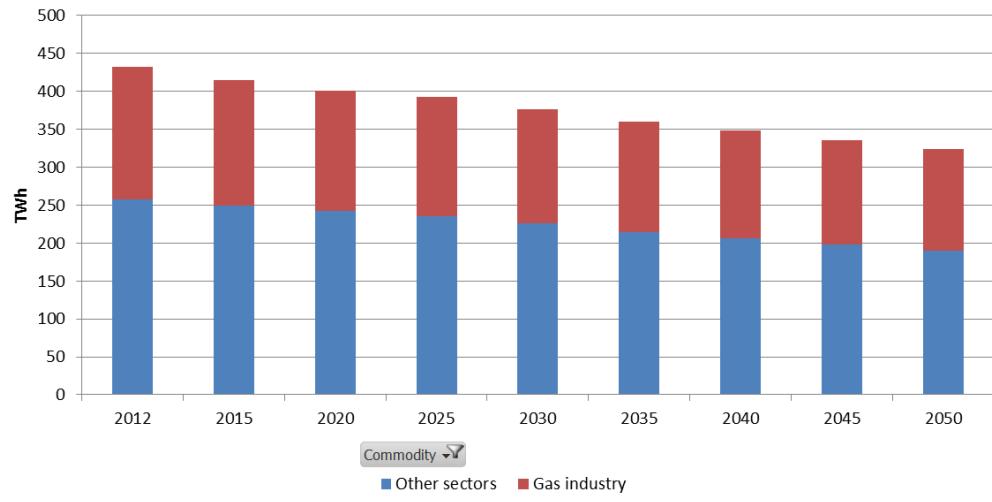


Demand assumptions



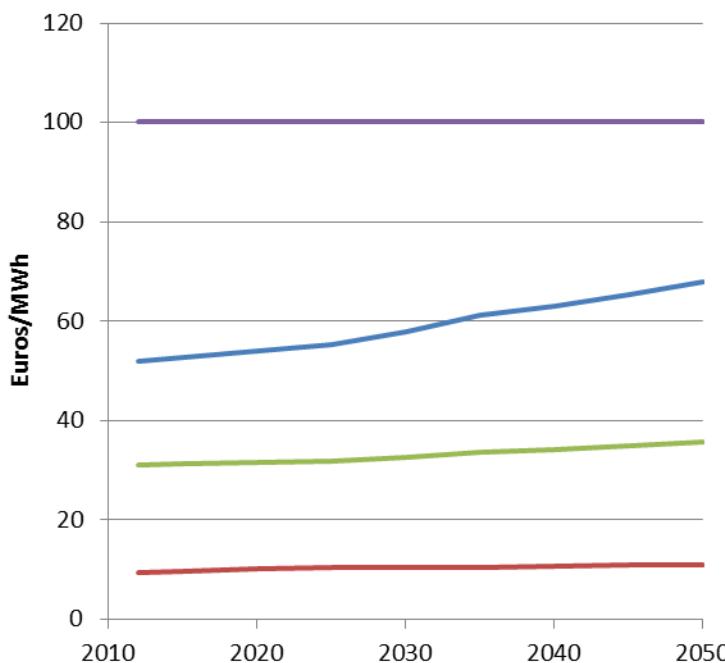
One load profile and consumption annual mean growth rate for each sector

RTE BP 2014, scénario C



Perspectives gaz naturel et renouvelables, scénario A

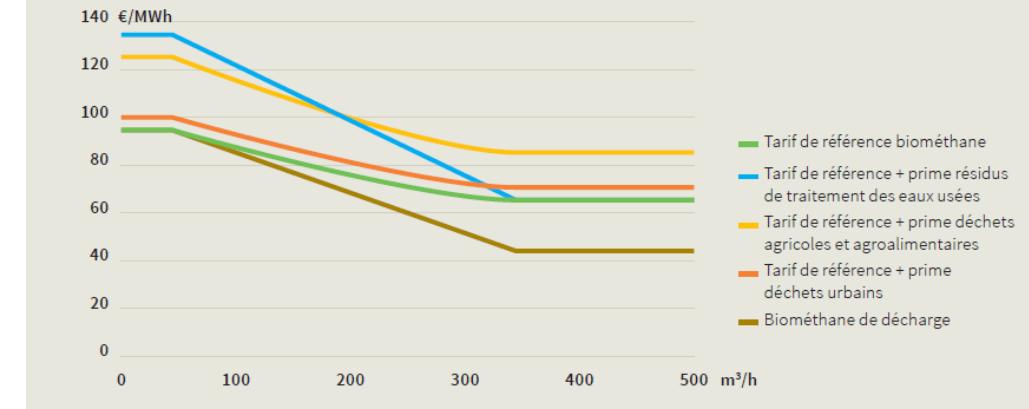
Energy prices assumptions



Source petrol/coal/natural gas : WEO 2013 new policies

- Petrol
- Coal
- Natural gas
- Biomethane G1

Tarif d'achat du biométhane en fonction du type de déchets et de la capacité maximale de production de biométhane de l'installation



Source : panorama du gaz renouvelable en 2016

CO₂ capture - industry

▶ Capture cost assumption: 75€/t

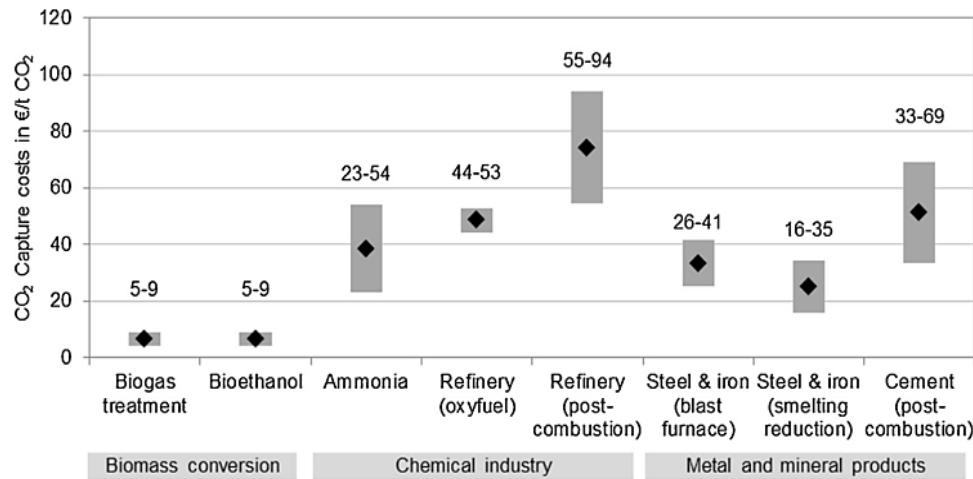
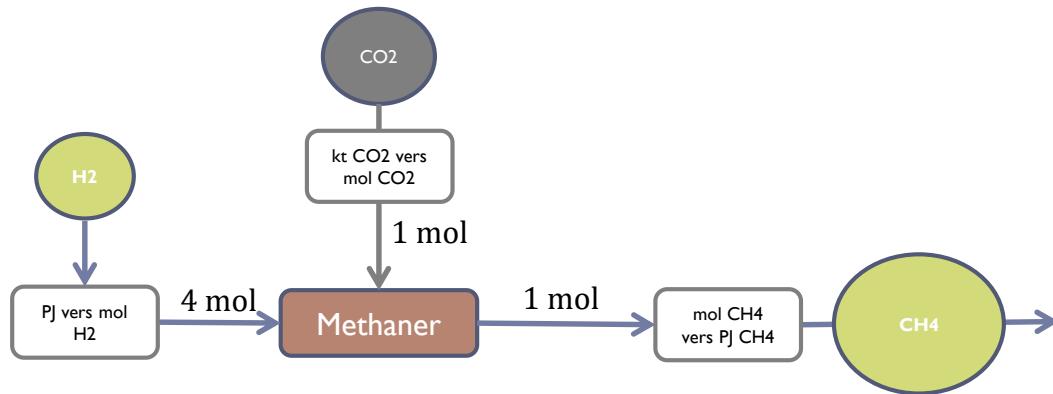


Fig. 6. Capture costs for CO₂ from industrial processes, with information from Kuramochi et al. [34].

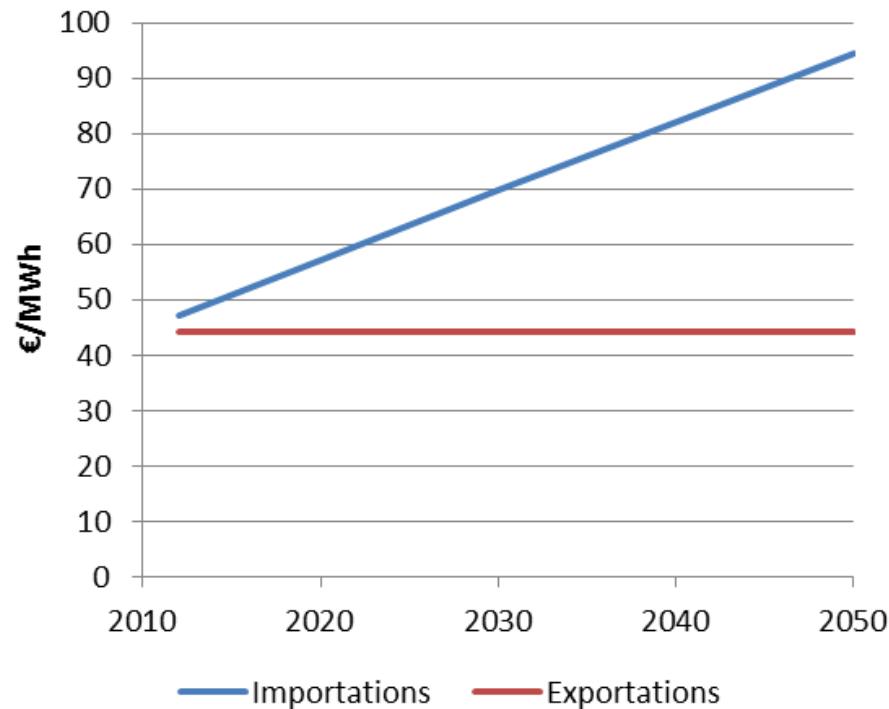
Source : Reiter et al., Evaluating CO₂ sources for power-to-gas applications – A case study for Austria, 2015

Methanation process

- ▶ Assumption : stoichiometric conditions



Electricity Import/Export



Source : Vincent Krakowski, 2016, « Renewable energy integration and power grid extension : reconciling spatial and temporal scales in long term planning exercises »