85. LCA forum "Electricity in buildings LCA“
9.11.2023, ETH Zürich

The French electricity models for buildings LCA: characteristics and effects

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Review of activities

- **Academic works**
- Herfray G., PhD, MINES ParisTech, 2011, **dynamic LCA**
- Roux C., PhD, MINES ParisTech, 2016, **consequential LCA**
- Pannier M.-L., PhD, MINES ParisTech, 2017, **uncertainties** in LCA
- Frossard M., PhD, MINES ParisTech, 2020, **prospective LCA**

- **Regulation** : draft 2020, in force 2021

Different types of tools

- **Certification, regulation**, requires a lot of details on building elements, LCA performed as a final check at the end of the design very simple calculation regarding electricity (static annual average)

- **Design aid**, LCA is more useful at early design phases (e.g. planning of urban projects, architectural sketch) when decisions have a large influence on the performance
- Requires user friendly interface, link with BIM, use of default values for less influent parameters (e.g. freight transport distance), easy comparison of alternatives (parametric variation)
- Test of several dynamic/consequential/prospective models

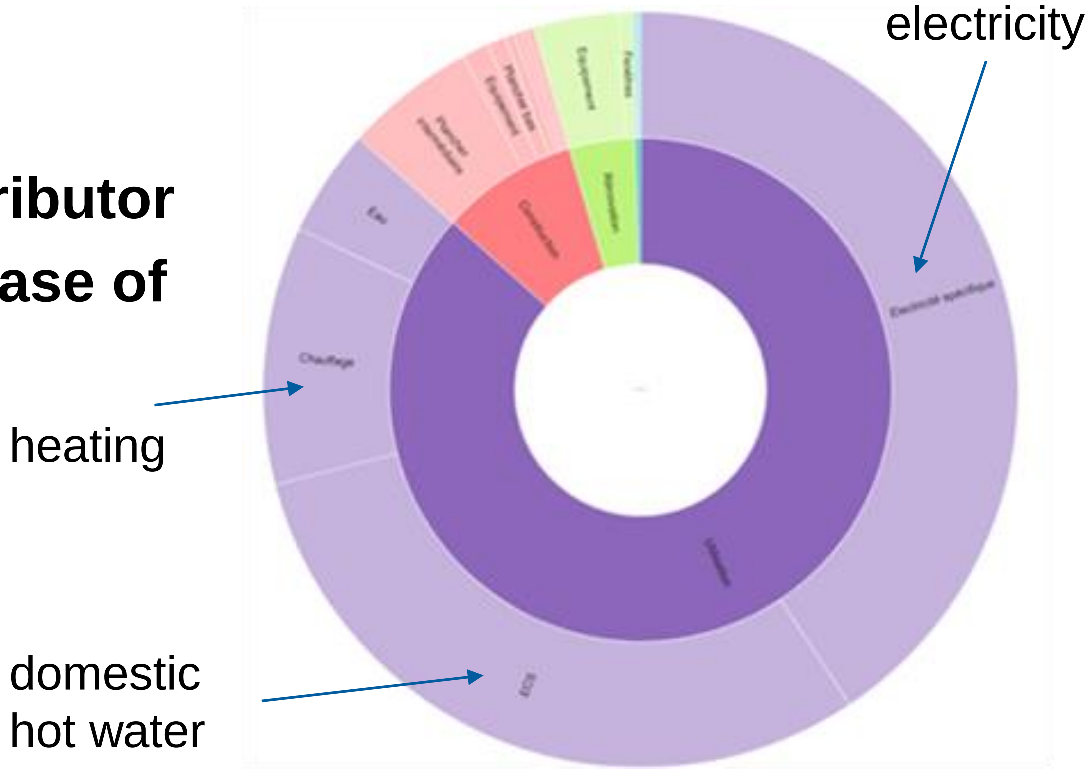
Link with energy simulation

- **Energy is an important contributor in most impacts, even in the case of low energy buildings**

Contribution analysis, CO_2 eq.

New residential building

Over 100 years



- **Many construction products influence energy performance**: insulation, but also thermal mass (masonry), painting (lighting consumption), flooring (access to thermal mass), HVAC equipment
- -> importance of linking LCA with energy simulation

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Electricity model in French regulation

- **Long term « incremental »**, hypotheses : +3 millions dwelling units heated with electricity and renovated (heating consumption 24 kWh/m^2/y) -> + 5 TWh electricity consumption
  Corresponding emissions increase on a European scale = 0,4 million ton CO_2 eq. -> 80 g / kWh electric heating (source : ADEME)

- **Short term : Use dependent (law of 4 August 2021)**

		Kg CO_2 eq. / kWh
Électricité chauffage	Heating	0,079
Électricité refroidissement	Cooling	0,064
Électricité ECS	Domestic hot water	0,065
Électricité éclairage tertiaire	Lighting (tertiary)	0,064
Électricité éclairage habitation	Lighting (dwelling)	0,069
Électricité autres usages	Other uses	0,064

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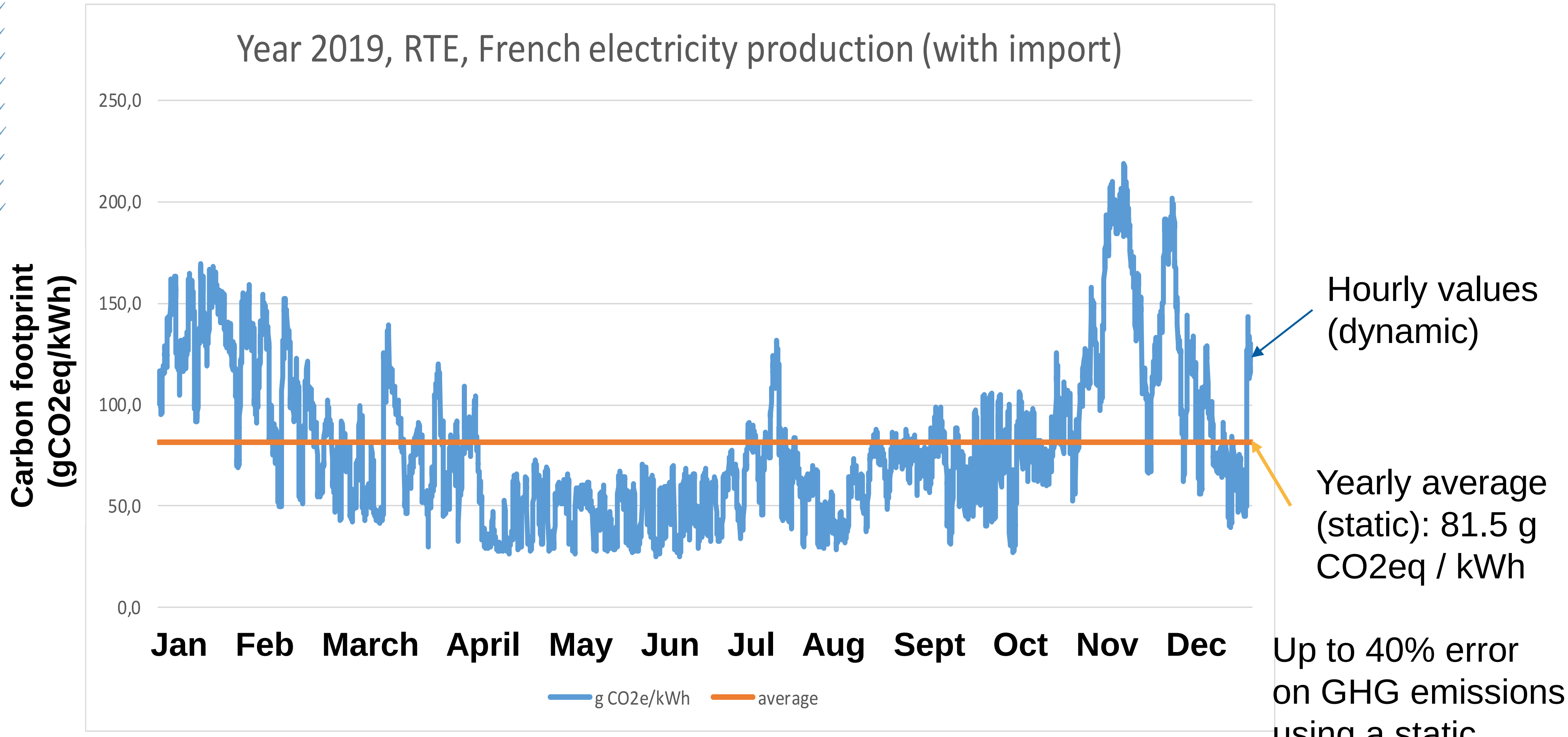
Electrical system, short term dynamic LCA



Up to 40% error on GHG emissions using a static approach

Average 111 g CO_2eq / kWh heating use (+ 36% compared to static)

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Electrical system model (Charlotte Roux)

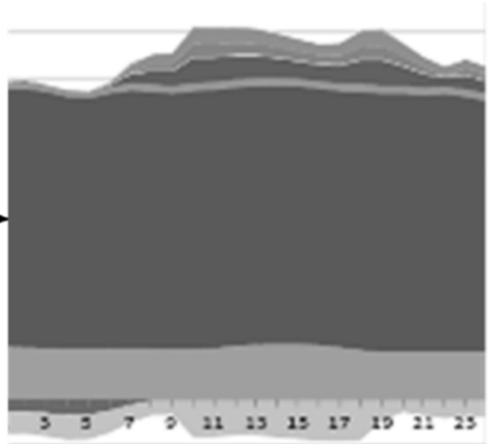
Roux, C. et al., Development of an electricity system model allowing dynamic and marginal approaches in LCA, Int. Journal of LCA, 2017

Installed Capacities
Hydraulic resources

Demand
- Nat. Demand
- Pumped storage
- Export

Technologies availabilities
Technologies efficiencies
Merit order
Technocal constraints
Technology type (base load, peak)

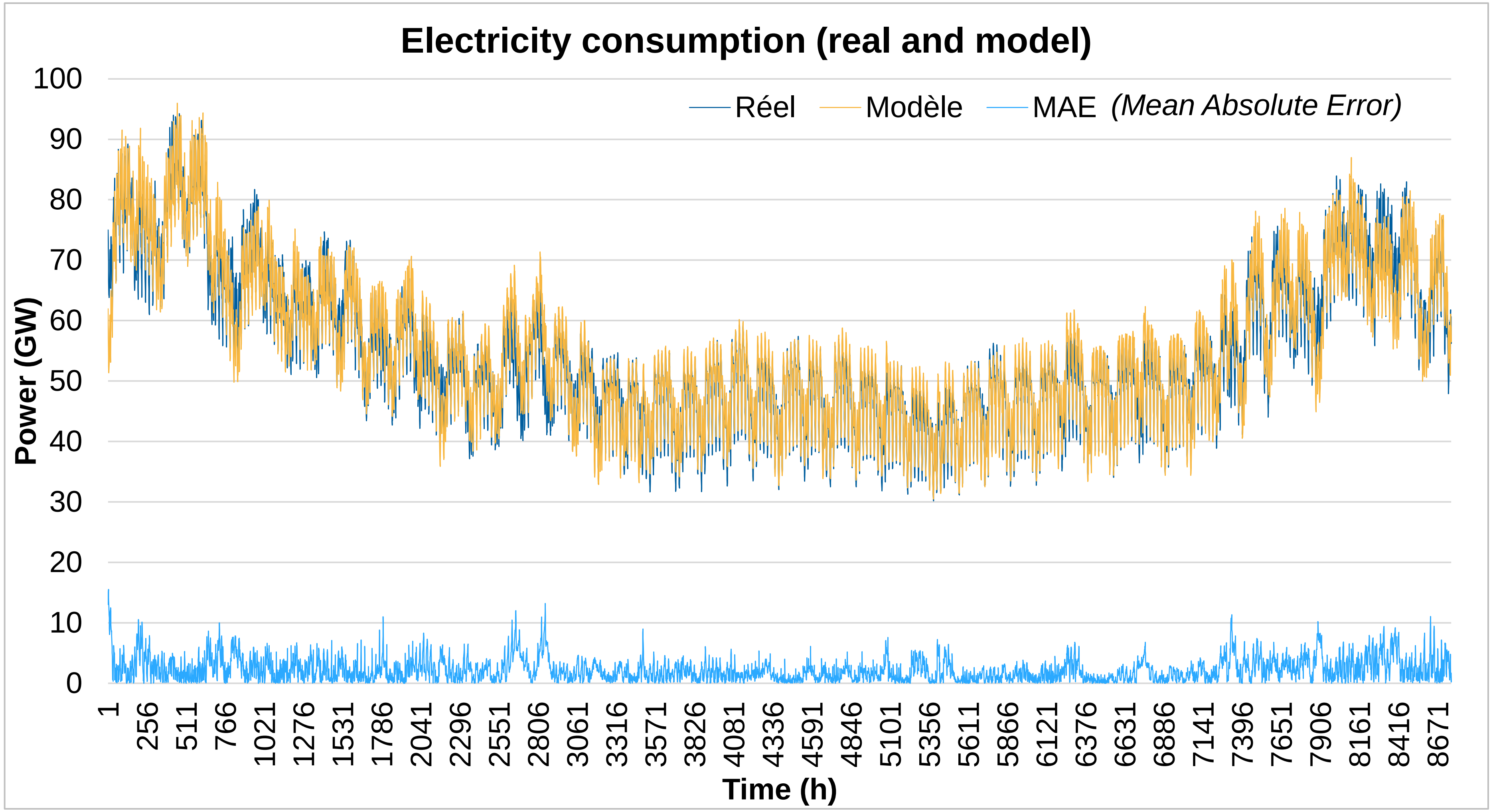
Dispatchable technologies



Non-dispatchable technologies

Physical model (solar, wind) using climatic data, neural network based upon historical data (exchange), merit order for dispatchable technologies (some hydro,nuclear, gas, coal)

Model validation, year 2017



Frapin M., Roux C., Assoumou E., Peuportier B., 2021. Modelling long-term and short-term temporal variation and uncertainty of electricity production in the life cycle assessment of Buildings, Applied Energy, https://doi.org/10.1016/j.apenergy.2021.118141

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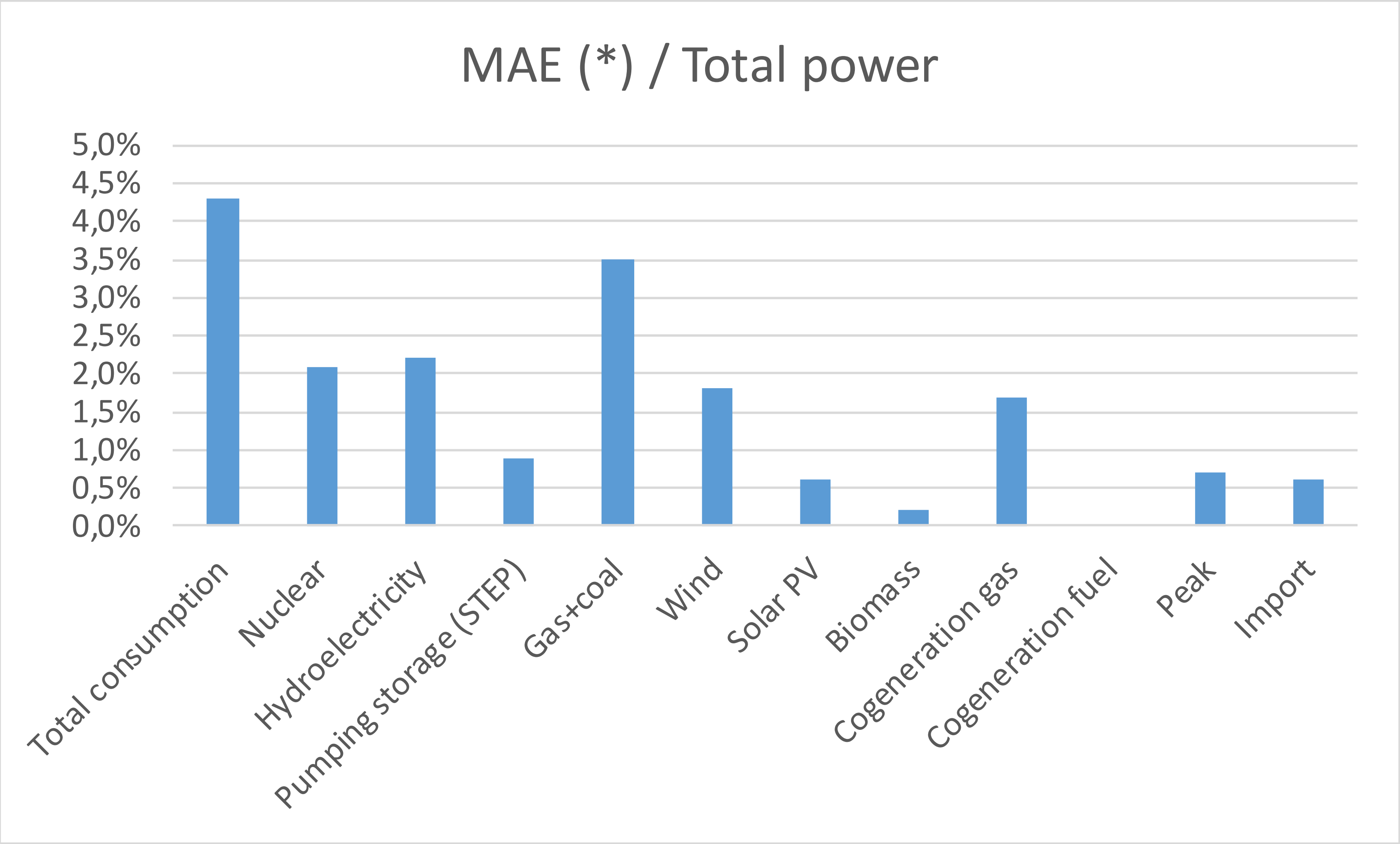
Model validation, year 2017



(*) *Mean Absolute Error*

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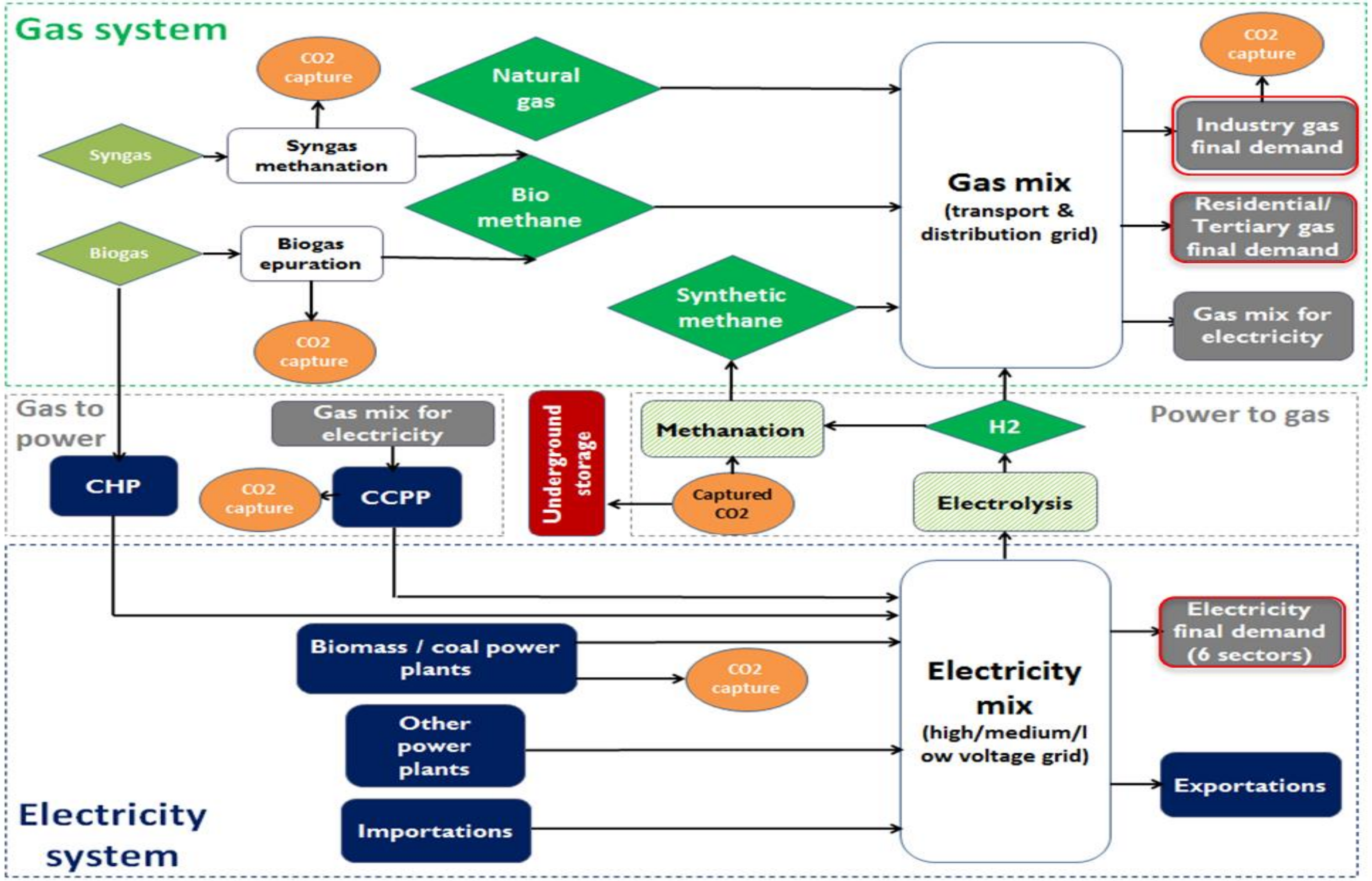
Long term dynamic LCA, scenarios

- French Transmission System Operator (RTE), 2050
  - M0: 100% renewable energies
  - M1: 87% RE diffuse
  - M23: 87% RE big farms (e.g. offshore wind)
  - N1: 74% RE and new nuclear reactors
  - N2: 63% RE and new nuclear reactors
  - N3: 50% RE and new nuclear reactors

- French Environmental Agency (ADEME)
  - 2035 and 2050, 100% RE but still import
  - hourly values -> usable in dynamic LCA

Long term dynamic LCA, model

- TIMES : bottom-up linear optimization models



Frapin M. et al., Applied Energy, 2021

Parameters:

30, 100 €/t CO2
0 carbon 2060 or 2050

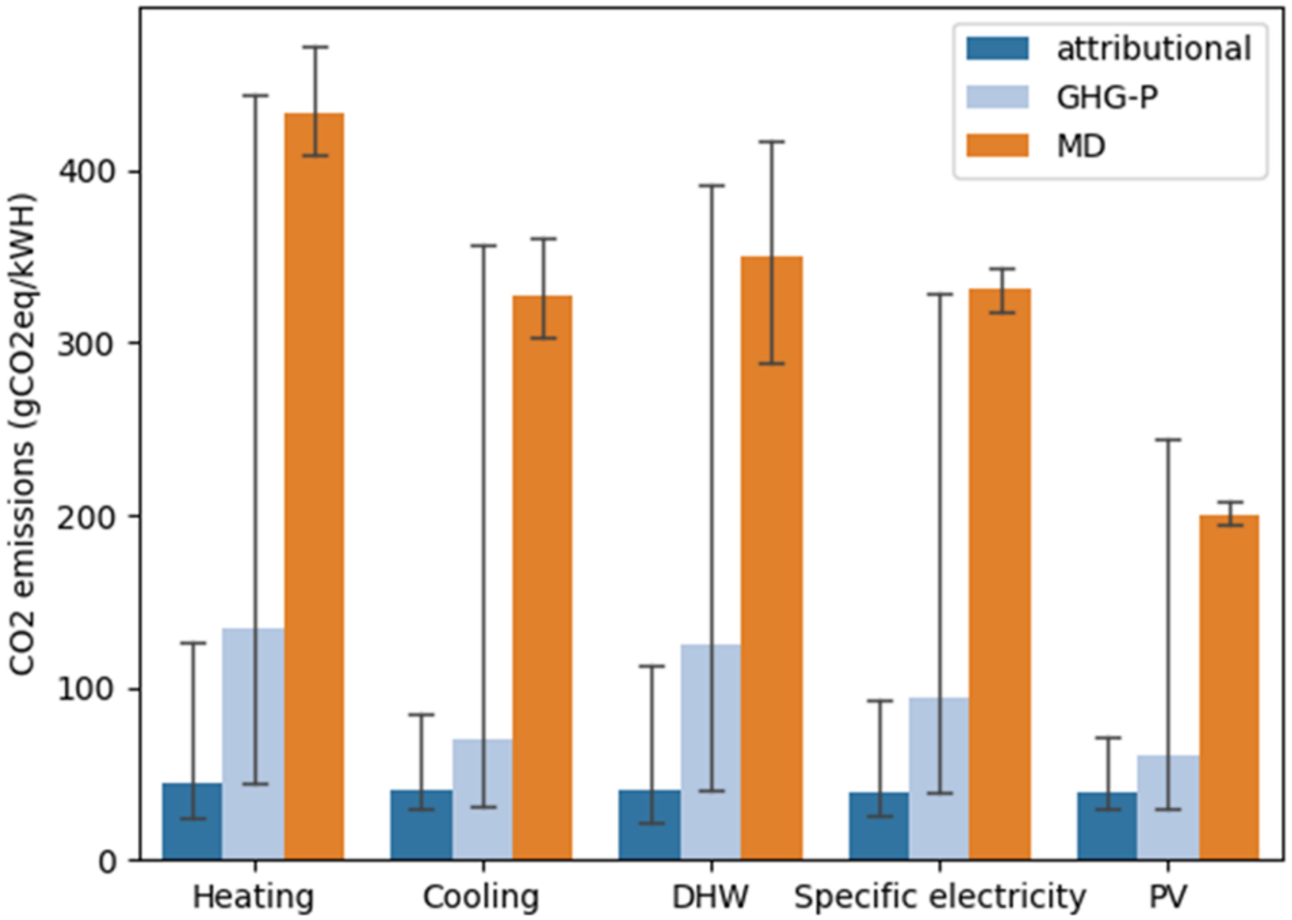
RE versus nuclear

+/- demand response

-> 48 scenarios
12 months
x 2 days (week, WE)
x 24h

Long + short term dynamic LCA, model

- 4 uses + PV production, 3 methods



Attributional LCA

Consequential LCA
GHG-P = greenhouse gases protocol (10% top merit order)
MD = marginal derivative mix (single building additional demand)

Uncertainties correspond to all studied long term scenarios (Times), ADEME as a reference

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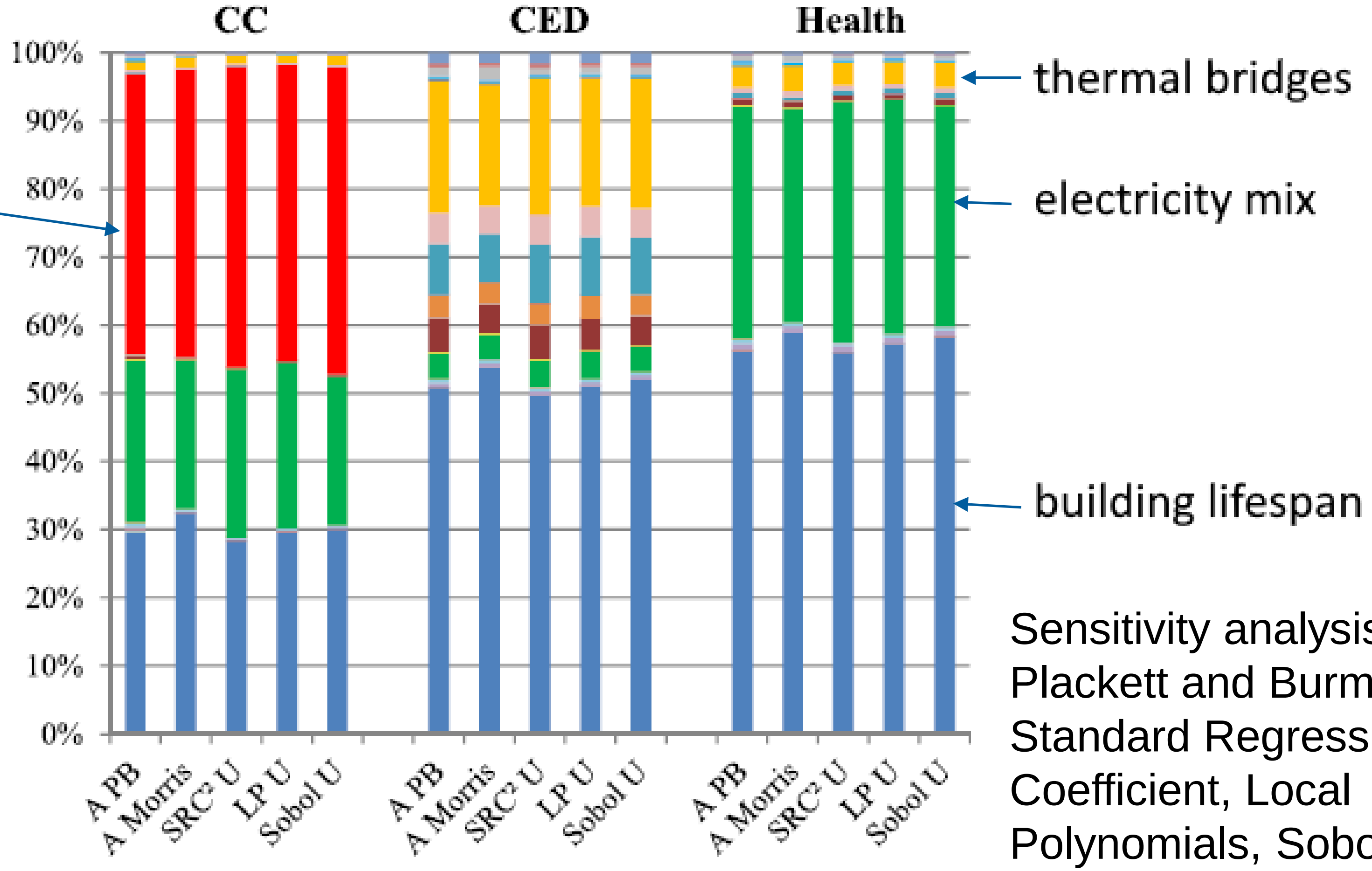
Sensitivity analysis

- Identification of the most important parameters (impacts / m^2.year)
- M.-L. Pannier et al., J. Cleaner Production, 2018

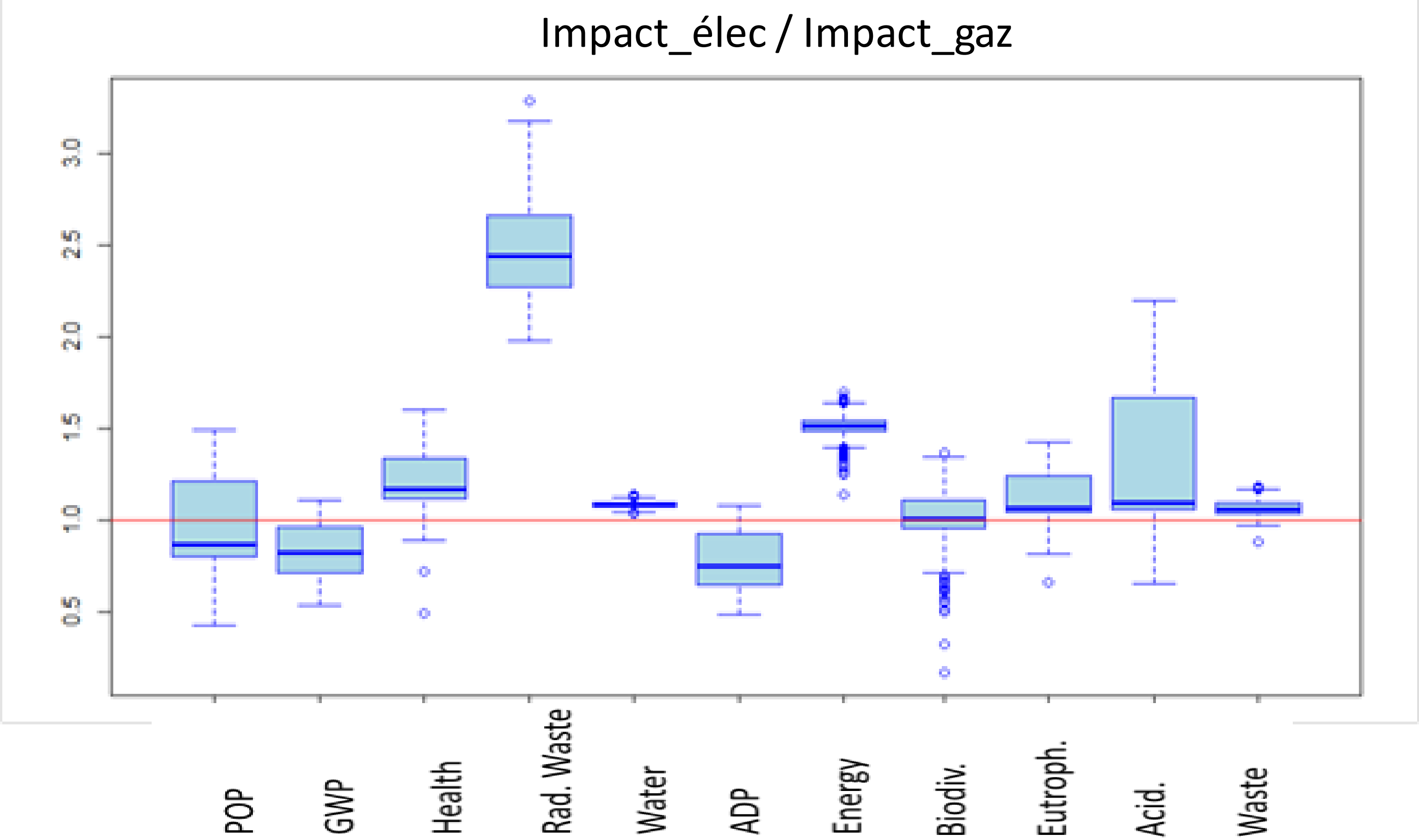


Case study: passive house

Sensitivity analysis methods: Plackett and Burman, Morris, Standard Regression Coefficient, Local Polynomials, Sobol

Uncertainty analysis

- Example : comparing gas and electric heating
- Probability distribution, Uncertainty propagation (Monte Carlo)
- Influence on the comparaison of alternatives (ex. gas/electric heating)



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Conclusions and perspectives

- Electricity is still a high contributor in GhG emissions
- Problem of peak demand
- Dynamic LCA models (proper modelling, no discounting)
- Uncertainty on long term scenarios
- Consequential LCA is more relevant as a decision aid, but induces higher uncertainty (marginal processes)
- Indicators: climate but also health, biodiversity, resources…
- Perspectives : compare electrical heat pumps versus biogas or district heating with renewables

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QUESTIONS ?

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