



HAL
open science

Strategies for decarbonisation of a heat district network using an optimization tool: Application to Grenoble city

Thibaut Wissocq, Loïc Giraud, Gilles Lavialle, François Boudehenn

► To cite this version:

Thibaut Wissocq, Loïc Giraud, Gilles Lavialle, François Boudehenn. Strategies for decarbonisation of a heat district network using an optimization tool: Application to Grenoble city. Smart Energy System Conference 2023, Sep 2023, Copenhagen, Denmark. cea-04774777

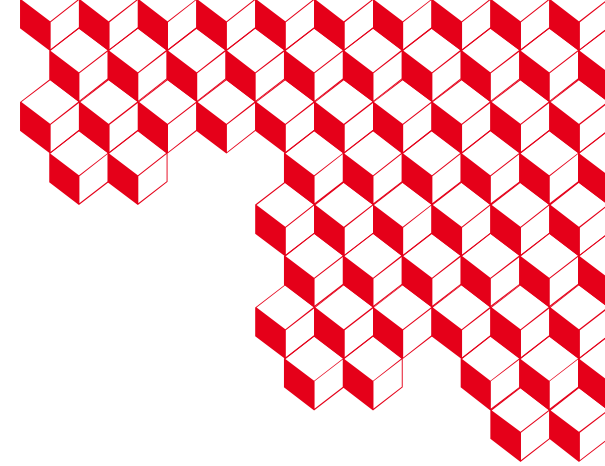
HAL Id: cea-04774777

<https://cea.hal.science/cea-04774777v1>

Submitted on 8 Nov 2024

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



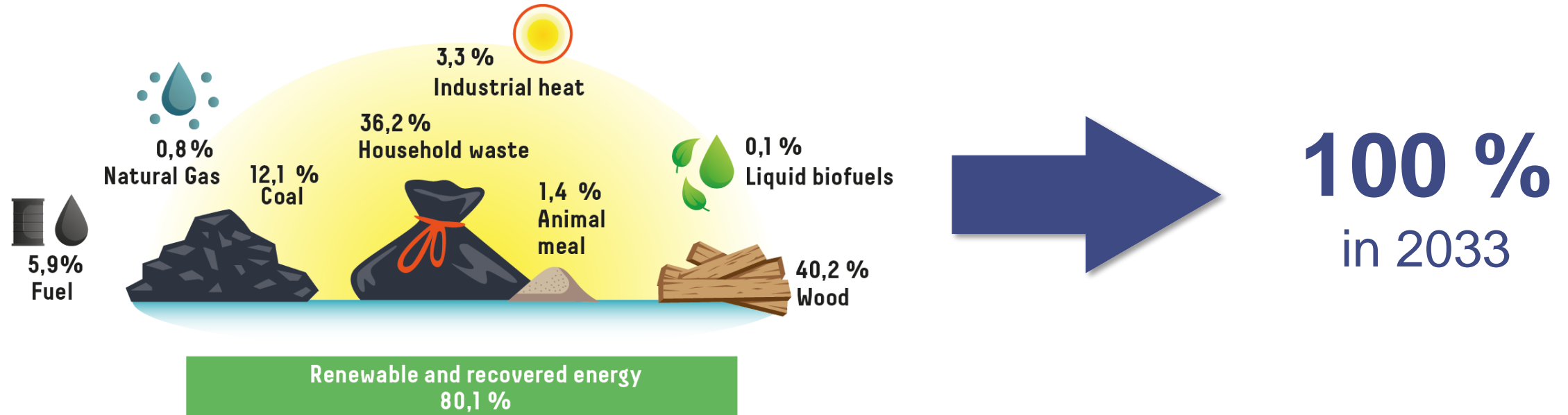
Strategies for decarbonisation of a heat district network using an optimization tool: Application to Grenoble city

Thibaut Wissocq (CEA), Gilles Laviale
(CEA), François Boudehen (CEA), Loïc
Giraud (CCIAG)

Context : Grenoble district heating

Case study based on the district heating of Grenoble (French Alps)

- ▶ Second French district heating (777 GWh delivered, 1/3 of the urban area)
- ▶ 5 plants (biomass, house-hold waste, gas, coal and industrial waste heat)

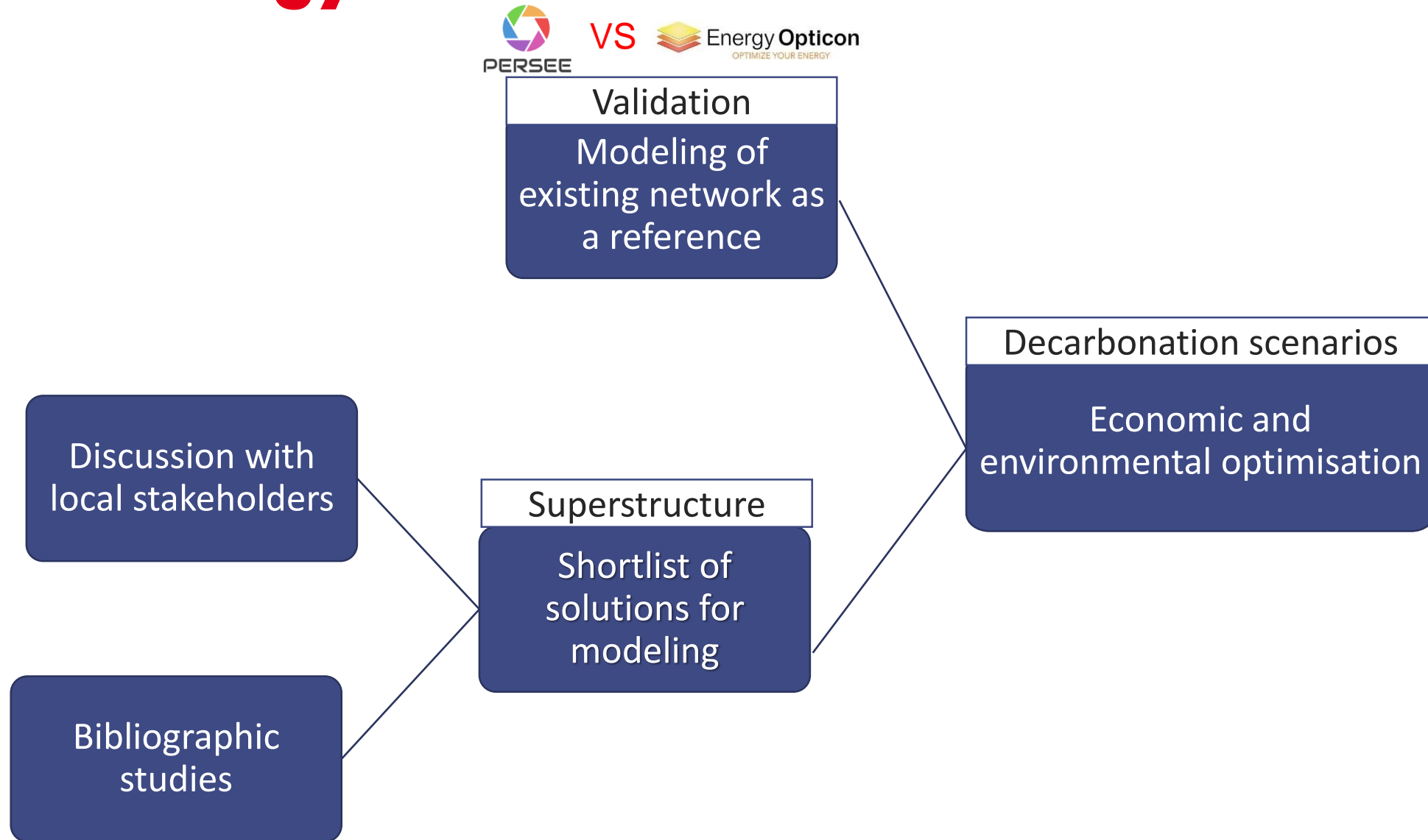


Objectives



- ▶ Conduct prospective studies
- ▶ Study and model decarbonization scenarios
- ▶ How we can reach 100% renewable energy?

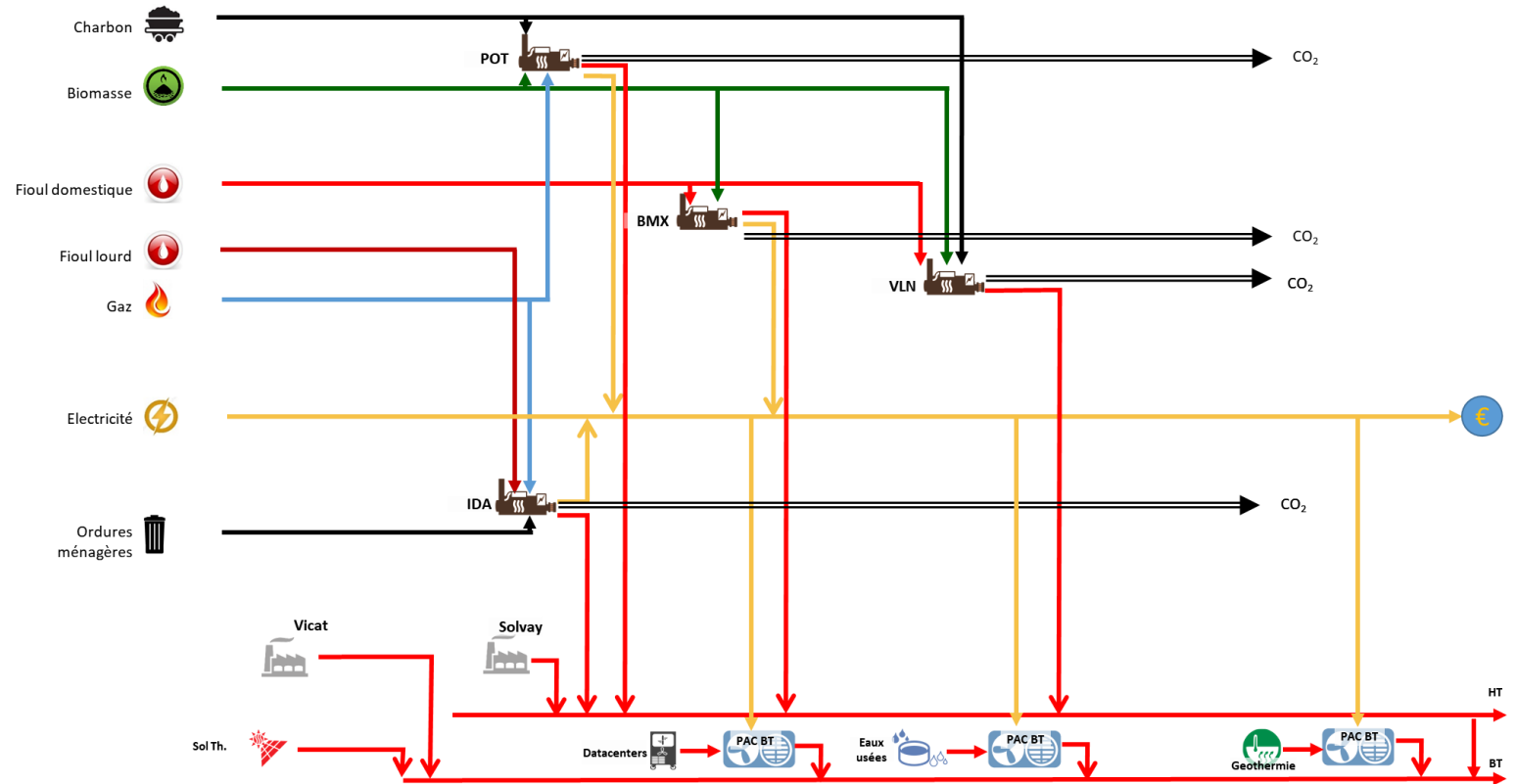
Methodology



Superstructure

Selection of technical solutions :

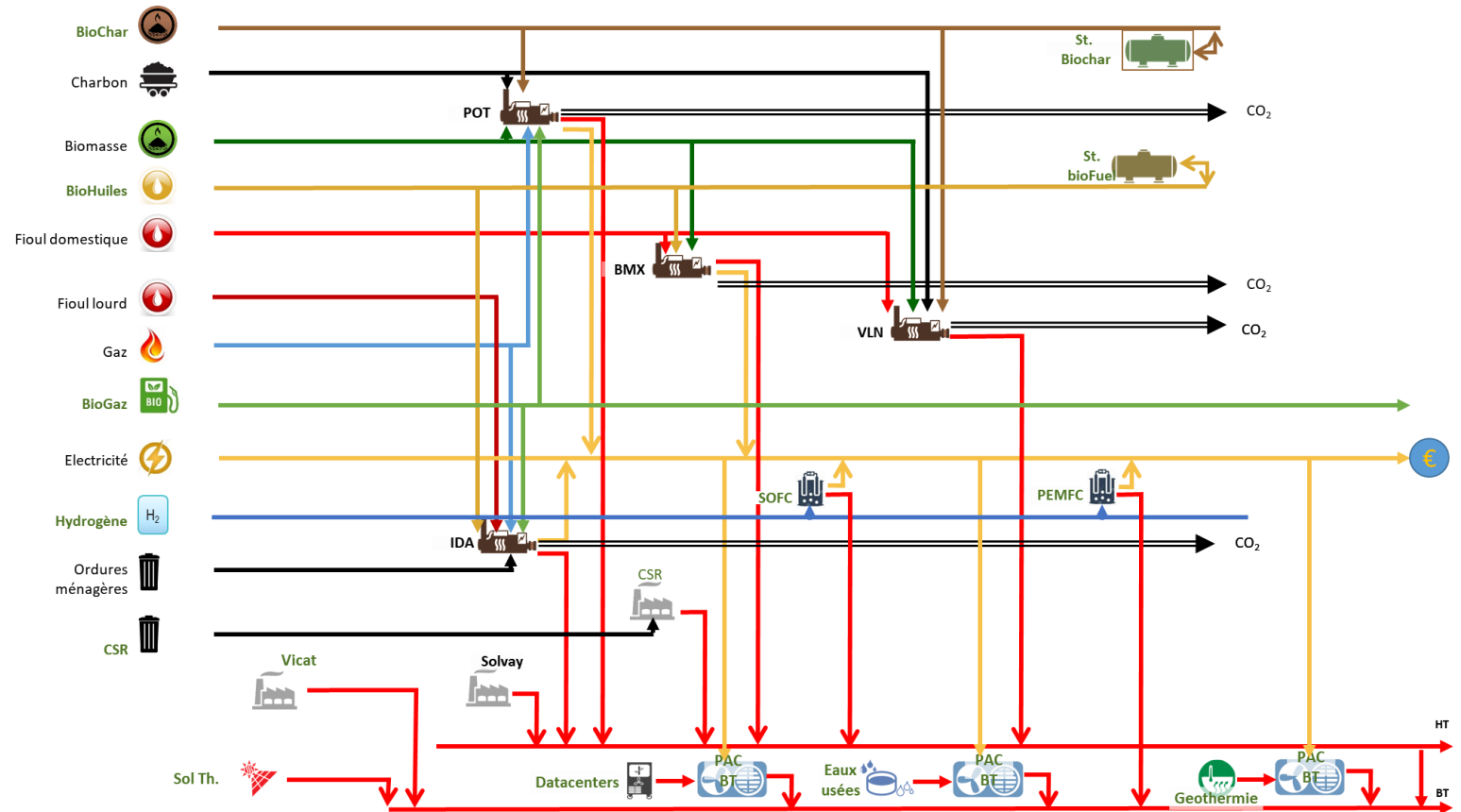
- **Fatal energy** (direct used or upgraded by heat pump): industrial waste heat, datacenters or sewage heat recovery
- **REN** : solar thermal, geothermal



Superstructure

Selection of technical solutions :

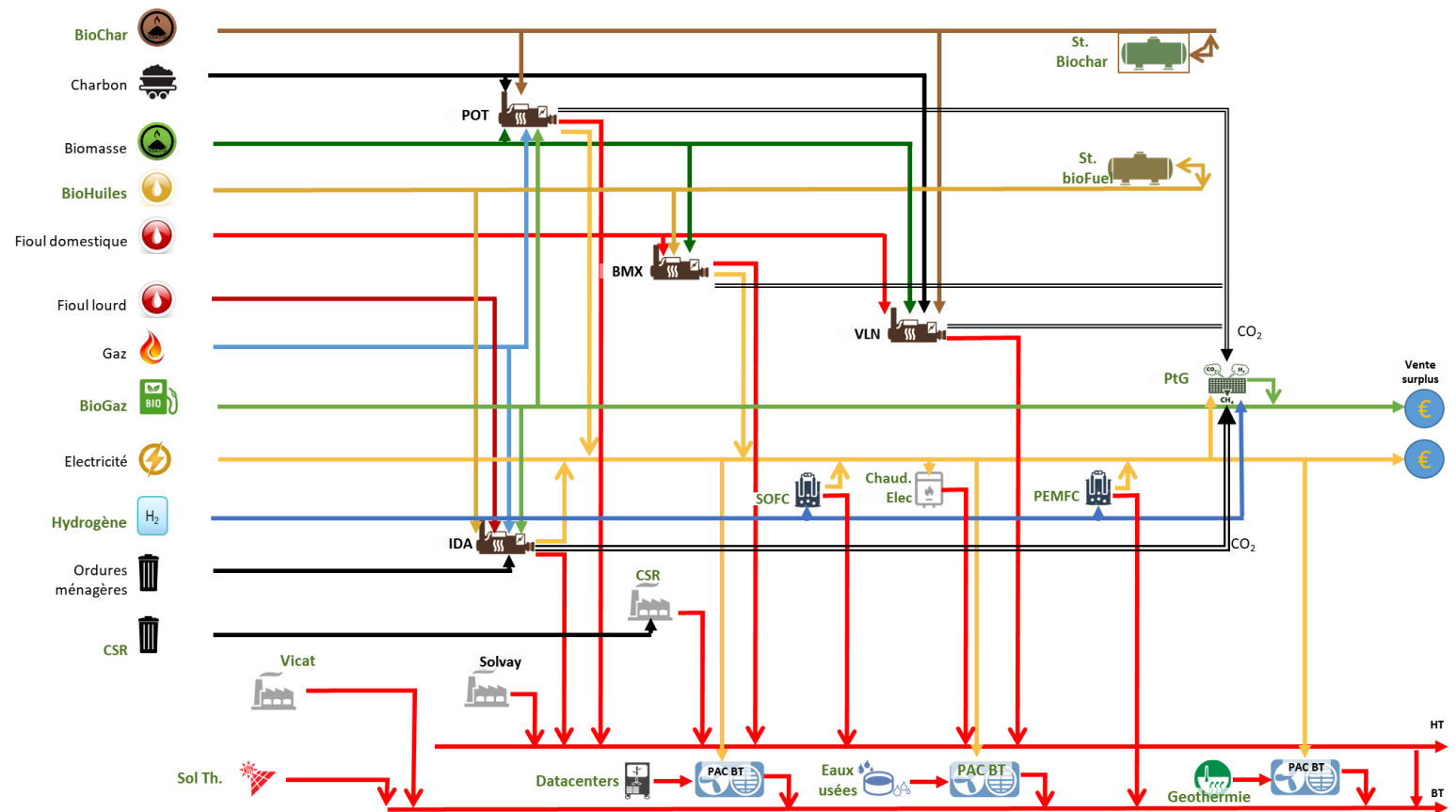
- **Fatal energy** (direct used or upgraded by heat pump): industrial waste heat, datacenters or sewage heat recovery
- **REN** : solar thermal, geothermal
- **Low carbon energy** (biogas, hydrogen, bio-oil, solid recovered fuel)



Superstructure

Selection of technical solutions :

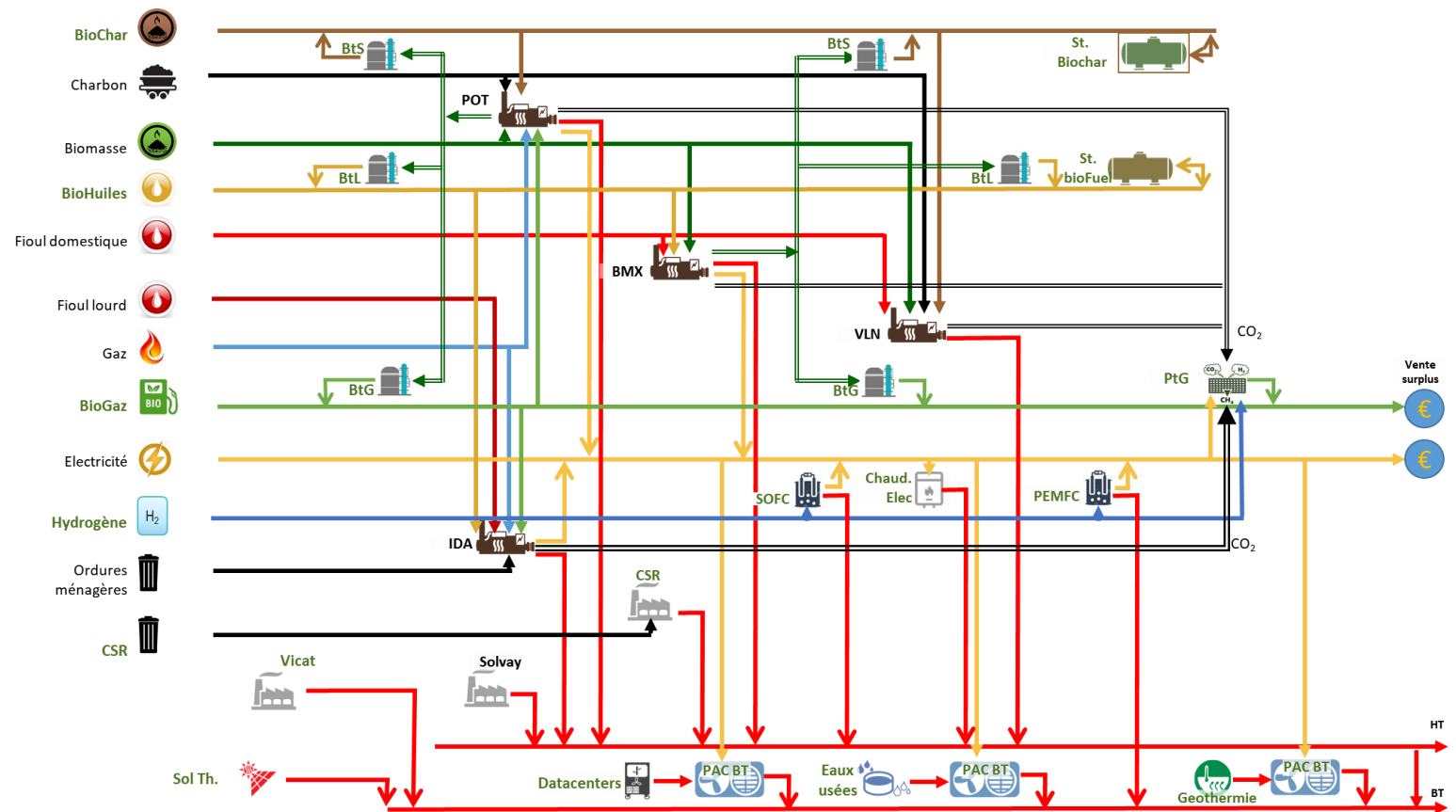
- **Fatal energy** (direct used or upgraded by heat pump): industrial waste heat, datacenters or sewage heat recovery
- **REN** : solar thermal, geothermal
- **Low carbon energy** (biogas, hydrogen, bio-oil, solid recovered fuel)
- **Energy conversion**
 - Power-to-Heat
 - CO₂ (capture and methanation)



Superstructure

Selection of technical solutions :

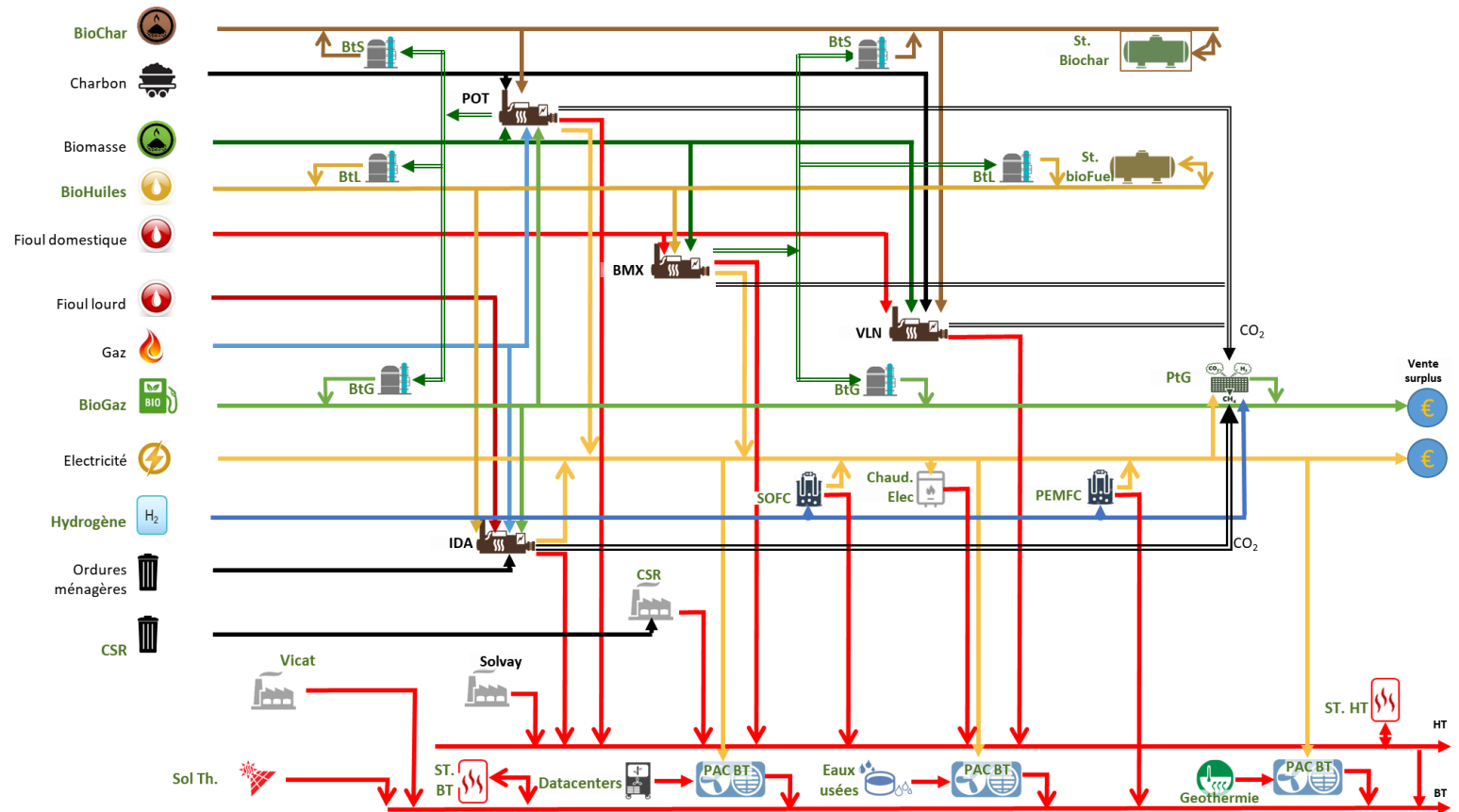
- **Fatal energy** (direct used or upgraded by heat pump): industrial waste heat, datacenters or sewage heat recovery
- **REN** : solar thermal, geothermal
- **Low carbon energy** (biogas, hydrogen, bio-oil, solid recovered fuel)
- **Energy conversion**
 - Power-to-Heat
 - CO₂ (capture and methanation)
 - Biomass-to-X



Superstructure

Selection of technical solutions :

- **Fatal energy** (direct used or upgraded by heat pump): industrial waste heat, datacenters or sewage heat recovery
- **REN** : solar thermal, geothermal
- **Low carbon energy** (biogas, hydrogen, bio-oil, solid recovered fuel)
- **Energy conversion**
 - Power-to-Heat
 - CO₂ (capture and methanation)
 - Biomass-to-X
- **Energy storage**
 - Short & long term storage
 - Building thermal inertia



Optimisation approach in Persee



Persee :

- Modelling tool for **optimal design** and **control** of multi-energy systems
- MILP formalism with Cplex solver
- All kind of operational constraints (ramp, stand-by time, etc)

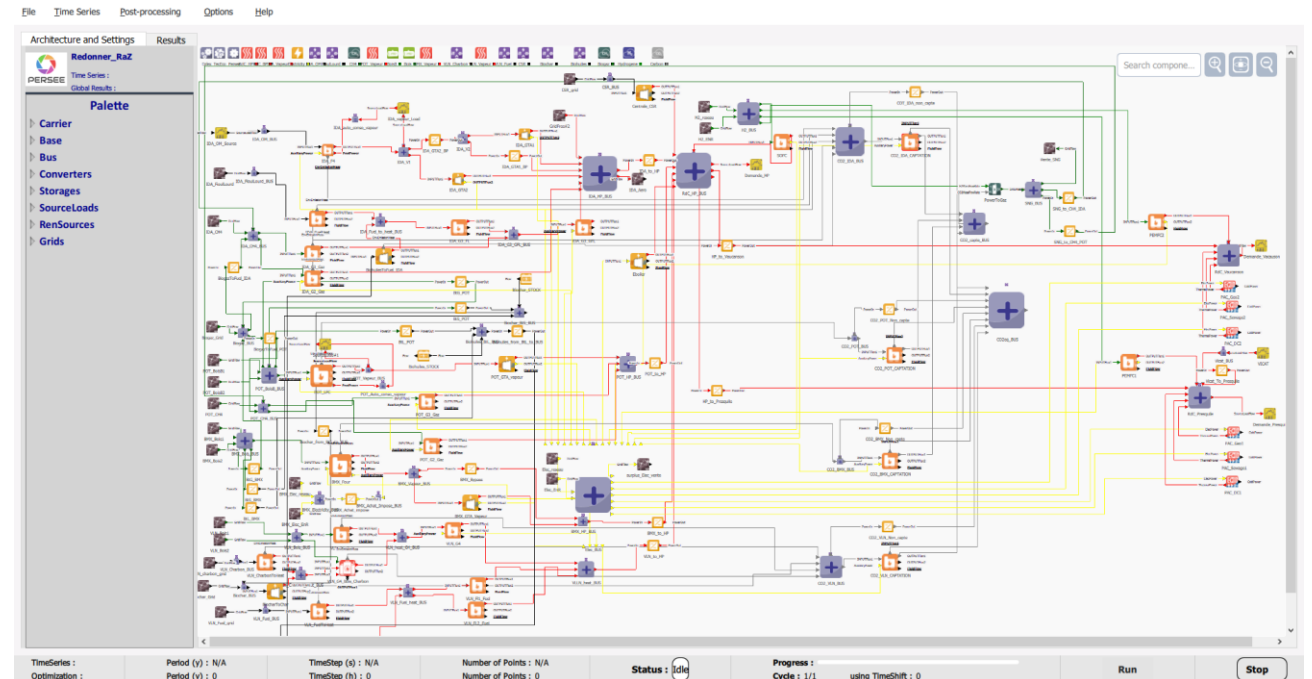
Integration of 17 solutions (associated with their technical, economic and environmental hypothesis)

➤ Some key figures of the model :

- 966 000 equations/constraints
- 695 000 variables
- Precision : ~ 1 %

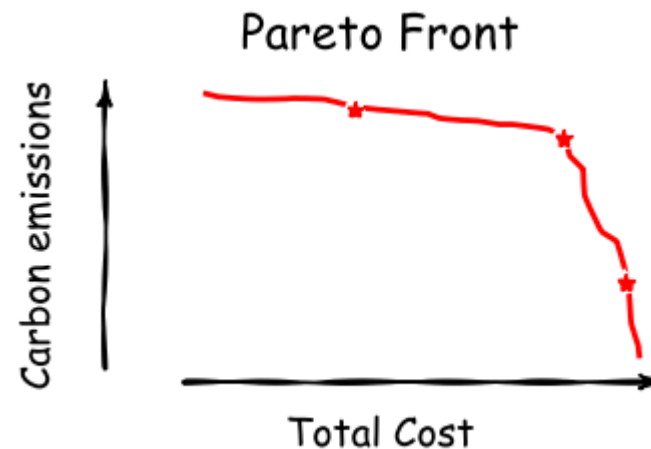
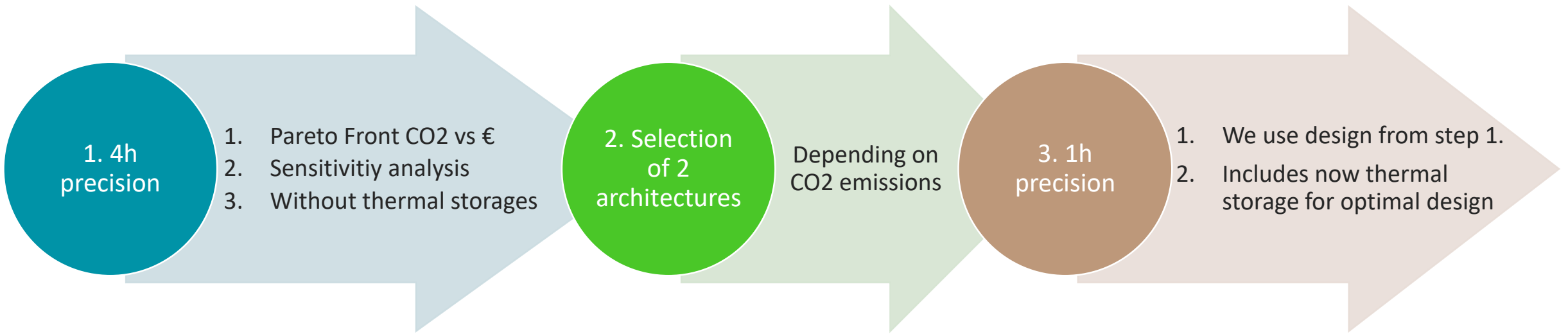
➤ Computational tractability challenge

➤ Progressive calculation with increasing complexity



Optimisation approach

To overcome computational difficulties, a 3-step methodology is applied:



Optimisation approach – Pareto front

Mono objective optimization of a cost function considering different **GHG emission constraints**

Total cost function :

$$Cost[€] = \sum_{el} \left[Capex(size) + \sum_y \frac{Opex}{(1+r)^y} \right]$$

- **Capex:** $CAPEX_{nom} \cdot \left(\frac{Size}{SIZE_{nom}} \right)^{0,7}$ modelled by a piece-linear function
- **Opex:** operational expenditures for maintenance, operation and energy

GHG emission:

$$CO_2[g_{CO_2eq}] = CO_2^{grey} + CO_2^{fuel} - CO_2^{captured}$$

- CO_2^{grey} : indirect CO₂-equivalent emission (infrastructures, electricity, biomass, ...)
- CO_2^{fuel} : direct CO₂ emission from fuel combustion (oil, gas, coal)
- $CO_2^{captured}$: captured emission from Carbon Capture installation (if any)

Sources:

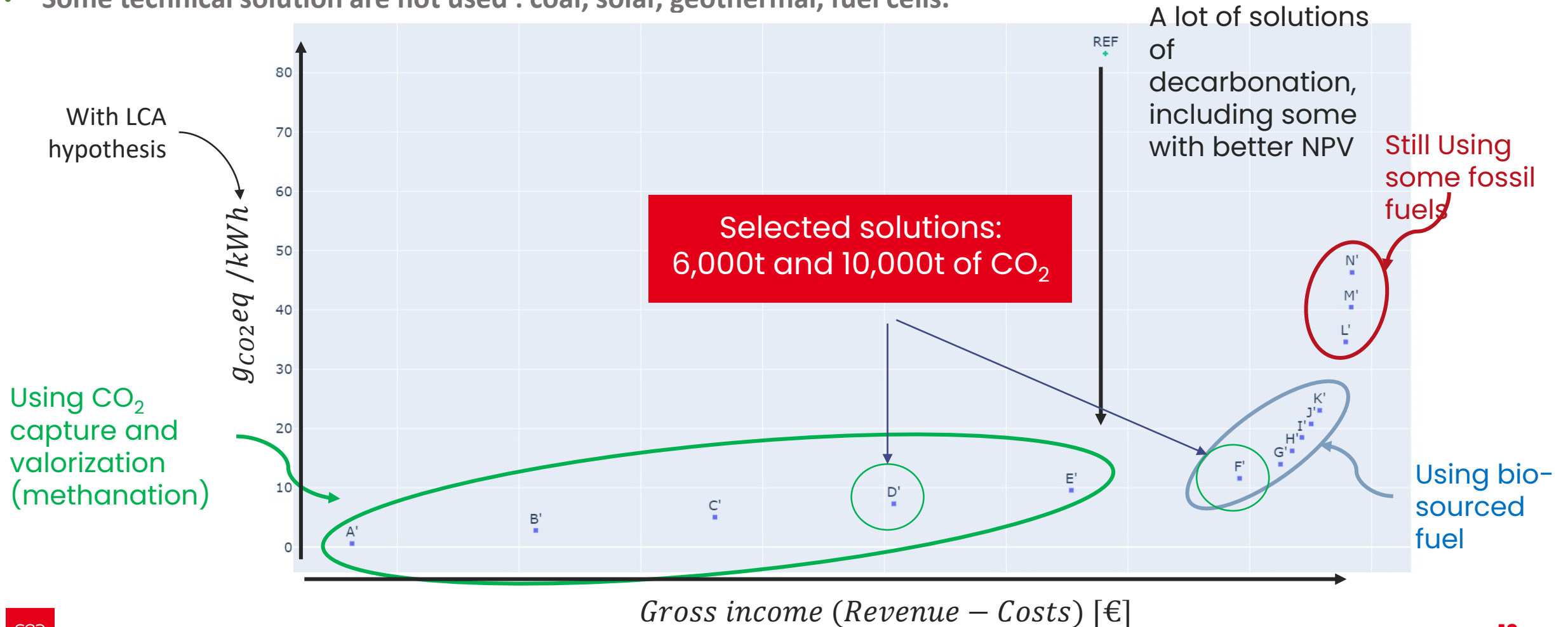
Technical data : CEA experts, Danish Energy Agency

Economic data : Industrial partner

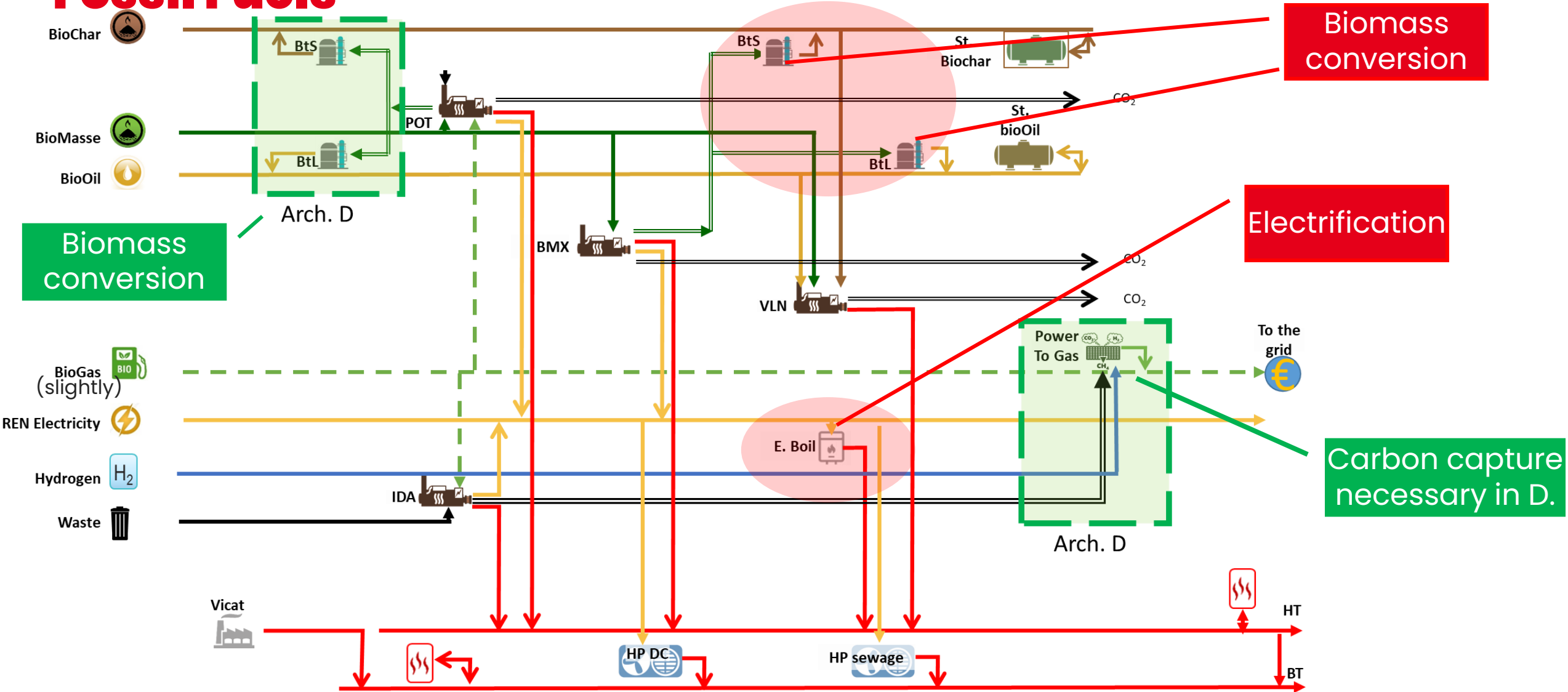
Environnemental data : FEDENE and Ademe carbon base

Results: Pareto front (4h time step)

- 14 optimizations under carbon emission constraints
- 3 main different architectures depending on carbon emission
- Some technical solution are not used : coal, solar, geothermal, fuel cells.

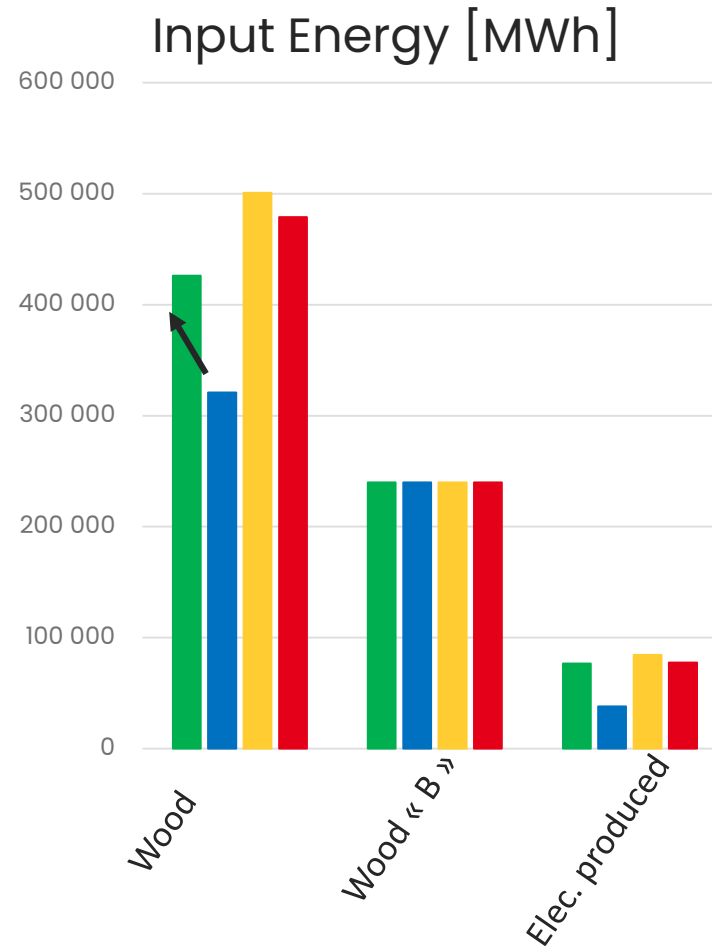
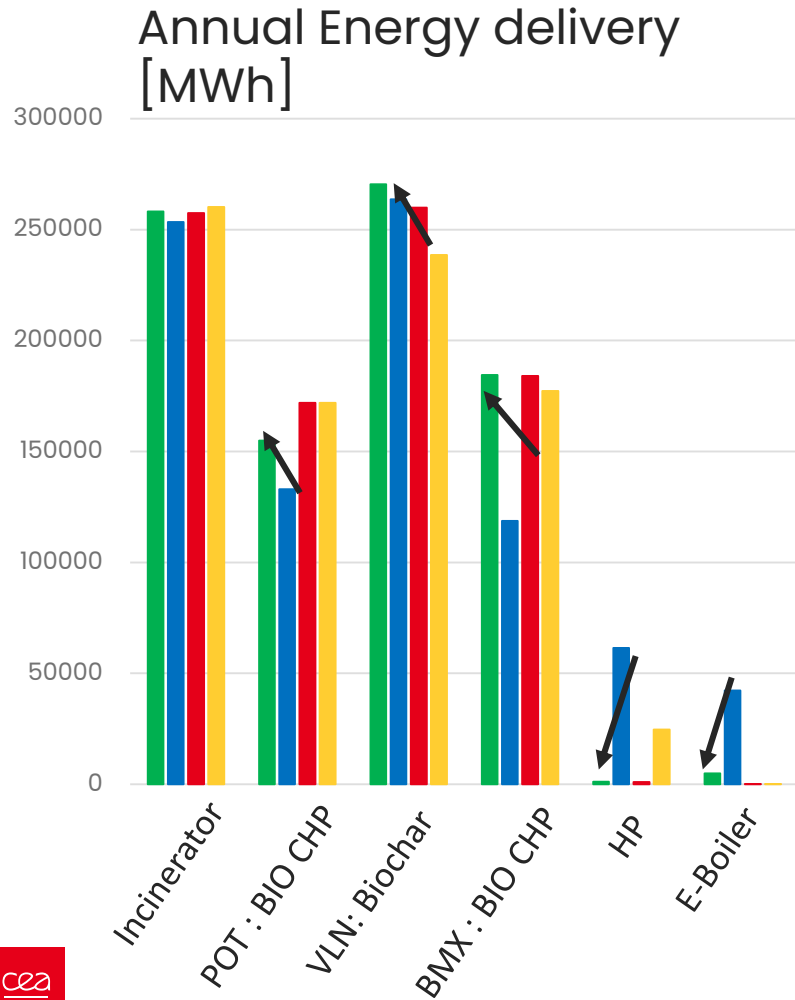


4. Look on results: D and F are almost similar without Fossil Fuels



Results at 1h time-step: Influence of thermal storage

Remind: design comes from 4h time step



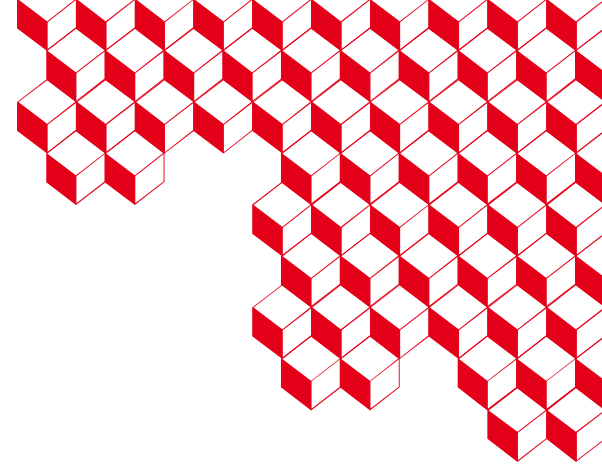
Impact of thermal storage :

- **Less electrification** (e-boiler, HP)
- More **biomass utilisation**
- **Extensive use of CHP biomass**
- Greater amount of **electricity** is produced and sold

Conclusions and perspectives

Main goal : Decarbonate the Grenoble District Heating system by 2033

- Main conclusions
 - Many studies of the district heating have been conducted
 - 3 solution trends identified based on carbon emissions
 - Carbon capture is necessary below 10gCO₂/kWh
 - Bio-source energies are important
 - Great impact of thermal storages on CHP use
- Perspectives
 - Model still hard to manipulate : efforts on simplification, new optimization methods
 - In discussion with the stakeholder for more detailed studies :
 - Thermal inertia,
 - Carbon capture + PtX
 - Biomass conversion



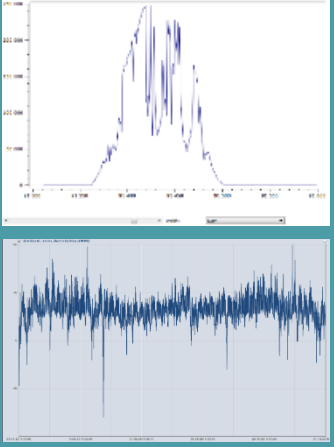
**Thank you,
questions ?**

thibaut.wissocq@cea.fr

Backup: oPTimizER for System Energy management



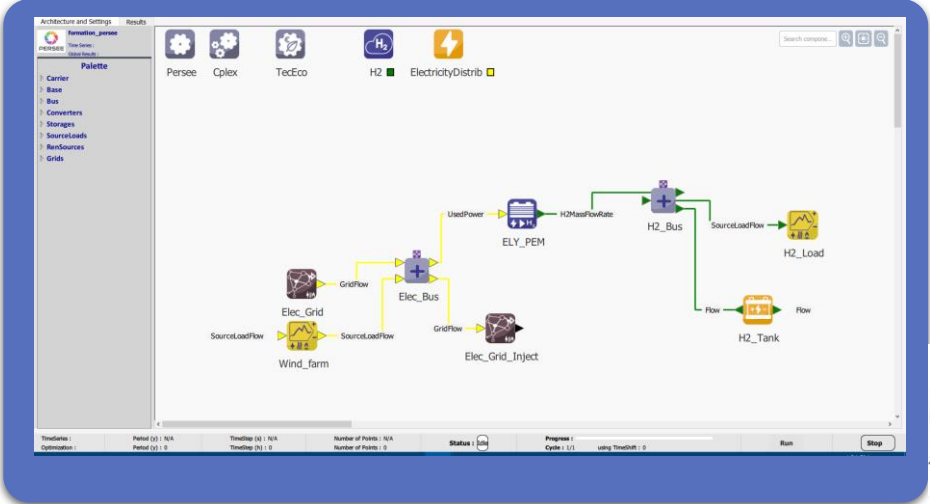
Input Data



- Energy Sources
- Load Profiles

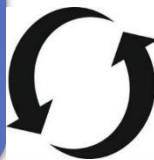
- Technical and economical data & hypothesis
- Local / global Constraints & Opportunities

System description with component library assembling

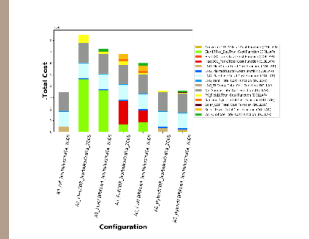
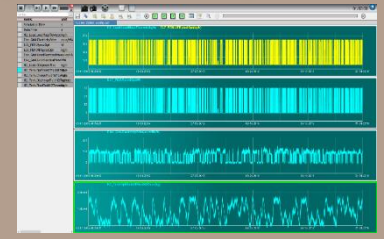
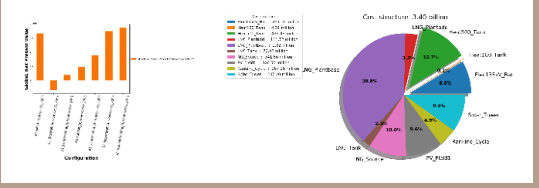


Minimization of the cost objective function

- With system constraints
 - Demand, availability
 - CO₂ emissions
 - With component constraints
 - Capex, Opex
 - Technical and operational constraints
- ☺ All energy carriers
 - ☺ System design in dynamic transients
 - ☺ Predictive Control

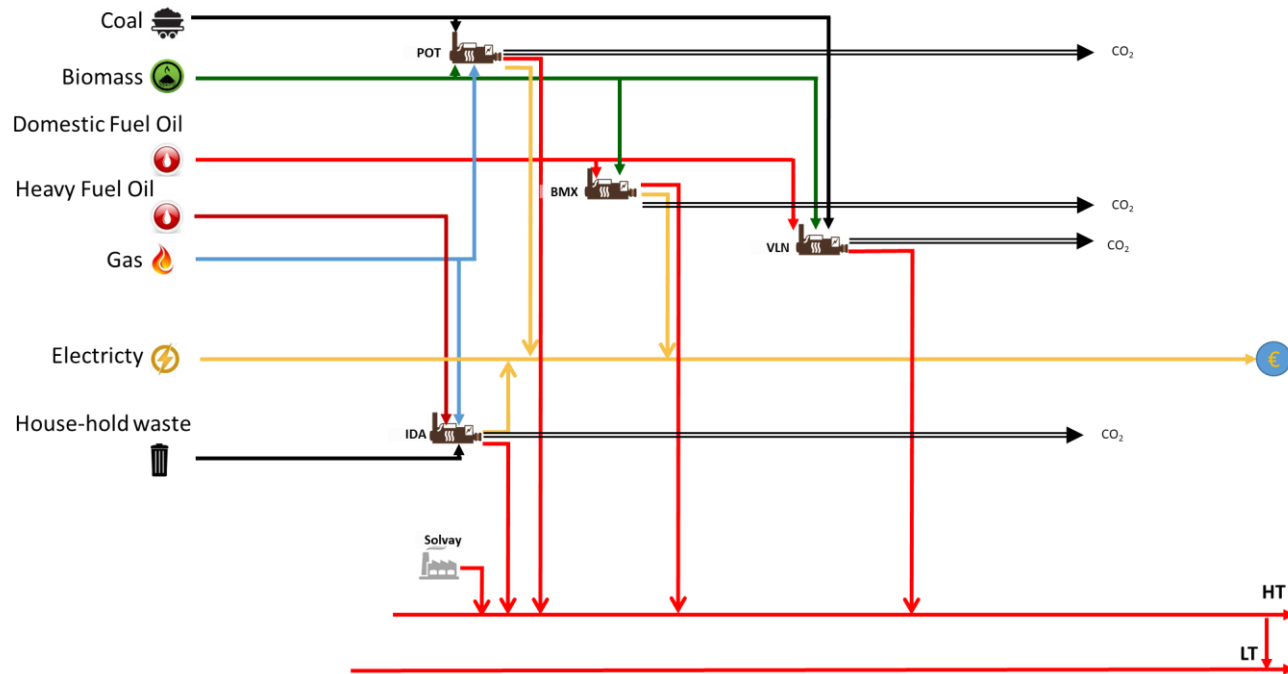


System analysis

- Optimal capacities
 
- Component dynamic operation
 
- Performance and Cost breakdown
 
- Sensitivity & Uncertainty analysis

Modeling of existing network

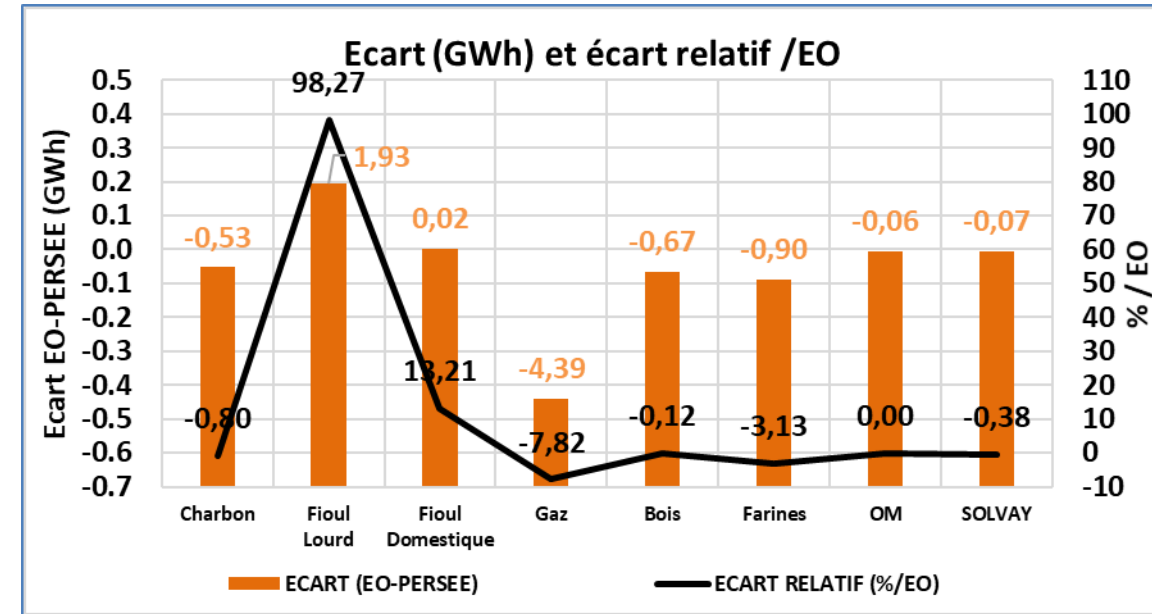
Current district heating network



- ✓ Extraction of real technical data for each plant
- ✓ Precise modelling of each thermal power plant
- ✓ Comparison EO vs PERSEE

Some Key figures :

- 777 GWh delivered (High and low pressure)
- 87 g_{CO₂ eq./kWh}
- 80% of REN&R energy
- 20% : fuel, natural gas & coals



Absolute and relative difference between EO and Persee

✓ Persee model validated