Evaluation of scenarios for an energy, economic and social transition of the Fessenheim region (ESTEES project)*

Florian LABAUDE[1], PhD student

Thierry de LAROCHELAMBERT[2], Associate researcher

Nadège BLOND[1], CNRS Research director

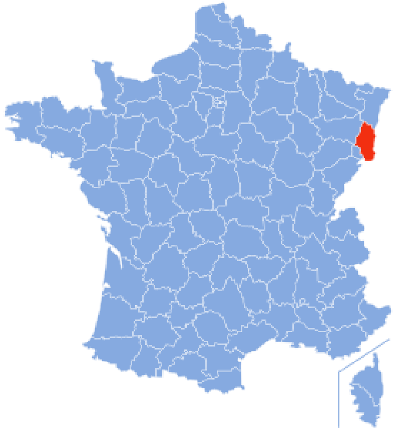
[1] LIVE CNRS (Unistra)

[2] FEMTO-ST Institute (Energy Dpt)

Assessment of the energy system Haut-Rhin

the Fessenheim territory

- 2020: closure & decommissionning of the Fessenheim NPP
- socio-economic changes
- local debate & transition planning:
  - *need for a new energy system:*
    technologies? efficiencies? costs? ROI? sustainability?
  - *employment & new jobs?*
  - *link between local – national objectives?*



objectives of the ESTEES project

- ❑ **development of an Energie-Climate data base**
  - exhaustive structure suitable for **SRES** (*Smart Renewable Energy Systems*) - **SERI** (Systèmes Energétiques Renouvelables Intelligents)
- ❑ **simulation of energy system transformations**
  - reference scenario 2018: simulation – validation
  - transitions scenarios 2030 & 2050: assumptions, parametric development & simulations

adopted methodology

- ❑ **sensibility analysis of systemic transformations**
  - impact of seperated transformations
  - effet of coupling those transformations
- ❑ **change in current structures and automatic regulation modes**
  - modified scenarios 2018
- ❑ **scenario projections**
  - **SRES** (**SERI**)-type structures
  - energy needs & production by 2050

Building an Energy-Climate data base

various data sources

Observatoire climat · air · énergie Grand Est — ODRÉ OPENDATA RÉSEAUX-ÉNERGIES — Rte — R-GDS Réseaux Gaz naturel Strasbourg — ...

energy-GHG data base

current situation
reference year: 2018

- demand for fuels, electricity, transport, heat
- hourly distributions of demands & productions
- energy production & utilization equipment

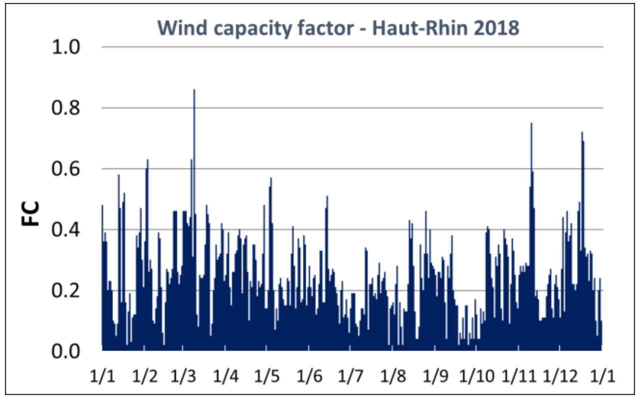
(disponible sur demande)

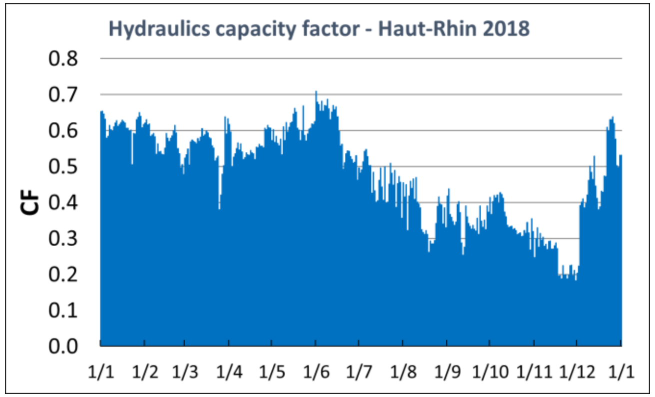
validation

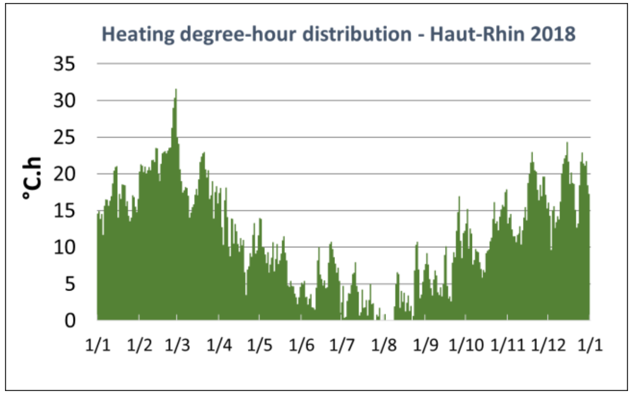
consistency check
(demand, production, GHG)

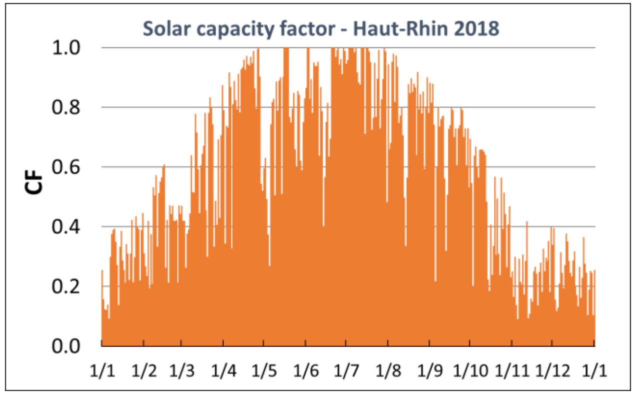
Difficult access to

- accurate and detailed data
- coherent structures of information
- agregated data of the territory
- hourly distributions





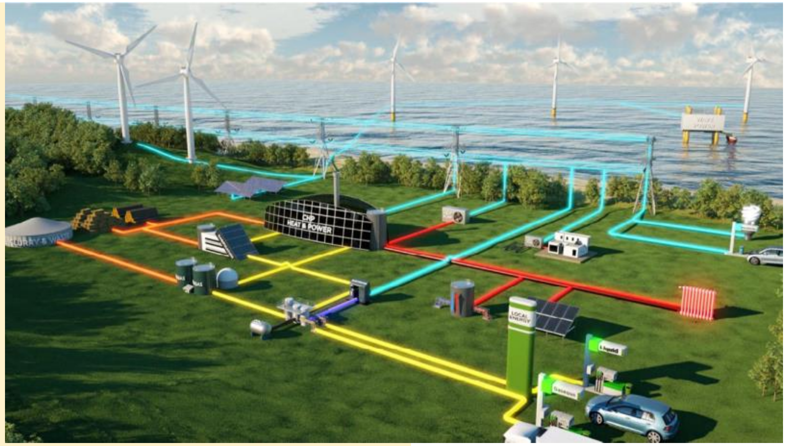




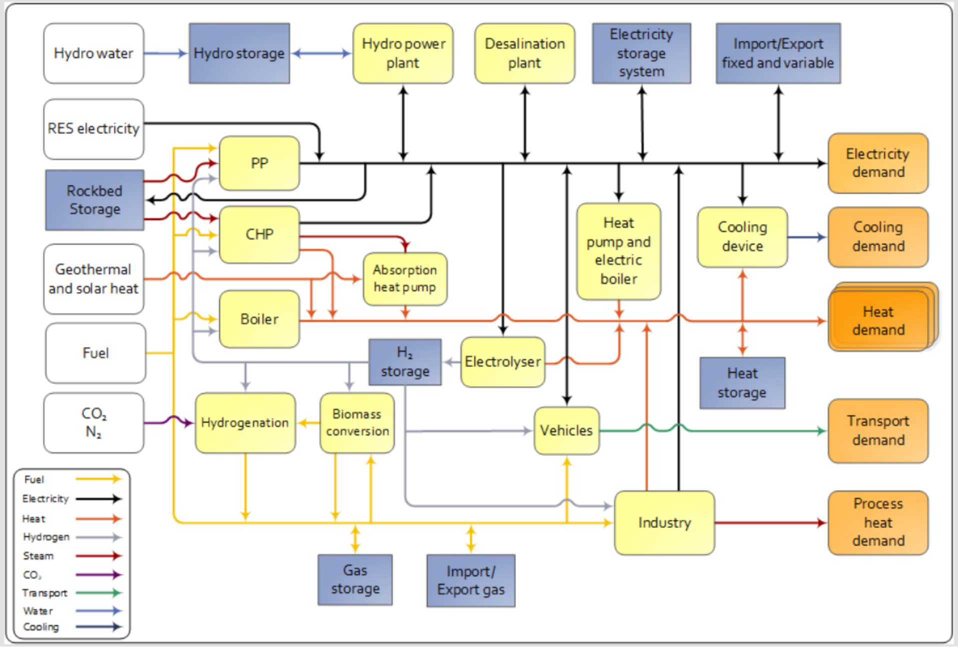
SES & SRES (SERI) concepts

Aalborg University (H. Lund, 2010) :
Smart Energy Systems (SES) concept

- **efficiency increase**
- **waste heat recovery**
- **renewable energy integration**
- **generalized coupling of**:
  - sectors & energy networks [electricity, heat, cool, gas, transport]
  - multi-energy, space & time multi-scale storage
  - district heating-cooling (DHC) & cogeneration (CHP)
- **intelligence** (flexibility, metering, automatic control & regulation)



Development of the EnergyPLAN model program (H. LUND et al., 2021)



FEMTO-ST (de Larochelambert, 2021) :
SRES – SERI concept (Smart Renewable Energy System - Système Energétique Renouvelable Intelligent)
+ local cross-sectorial approach, maximum integration of local RE, minimization of energy import-export, energy sufficiency

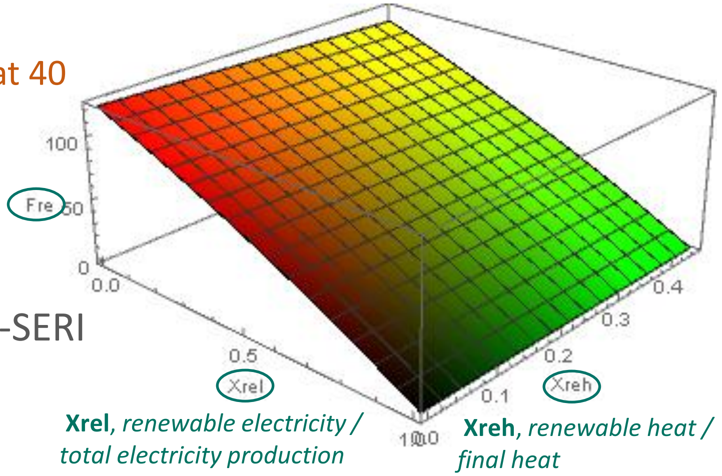
Cross-sectoral coupling in SRES (SERI)

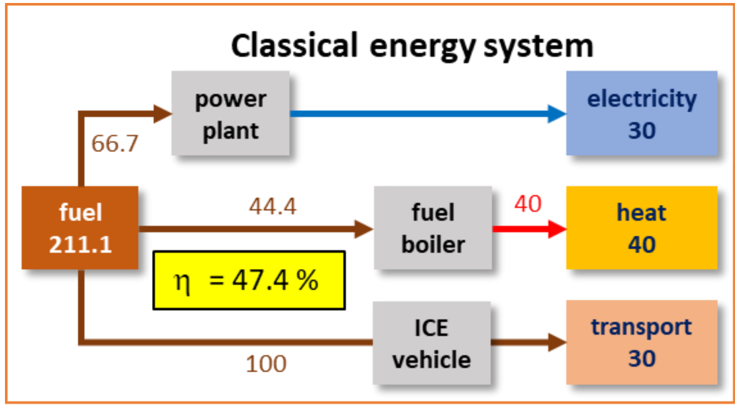
structure efficiency

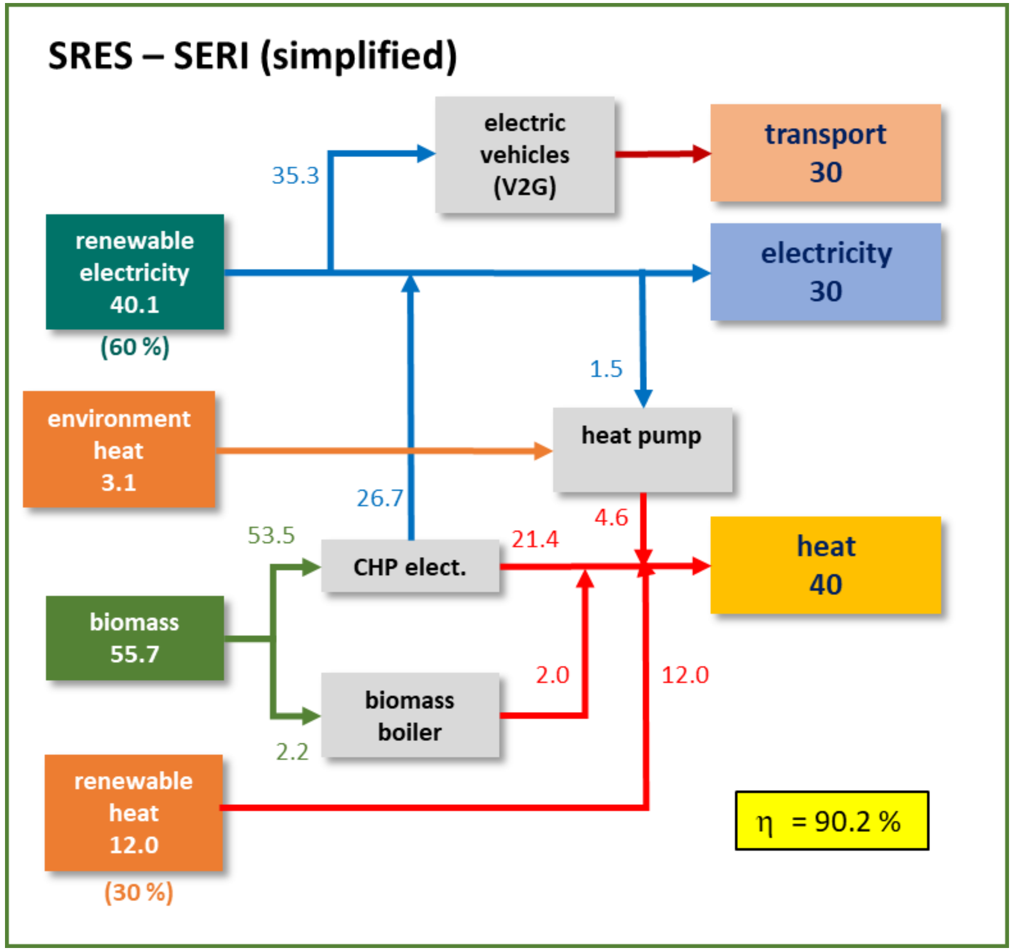
- **given final energy needs**
  example (TWh, %, etc.):
  transport 30 – specific electricity 30 – heat 40
- **given equipment efficiencies**
  (grey frame ↓)
- ➢ **unique energy dispatch solution**
  comparison: classical system & SRES-SERI

system efficiency
$$\eta = \frac{Final\ energy\ used}{Primary\ energy}$$

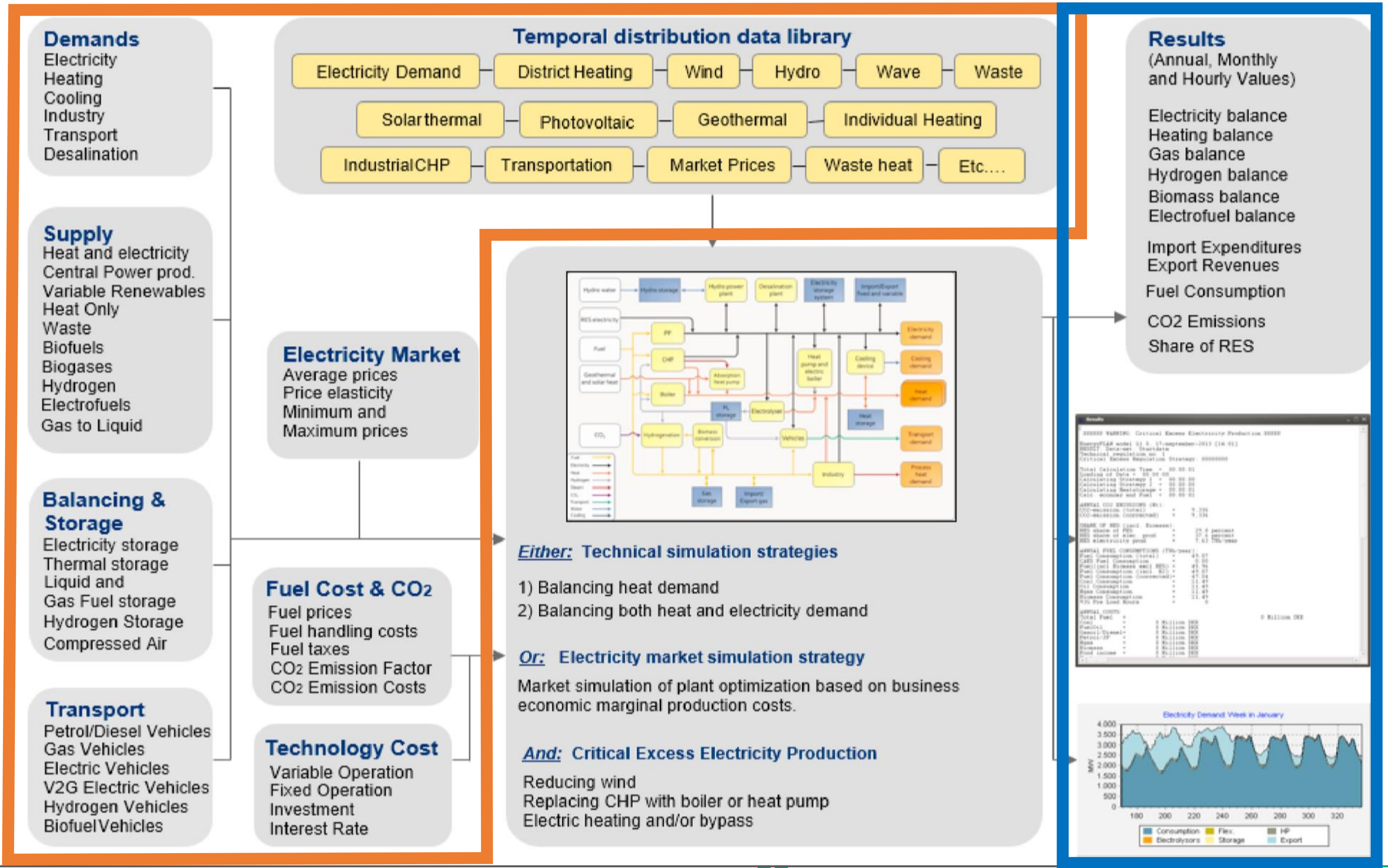
specific efficiencies :
Power plant = 45 %
Electric boiler = 95 %, Fuel boiler = 90 %
Combined Heat Power (CHP) Electric = 50 %
Combined Heat Power (CHP) Heat = 40 %
Heat pump (HP) COP = 3
Internal combustion engine vehicle (ICEV) = 30 %
Rechargeable electrical vehicle (EV) = 85 %







EnergyPLAN simulations



Analysis of the reference year 2018 : looking for coherence

two information sources

- **ATMO Grand Est** : consumptions per energy type & carriers
- **ATMO Grand Est** : productions per energy type & carriers
- ATMO Grand Est / **EnergyPLAN** simulations: imports/exports
- ATMO Grand Est / **EnergyPLAN** simulations: CO_2 emissions

input data for EnergyPLAN are structured differently

calibration

- checking total consumptions/ productions after rebuilding

validation

- comparing data with simulation for GHG emissions, electricity imports/exports

Reference scenario: validation in EnergyPLAN (Haut-Rhin 2018)

Fuel consumption (GWh/year)	ATMO GE	EnergyPLAN	Relative difference
Oil	8570,2	8454,0	-1,356%
Natural gas	7337,4	7540,0	2,761%
Total	**15907,6**	**15994,0**	0,54%
CO2 emissions (kt CO2)	**ATMO GE**	**EnergyPLAN**	**Relative difference**
Oil	2247,8	2252,0	0,19%
Natural gas	1963,4	2008,0	2,27%
Total	**4211,2**	**4260,0**	**1,16%**
Electricity export/import (GWh/year)	**ATMO GE**	**EnergyPLAN**	**Relative difference**
(including nuclear)	9 235	9 505	2,92%
Renewable electricity production (GWh/year)	**ATMO GE**	**EnergyPLAN**	**Relative difference**
Nuclear	11841	11841	0,00%
Hydroelectricity	3080	3081	0,03%
Solar PV	63	63	-0,75%
Final energy demand per EnergyPLAN sector - oil, natural gas and biomasse (GWh/an)	**ATMO GE**	**EnergyPLAN**	**Écart relatif**
Industrial	5958,5	5839,0	-2,01%
Residential - Tertiary - Agriculture	5728,4	5470,0	-4,51%
Transport	5475,2	5501,0	0,47%

Reference year 2018 : energy production & consumption

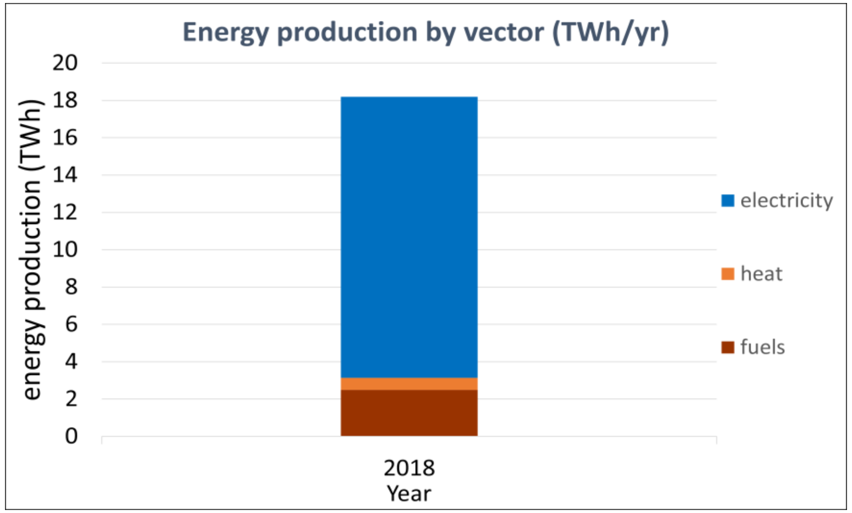
Source: ATMO grand Est

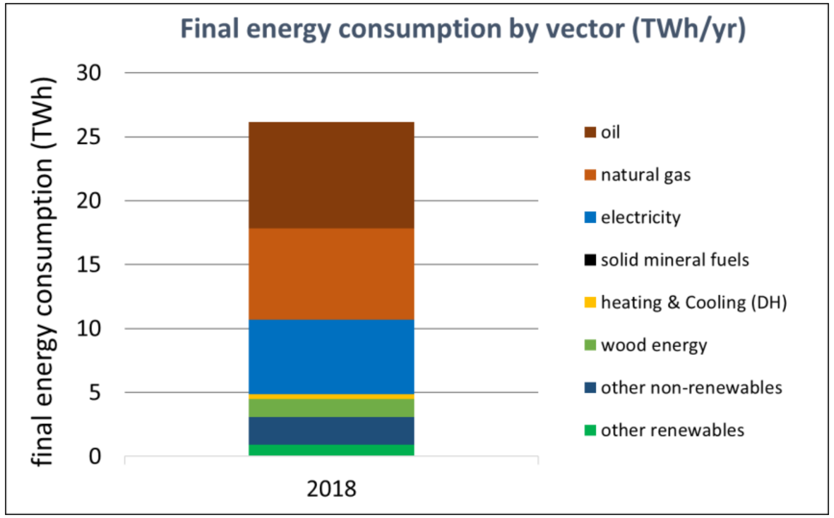
energy production

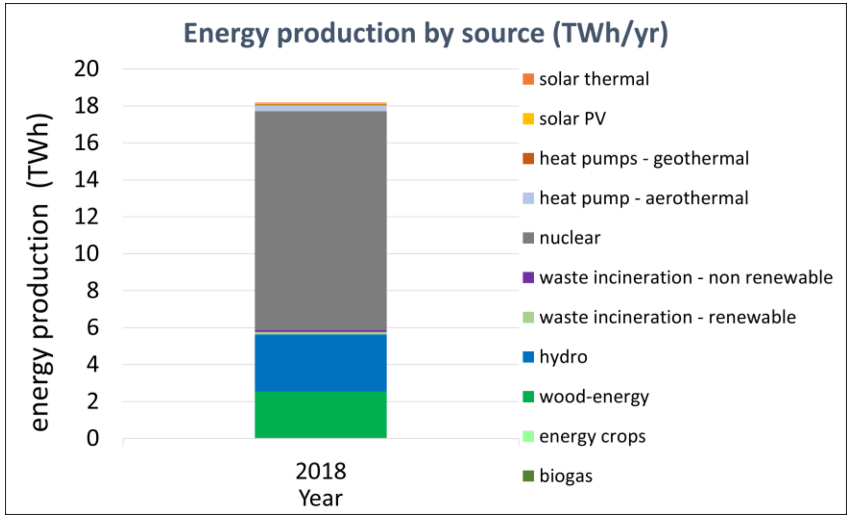
- by source
  - nuclear (65.1 %)
  - renewables (34.3 %)
- by vector
  - electricity (82.7 %)
  - fuels (13.7 %)
  - heat (3.6 %)

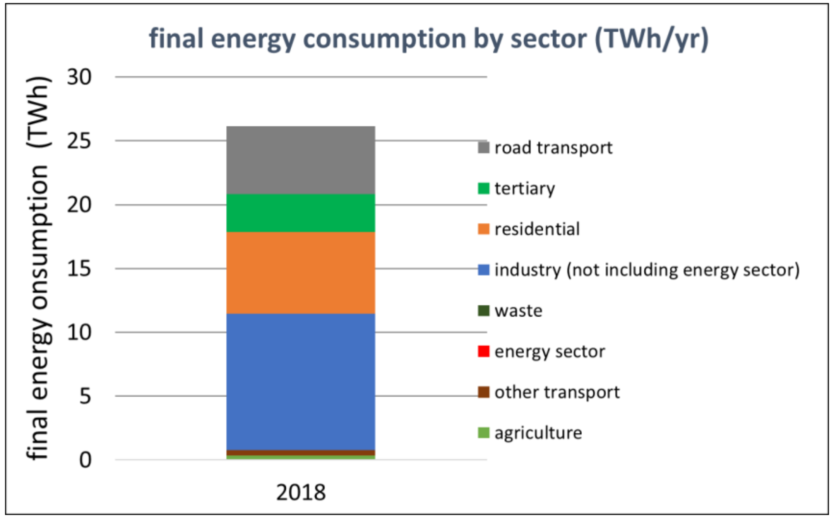
energy consumption

- by sector
  - industry (40.9 %)
  - residential & tertiary (35.9 %)
  - road transport (20.3 %)
- by vector
  - fossil fuels (59.2 %)
  - electricity (22.2 %)
  - renewable fuels & heat (9.0 %)
  - district heating (1.4 %)









Scenarios

separated changes

individual heating
(heat pumps + district heating + combined heat & power, heat & electricity balance)

electric vehicles
(dump charge, smart charge, V2G)

+

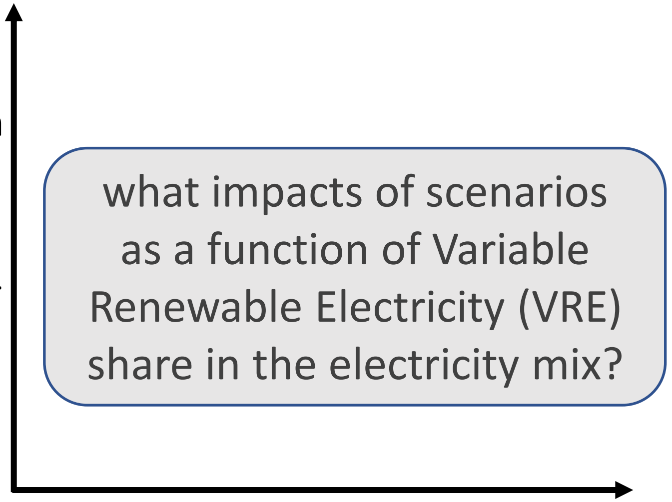
integrated scenarios

SERI 1 (heat balance, no electricity balance)
- thermal RE production (solar, geothermal)
- structural changes (CHP, DH, HP)
- partial fossil fuel substitution
- thermal storage

SERI 2 = SERI 1 (heat and electricity balance)

reference year 2018 (nuclear electricity as import)

- energy consumption & production
- CO_2 emissions
- electricity imports & exports

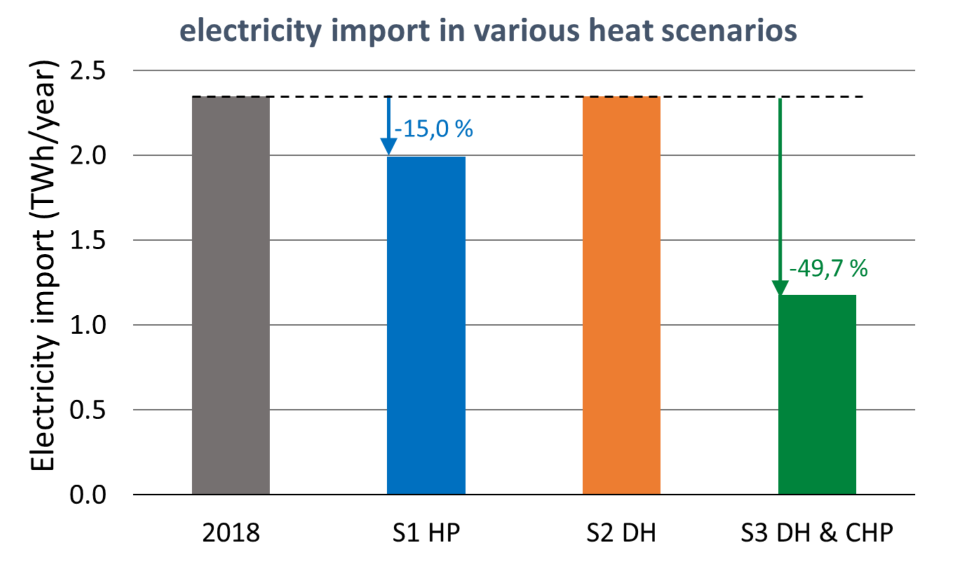


- various scenarios
- % VRE / electricity demand (50% PV + 50% wind)

Effects of changes in heating system only

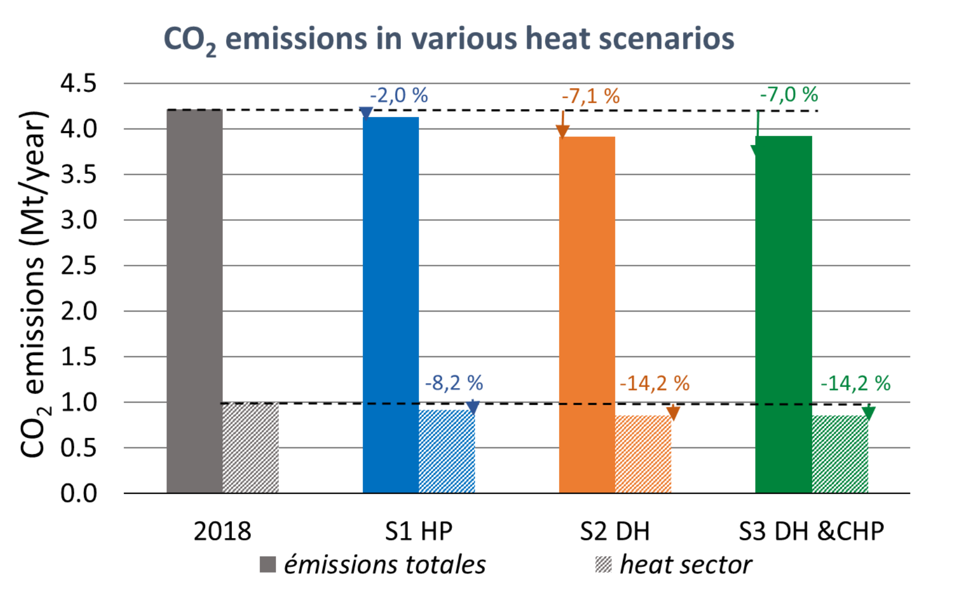
impact on electricity imports

- **100 % of electric heating → heat pumps (S1 HP)**
  - ➢ -15 % electricity imports
- **50 % of individual heating → district heating, no CHP (S2 DH)**
  - ➢ very low impact on electricity imports
- **50 % of individual heating → district heating with CHP + heat & electricity balance (S3 DH&CHP)**
  - ➢ -50 % electricity imports



impact on GHG emissions

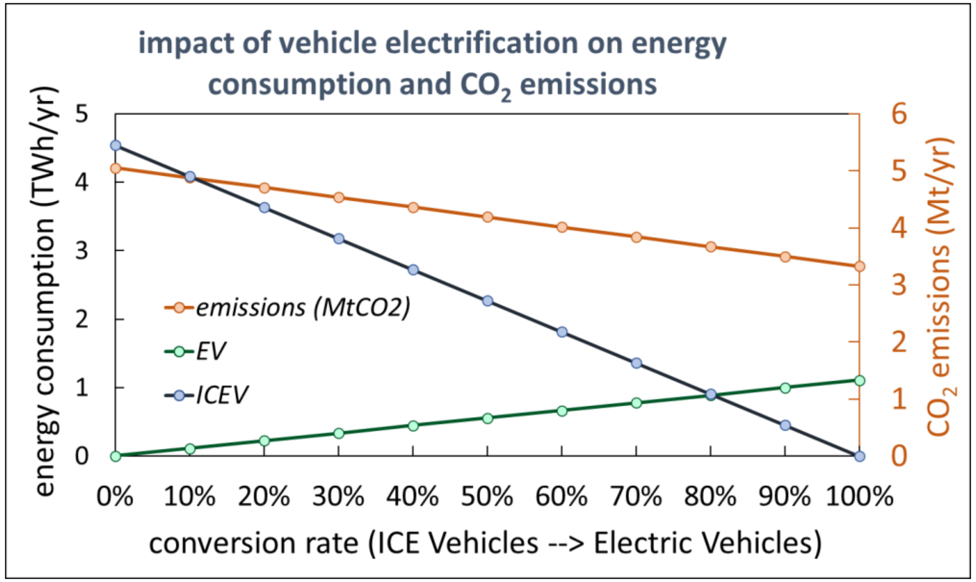
- ➢ **-2 % to – 7.1 % reduction on total emissions (all energies)**
  - ○ no change in heating equipments' efficiencies
  - ○ no change in fossil fuel used for heating, transport, industry
- ➢ **-8.2 % to – 14.2 % reduction on heating emissions**
  - ○ idem



Effects of transport electrification only

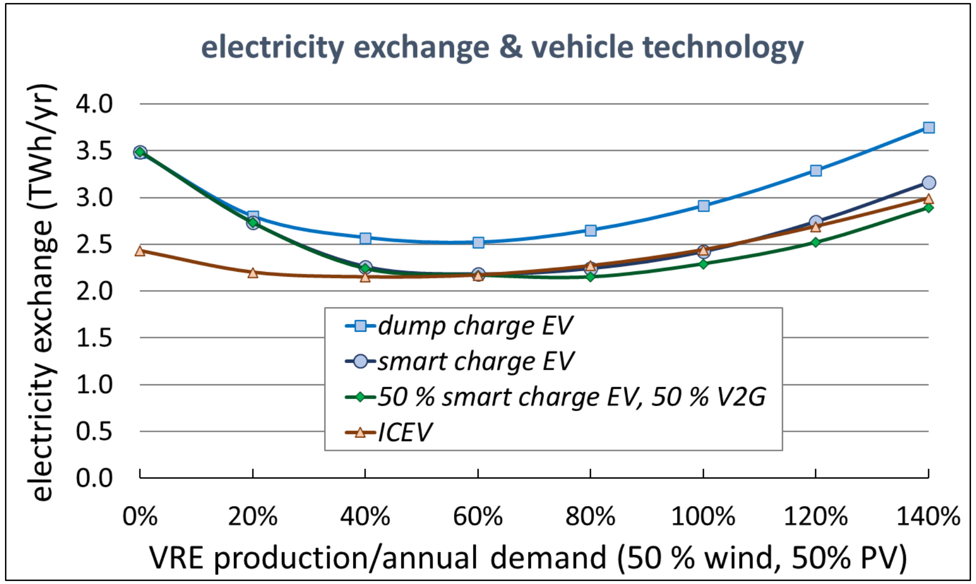
without changing the electricity mix

- **moving 100% ICEV → 100 % EV**
  - ➢ -100% de fossil fuel consumption
  - ➢ -80 % energy consumption (transport sector)
  - ➢ -30 % direct CO_2 emissions of the energy system

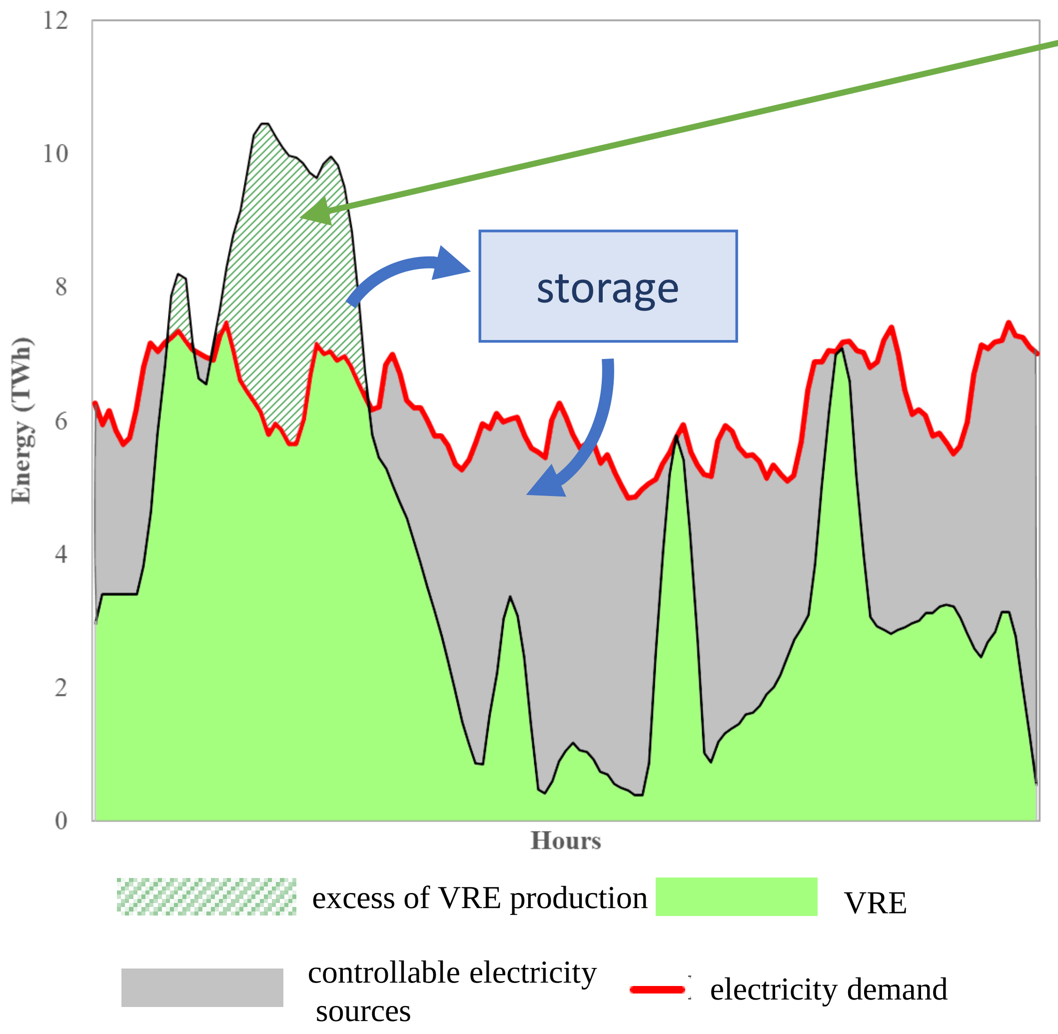


integrating variable renewable electricity 0 % → 100 %
(50 % wind + 50 % PV)

- **comparing EV dump charge, 100% smart charge, 50% smart charge + 50 % V2G, and no EV**
  - ➢ at least -19% electricity exchange (|import| +|export|) with 60-80 % variable renewable electricity



Automatic regulation modes



How to use excess of VRE?

2 strategies :

- export (limited by the transmission grid capacity)
- storage
- (*and also smart flexibility and shift of demand*)

2 types of automatic regulation :

- **SERI 1 :** heat demand balance (*adapts production to consumption*)
  Possible means: cogeneration unit shutdown when no electricity is needed.
  V2G only use critical excess of electricity when exceeding transmission grid capacity

- **SERI 2 (flexibility) :** electricity & heat demand balance.
  V2G used to (dis)charge electricity imports & exports,
  HP use electricity exports

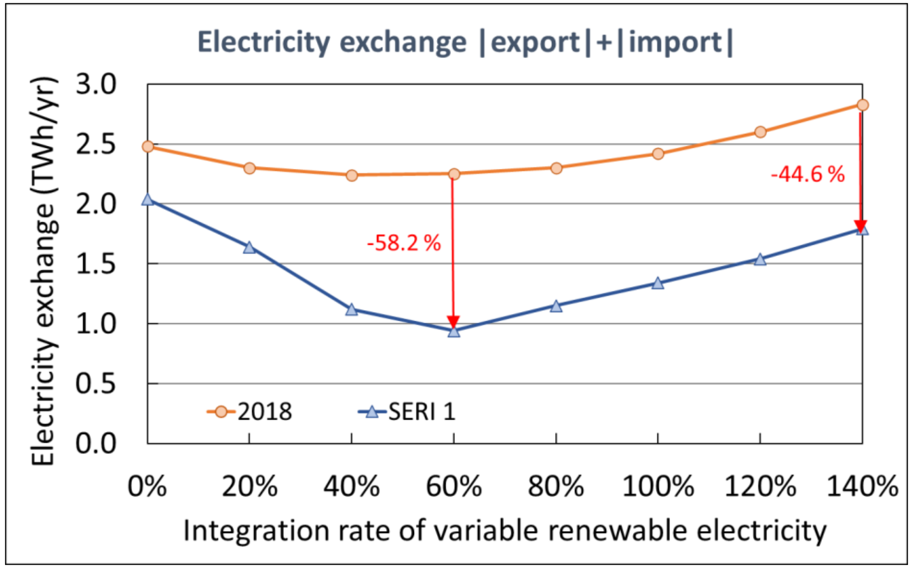
Impact of SERI 1 (no electricity balance, only heat balance)

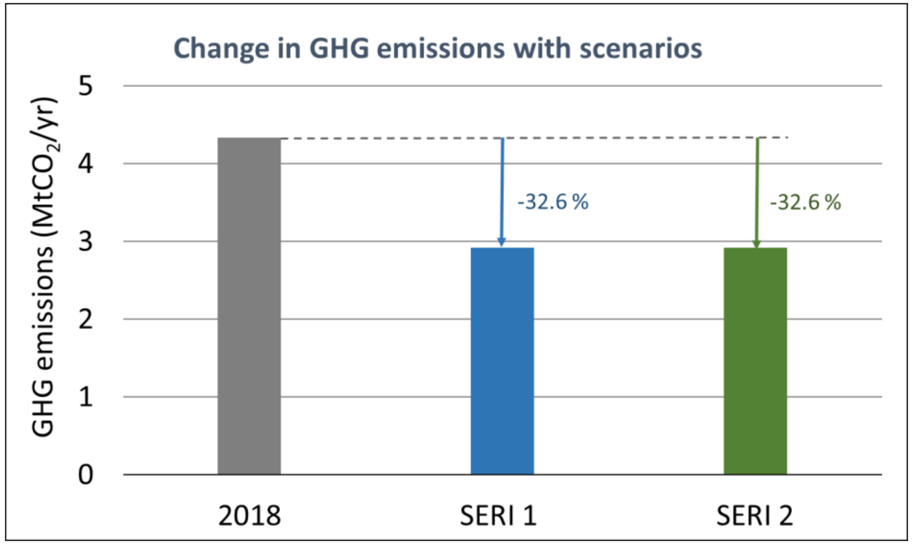
heat: 50% individual heating → district heating
+ fuel change
- 100 % oil → biomass
- - 50 % natural gas → biogas & biomass

+ energy source change
- industrial heat x 3
- district heating (not including industry) x 3
- cogeneration (not including industry) x 13
- solar thermal heating 0 GWh → 800 GWh

transport : 50 % ICE vehicles → electric vehicles
- 50 % smart charge
- 50 % V2G (only for critical excess – limiting exports)

storage
- hydro-pumping station (HPS-STEP) 55 MW, 590 MWh
- thermal : 50 GWh
- V2G (only to avoid critical excess)





Impact of SERI 2 (no electricity balance, only heat balance)

heat: 50% individual heating → district heating
+ fuel change

- 100 % oil → biomass
- \- 50 % natural gas → biogas & biomass

+ energy source change

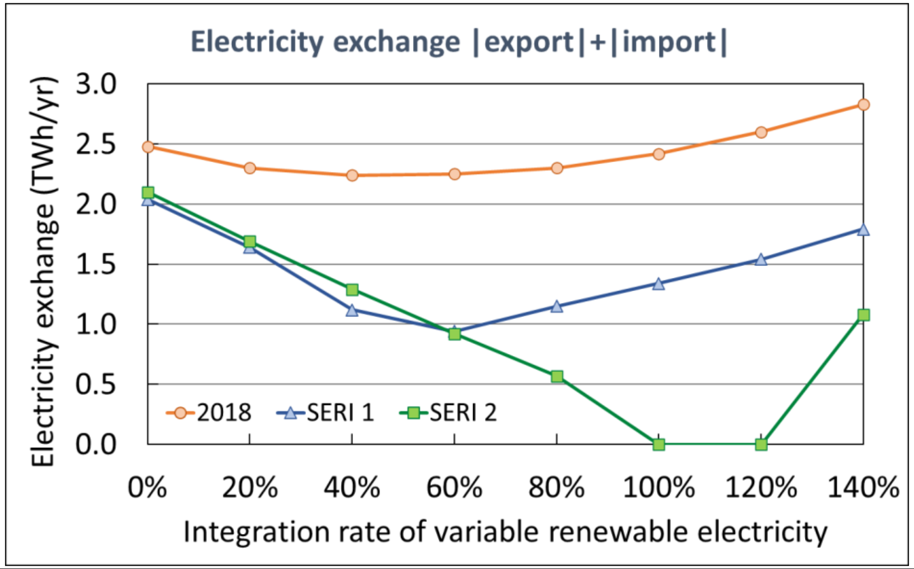
- industrial heat x 3
- district heating (not including industry) x 3
- cogeneration (not including industry) x 13
- solar thermal heating 0 GWh → 800 GWh

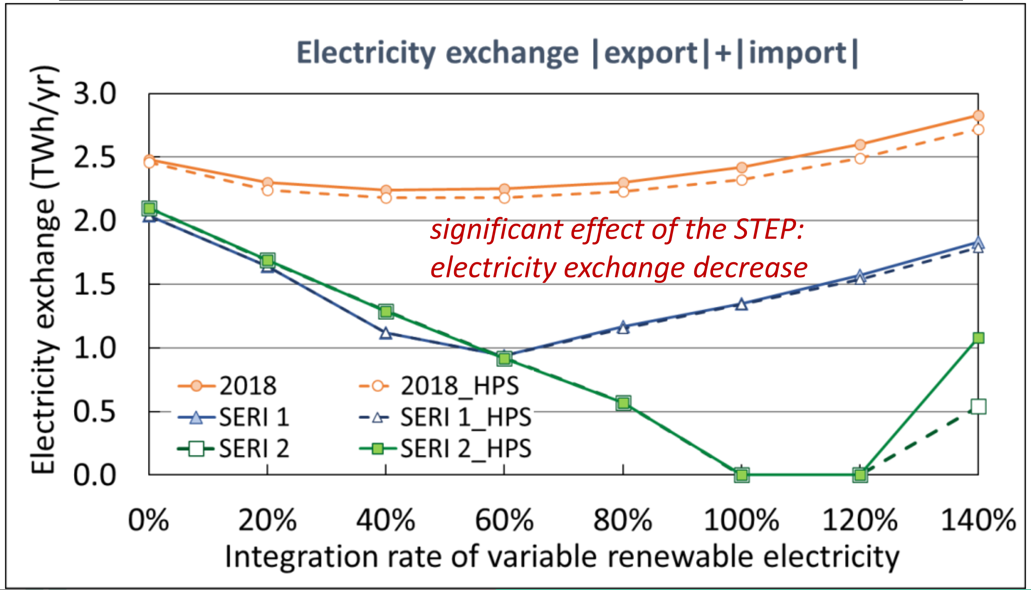
transport : 50 % ICE vehicles → electric vehicles

- 50 % smart charge
- 50 % V2G (for balancing imports & exports)

storage

- hydro-pumping station (STEP) 55 MW, 590 MWh
- thermal : 50 GWh
- V2G (charging-discharging surplus & deficit)





Conclusions

- **results**
  - first simulation of **integrated & holistic scenarios** for local energy system
  - high impact of **EVs** & **charge mode** of EVs
  - high impact of extending **District Heating & Cooling** networks along with biomasse & biogaz CHP
  - high impact of **energy networks coupling**
  - high impact of **balance regulation strategies** (heat only, heat & electricity)
  - high impact of **renewable heat** integration (solar thermal, geothermal)
- **perspectives**
  - **multi-scale planning** (PhD Thesis of Florian Labaude, 2023-2026)
  - integrating **local renewable potentials & constraints**
  - **full simulation of SERI** :
    - energy sufficiency
    - demand flexibility
    - maximum RE integration
    - 50% --> 100% EVs, etc.
  - integrating **industry** & **agriculture**
  - **planning support** tool for planners, decision-makers
  - installing a local experimental SERI {Colmar, Mulhouse, Freiburg} with Universities & local authorities

Valorization of this work

Master thesis

- Florian Labaude, *Évaluation de scénarios de transition énergétique, économique et sociale du territoire de Fessenheim* (February - July 2023), LIVE Unistra-CNRS-ENGEES, FEMTO-ST Energy Dpt

Conferences, seminars, publications

- Blond, N, de Larochelambert T, Labaude F, *Évaluation de scénarios pour une transition énergétique, économique et sociale de la région de Fessenheim (ESTEES)*, **Séminaire de restitution OHM Fessenheim**, Strasbourg, 18 novembre 2022.
- Blond, N, de Larochelambert T, Labaude F, *Évaluation de scénarios pour une transition énergétique, économique et sociale de la région de Fessenheim (ESTEES)*, **OHM international seminar, LabEx DRIIHM**, Strasbourg, 5 - 7 juin 2023.
- Larochelambert (de) T, Labaude F, Blond N, *Transitions énergie climat locales & trajectoires systémiques scénarisées – Application aux territoires autour de Fessenheim, Haut Rhin*. **Séminaire de Recherche sur la Durabilité Transitions, risques, territoires, Université de Haute-Alsace**, Mulhouse, 6 juillet 2023.
- Larochelambert (de) T, Blond N, Labaude F, Ap*plication of a Smart Renewable Energy System for sustainable and resilient energy-climate planning of the Fessenheim territory (Haut-Rhin, France)*. **AICC 2024 – 2ème édition | Action versus Inaction facing Climate Change | Strasbourg**, 17 juin 2024.
- Larochelambert (de) T, Blond N, Labaude F, *Intégration du Système Energétique Renouvelable Intelligent pour la planification urbaine soutenable et résiliente*, **Journées Internationales de Thermique. JITH 2024** – 20ème édition | Bâtir écologique pour une résilience climatique | Paris, 29 – 31 octobre 2024
- Larochelambert (de) T, *Impact des choix structurels des Systèmes Energétiques Renouvelables Intelligents (SERI) sur le bilan et l'efficacité des transitions énergie-climat locales*, Congrès Français de Thermique 2025, Chambéry (soumis).
- Larochelambert (de) T, Labaude F, Blond N, *Assessement of planning methodology and simulation of energy transition scenarios for the French Fessenheim territory as a planning tool for decision-makers* (in preparation for submission to Applied Energy).

Merci

Florian LABAUDE
LIVE CNRS, Unistra, ENGEES
florian.labaude@live-cnrs.unistra.fr
Thierry de LAROCHELAMBERT
Institut FEMTO-ST, Département Energie
thierry.larochelambert@femto-st.fr

Nadège BLOND
LIVE CNRS, Unistra, ENGEES
nadege.blond@live-cnrs.unistra.fr

Annexe: energy trends of the French Haut-Rhin department