HEIG-VD

The EcoDynElec electricity model for buildings LCA: characteristics and effects

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Hes·so Haute Ecole Spécialisée de Suisse occidentale

Background, objective and timeline

- **Background**:
    - Lack of temporal resolution for LCA of electricity in buildings (e.g., annual data in buildings LCA)
    - Significant increase of heat pumps installed in buildings → stress the swiss electricity supply especially in winter/cold season resulting in increasing the importations level e.g. from Germany

- **Goal of the project:** assess the carbon footprint(1) in Dynamic LCA of the electricity used in buildings for different time steps (from an hourly to an annual average).

- **Timeline** (method, data collection, code development and case studies) :
    - 2018-2021 for buildings LCA applications(2)

      (2021-today for new research projects/applications)

(1) Carbon footprint in this presentation = GHG emissions calculated with a LCA approach ; other LCA indicators were also calculated but not presented here

(2) Through the EcoDynBat (2018-2020) and Contribution à l'IEA EBC Annex 72 (2018-2021) research projects of the Swiss Federal Office of Energy (SFOE)

The team behind the EcoDynElec initiative

Main LCA experts involved

- Pierryves Padey, Kyriaki Goulouti, Mija Frossard, Sébastien Lasvaux (HEIG-VD, Yverdon-les-Bains/CH)
- Didier Beloin-Saint-Pierre (EMPA, St. Gallen/CH)

Main data scientist and Python developers involved

- François Lédée & Aymeric Bourdy (HEIG-VD, Yverdon-les-Bains/CH)

And all the other colleagues and partners at **HEIG-VD** (M. Fesefeldt, M. Capezzali, S. Citherlet), **EMPA** and **SUPSI** (V. Medici, J. Maayan Tardif) having been involved in one of the Swiss Federal Office (SFOE) EcoDynBat, IEA EBC Annex 72 and S-DSM research projects, as well as expert's discussion about the Electricity networks at the Institute of Energy and Electrical Systems/HEIG-VD (M. Bozorg)

Materials Science and Technology

Scuola universitaria professionale della Svizzera italiana

EcoDynElec: characteristics and effects for the Swiss context

Step 1

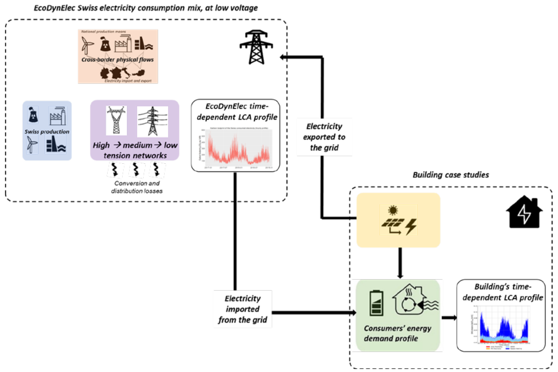
EcoDynElec model and tool for hourly calculations of electricity supply mixes

Step 2

EcoDynElec applied to the calculation of the Swiss hourly supply mix

Step 3

EcoDynElec applied to the dynamic LCA of electricity used in Swiss buildings



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EcoDynElec: main model characteristics

- Geographical scope: **European countries including Switzerland**
- Type of mix: **Supply mix, as universal & average mix** *(not end-uses specific, not marginal)*
- Cross-border exchanges: **physical net exchanges** for the **import / export flows**
- Resolution**: hourly data** and by aggregation up to more aggregated time steps (daily, monthly...)
- Electricity model for the supply mix:
  - **« Production + import (P+I) »** model[1] using **physical flows**

  *(reasoning behind, **ensure a grid stability perspective at each hour**)*
- Supply mix calculations in EcoDynElec (for each hour):
  - **accounting for all ENTSO-E countries & cross-border exchanges with a matrix-based calculation**[2] (tracing, for 1 kWh of a supply mix of the country of interest (e.. Switzerland), the shares between the production mix of the country and the exchanges of production mixes from neighbouring countries)

(1) Ménard, M., et al., "Strommix in Ökobilanzen: Aus-wirkungen der Strommodellwahl für Produkt- und Betriebs-Ökobilanzen," PSI-Bericht, Paul Scherrer Institut, Villigen, CH, 1998

(2) Padey, P., Goulouti, K.,Capezzali, M., Fesefeldt, M., Lasvaux, S., Beloin-Saint-Pierre, D:, Medici, V., Maayan Tardif, J., 2020, EcoDynBat – Final Report: Dynamic Life Cycle Assessment of Buildings, Report 3: Methodological framework for dynamic life cycle assessment (WP3), chapter 3: The Computational Structure

EcoDynElec: initial data source

- Geographical scope: **European countries including Switzerland sharing their data in ENTSO-E transparency platform**[(1)]

- Production mix: **15min/hourly data of production power per energy carrier in every ENTSO-E countries**

- Cross-border exchanges: **hourly data cross border physical flows from ENTSO-E for all countries**

(1) https://transparency.entsoe.eu/

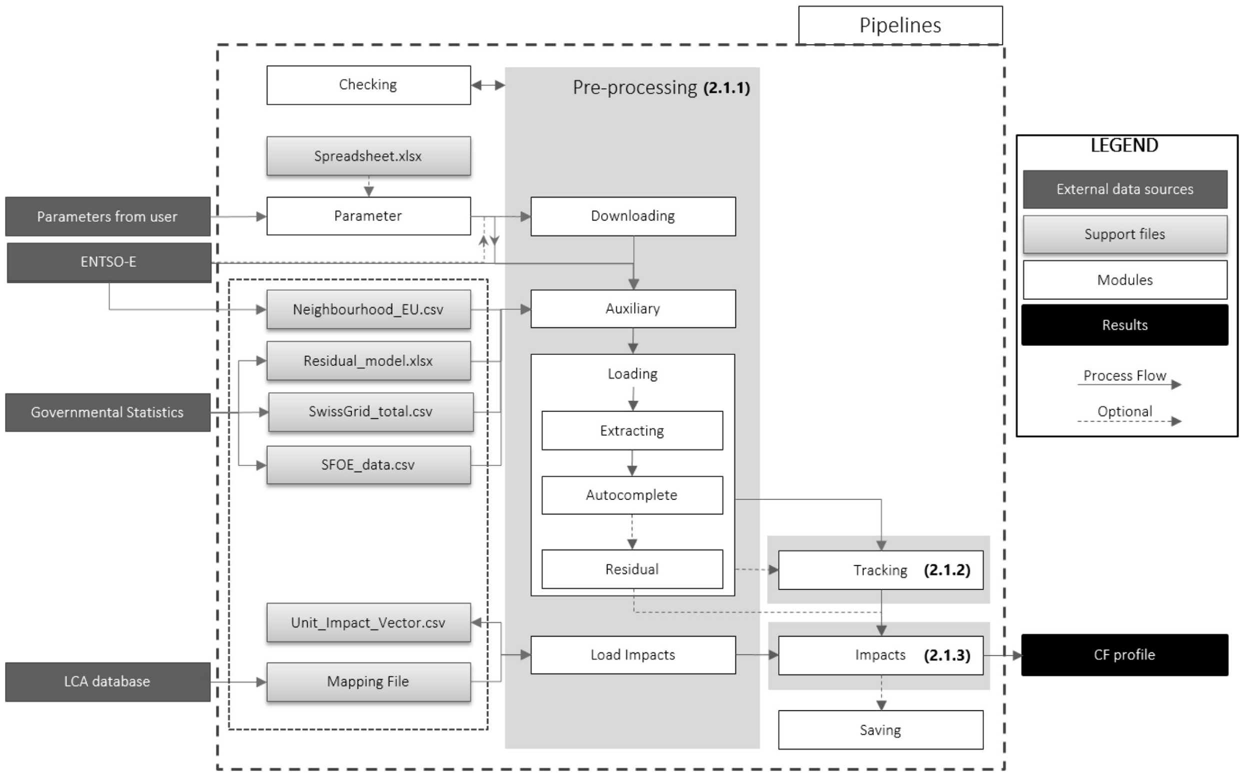
EcoDynElec: the calculation tool

GitHub : https://github.com/LESBAT-HEIG-VD/EcoDynElec

- **Open-source calculation tool** (Python language)
- Applied to the Swiss context but **applicable to** other **European countries**
- **No LCA data provided in EcoDynElec** as most LCA data are to date **under licence** (e.g. ecoinvent) → responsibility of the user to use country energy carriers data to run the code

Code paper(1): https://www.sciencedirect.com/science/article/pii/S2352711023001814#fig1

(1) Lédée, F., Padey, P., Goulouti, K., Lasvaux, S., Beloin-Saint-Pierre, D. 2023. EcoDynElec: Open Python package to create historical profiles of environmental impacts from regional electricity mixes, SoftwareX, Volume 23, July 2023, 101485.



Structure of EcoDynElec package and its modules to calculate the carbon footprint (CF) and other impact categories

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Additional modelling choices for the CH supply mix calculation

General modelling choices for CH supply mix

	Hourly resolution & data	Annual resolution & data
Country of interest (for calculating the 1kWh of supply mix)	CH	
Production mix, 1st level of countries	CH + neighbouring countries (AT, DE, FR, IT) and CZ	
Production mix, 2nd level of countries		ENTSO-E countries (excl. CH + 1st level of countries)
Cross-border Exchanges	All countries	

Specific data adjustments for CH electricity flows

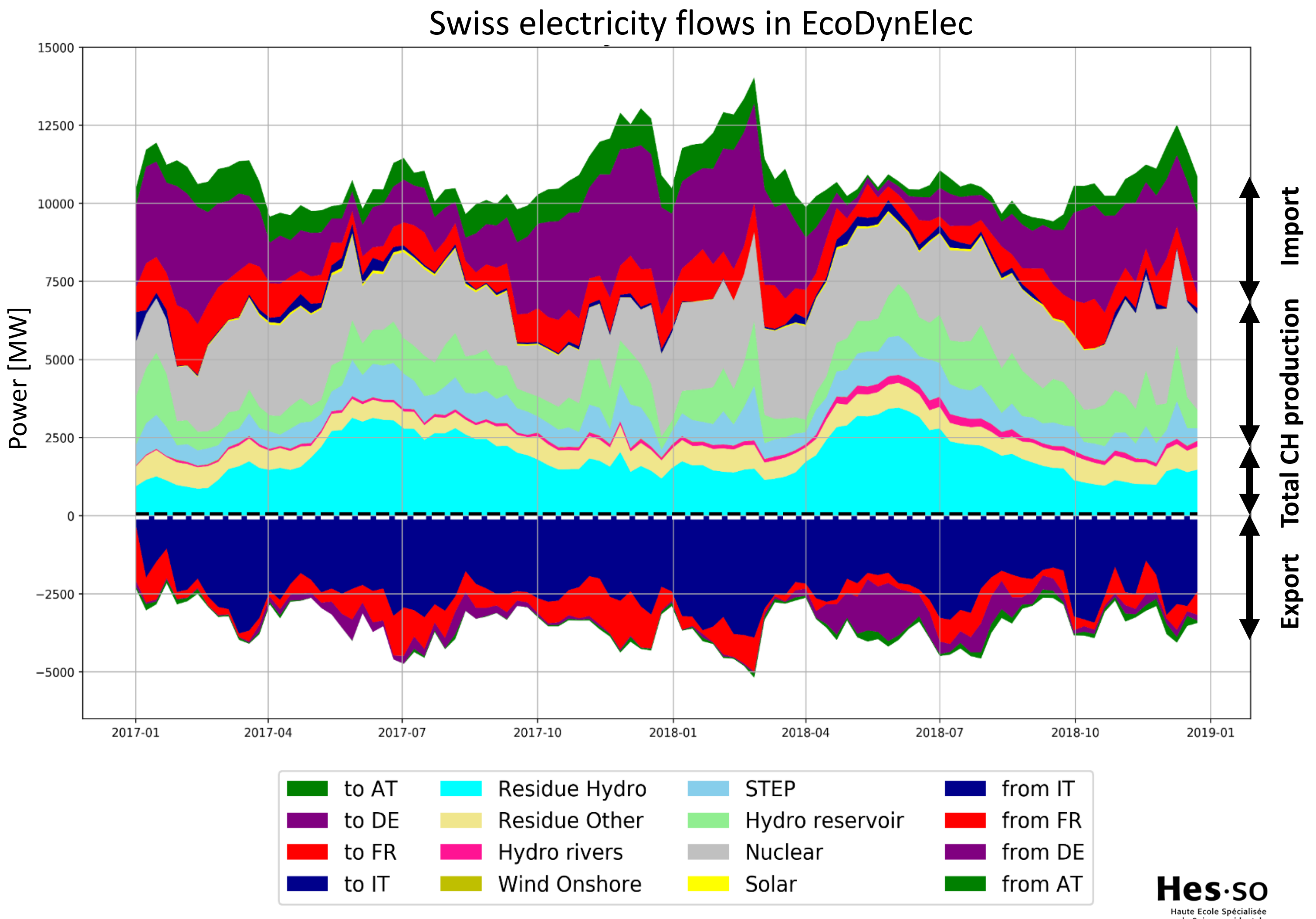
- Domestic CH production → Adjustment of ENTSO-E data (due to a data gap) with Swiss Federal Office of Energy (SFOE) statistics with an **additional power of « hydro run-off river » + « other »** to cover the entire CH production as found in swissgrid data
- **Import/export flows** from direct neigbouring countries & grid losses → **gross exchanges** & losses values from **Swissgrid data**

Linking electricity flows with LCA data

- **Mapping of energy carriers for electricity with LCA data →** use (to date) of ecoinvent v3 datasets (v3.4, then v3.8) using a « mapping file » between ENTSO-E naming and LCA naming in ecoinvent v3

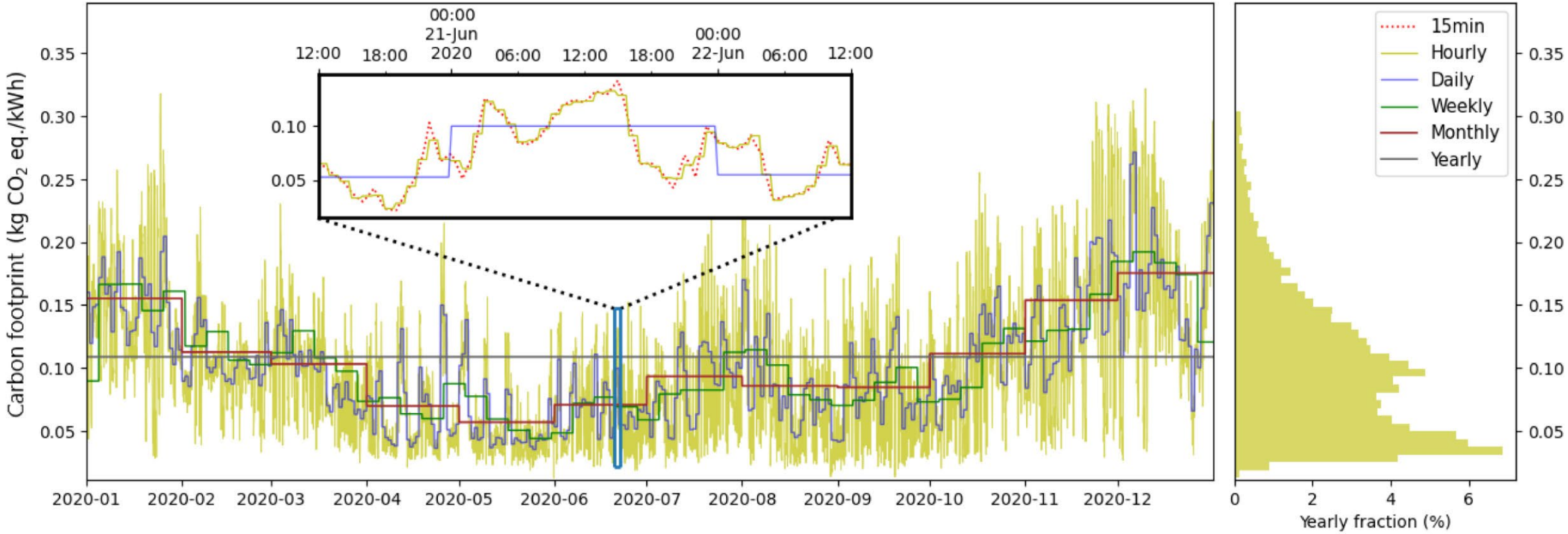
- Example on the right for Swiss electricity flows, the same was done for all 1st level neighbouring countries

- **Remark: for hydro pumped storage (STEP) →** annual average data provided by ecoinvent v3 not accounting for the temporal varability of the storage mix



EcoDynElec/CH: carbon footprint for different time steps

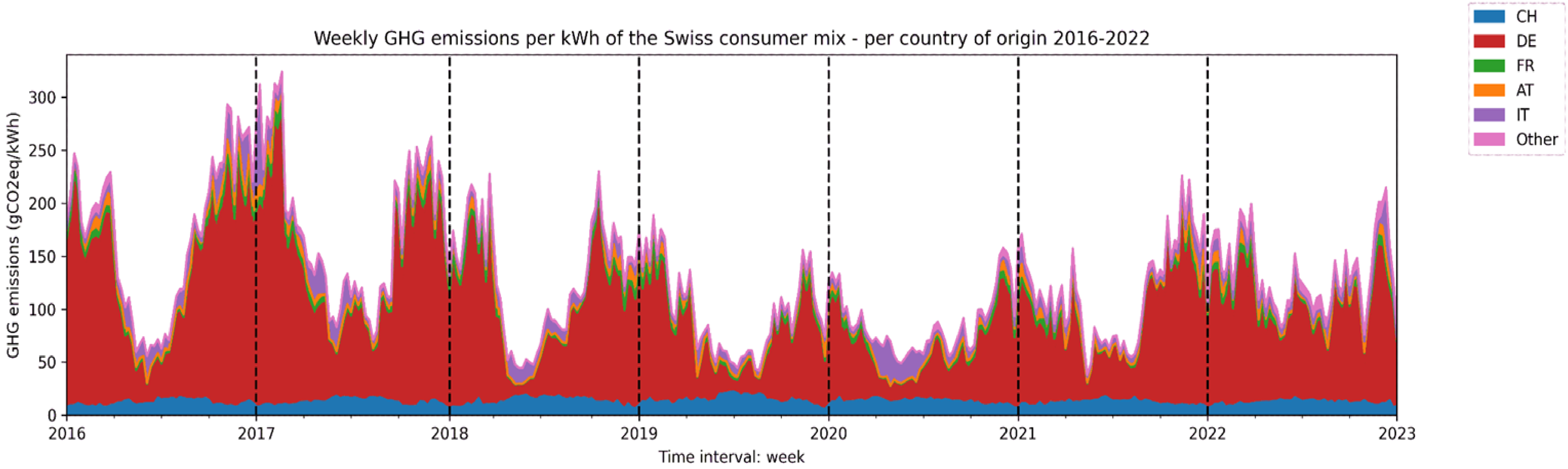
- Example for 2020, carbon footprint from 15 minutes/hourly → annual average



- Other LCA-based indicators have been calculated by EcoDynElec beyond the carbon footprint...but the temporal variation are less pronounced.

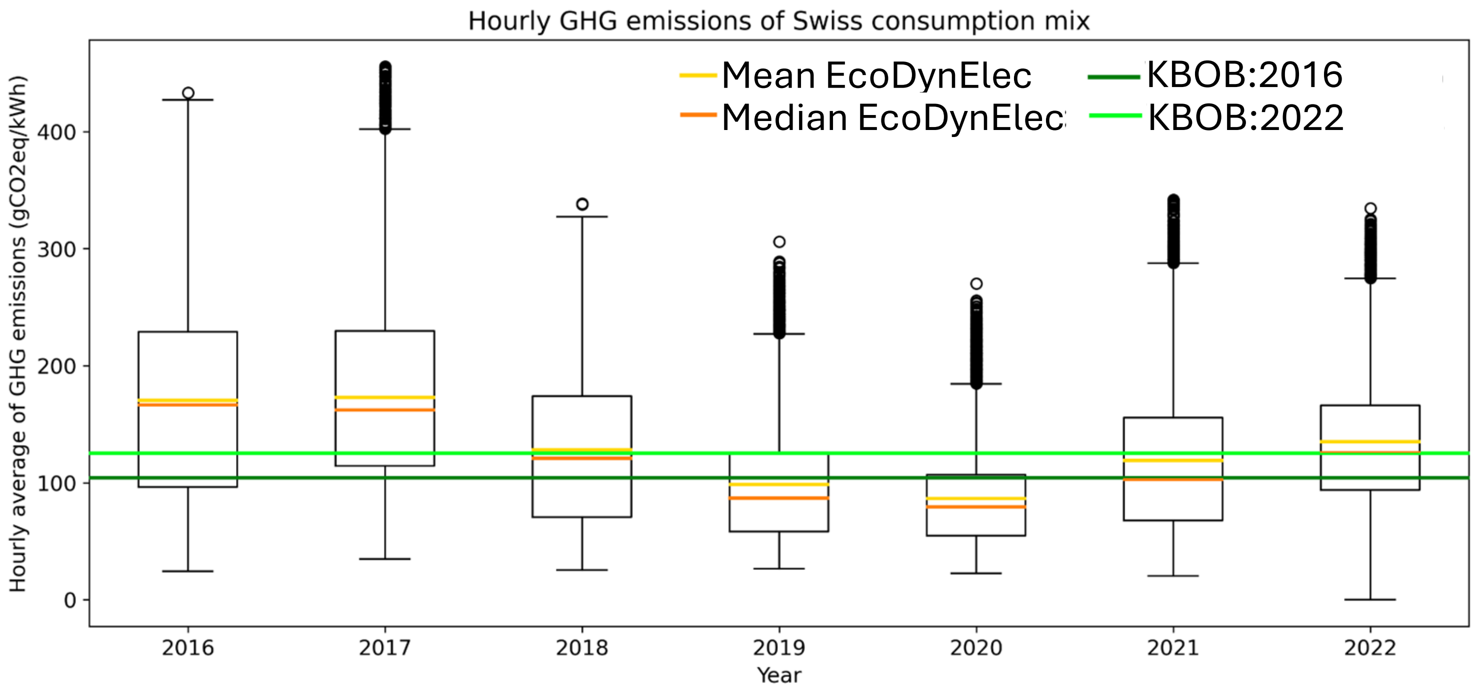
EcoDynElec/CH: carbon footprint per countries of origin

- Decomposition of the carbon footprint “origins” in the supply mix



EcoDynElec/CH: carbon footprint profiles for 2017-2022

- Different profiles of carbon footprint of the Swiss electricity supply mix (examples from 2017 to 2022)



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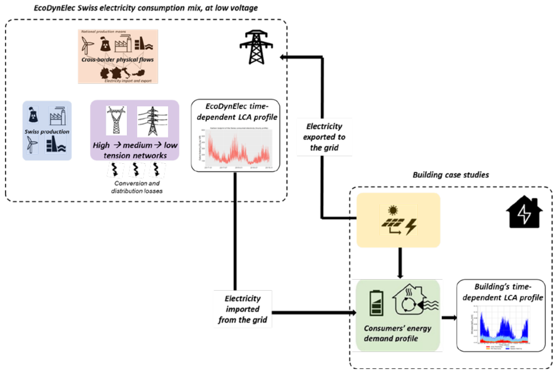
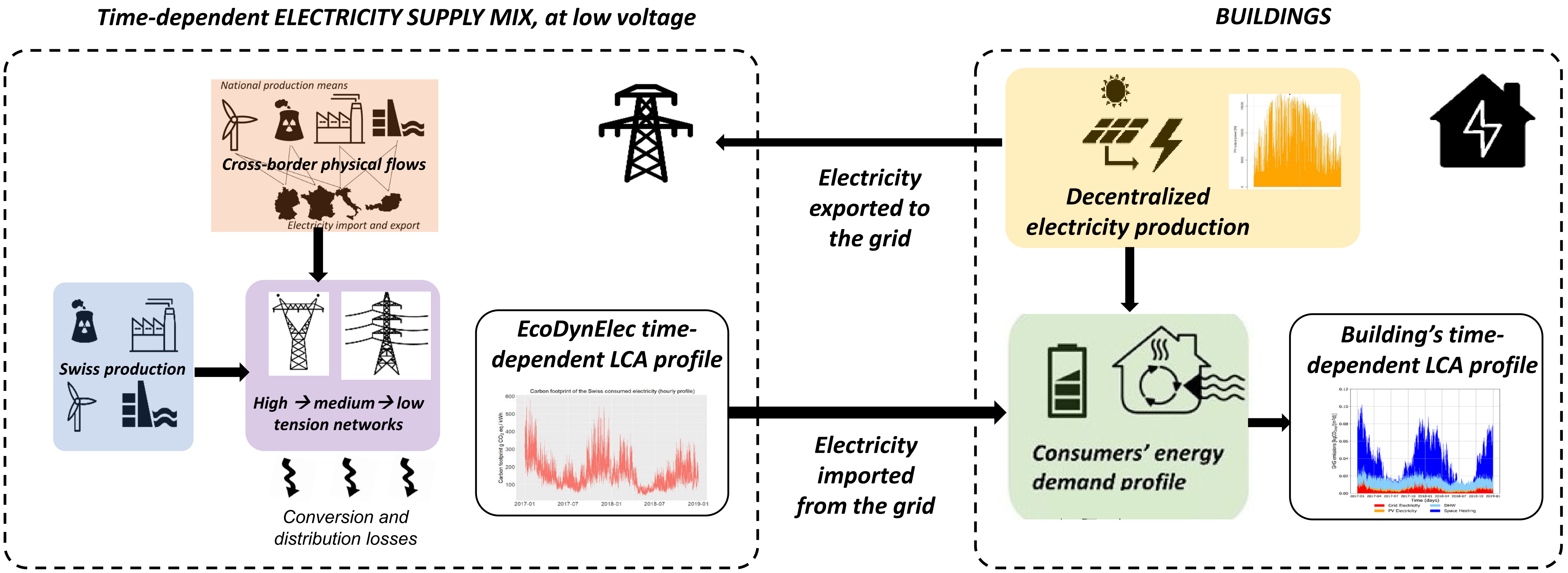


Application framework for buildings LCA



System boundaries: *Operational energy use (module B6 according to SN EN 15978, or the Exploitation domain according to SIA 2040 / prSIA 390:2023) + Construction (module A1-A3 and C1-C4) only for decentralized energy systems (PV…)*
Remark: *LCA conducted for building case studies* *in-use* *(not in the planning process)*

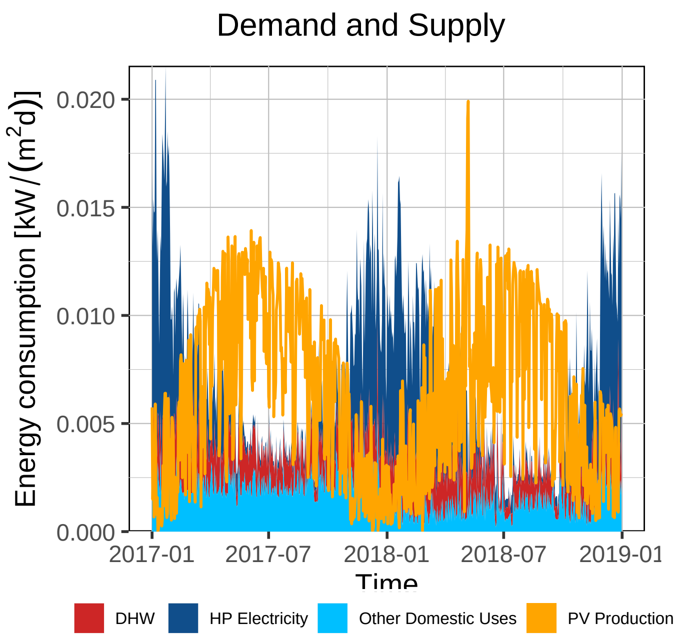
Building case studies analysed

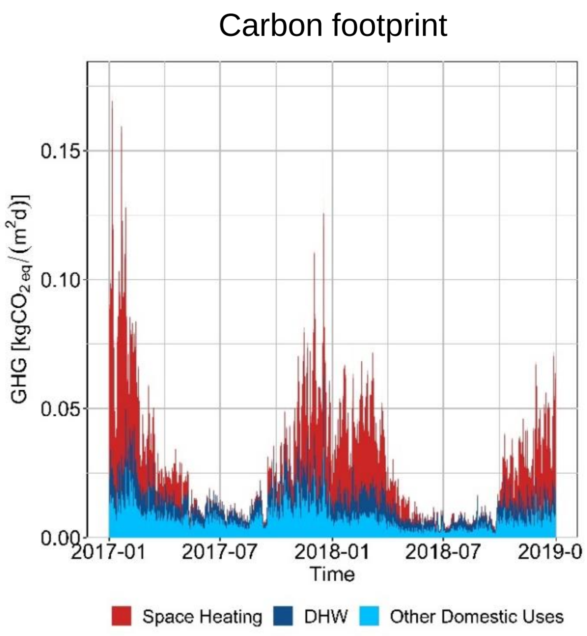
- **Dynamic LCA** of existing **building** case studies **with measured electric load curves matched with** the **time dependent swiss supply mix** of electricity **for the 2017 + 2018 years** (synchronisation of the input data)
- 4 time steps x 6 case studies with/or no PV = ~**50 scenarios**

Case study	Description	Heating system	PV	Time step
CS 1 - 4	Single family house, ERA= 247m^2, construction year: 1975	Heat pump	10 kW	Annual, monthly, daily, hourly
			-	
	Single family house, ERA= 273m^2, construction year: 2000		10.7 kW	
			-	
	Single family house, ERA= 149m^2, construction year: 2000		7.4 kW	
			-	
	Single family house, ERA= 130m^2, construction year: 1987		6.6 kW	
			-	
CS - 5	Multi-family house, ERA= 2663m^2, construction year: 2013		20 kW	
			-	
CS - 6	Office building, ERA= 14'195m^2, construction year: 2013		230 kW	
			-	

Example of 1 out of 50 scenarios → CS 4 for the daily time step

- **From the demand and supply of electricity (grid + PV) → carbon footprint of the building**





	Space heating	DHW	Other domestic uses	Total
GHG emissions [kgCO_2-eq/(m^2.a)]	5.8	2.4	2.5	**10.7**

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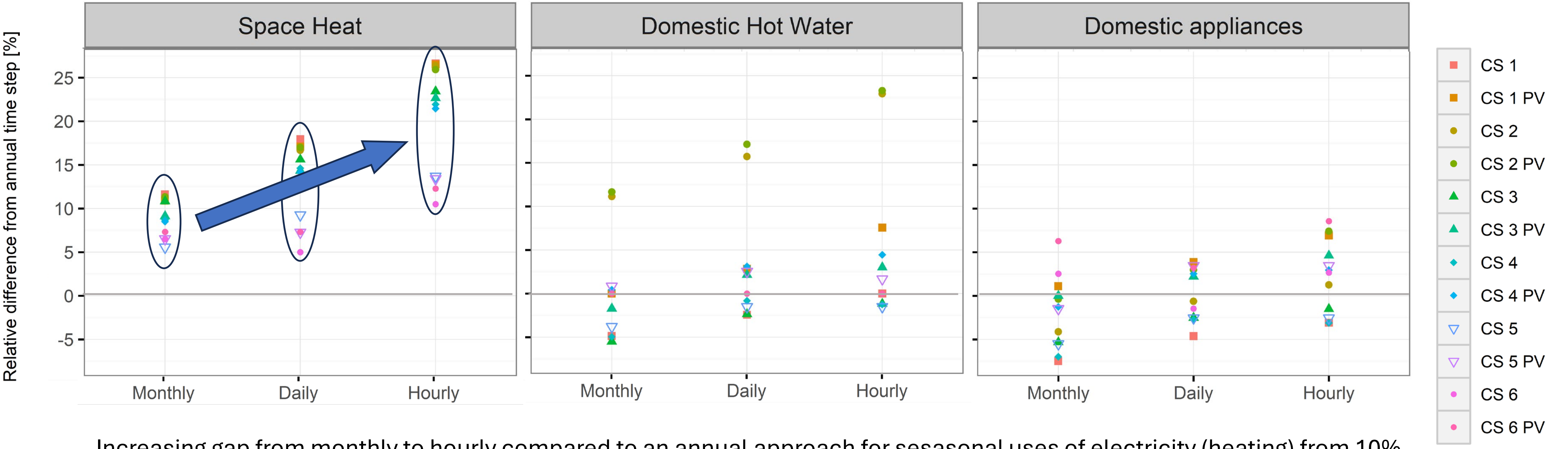
Time step resolution influence for the carbon footprint

- Results for 6 different building case studies (CS) for the different time steps



Increasing gap from monthly to hourly compared to an annual approach for sesasonal uses of electricity (heating) from 10% to 27% differences, less prononced for the constant uses like domestic hot water, and domestic appliances
Time step influence more pronounce for CS1-4 than CS5 and CS6 as the latter are more energy-efficient

Conclusions & Perspectives

Conclusions

- EcoDynElec is a model and tool representing the physical flows to calculate historical LCA profiles of electricity consumption mixes
- Applied successfully to the building electricity demand of Swiss case studies heated with an heat pump using real electrical load curves.
- Time step influence is up to 25-30% for the heating between an hourly vs. an annual time-step for the carbon footprint of the Swiss supply mix. Less influence for constant use (DHW and other electricity uses).

Perspectives

- Historical profiles (2017-today) gathered in EcoDynElec can also be used in other applications than buildings LCA e.g., for short term forecasting (24h-48h) applications in Demand-Side Management strategies (e.g. for load shifting) by training machine learning algorithms on these data…

Acknowledgments

- The authors wish to acknowledge the financial support of the SFOE (**EcoDynBat "Ecobilan Dynamique de l'Electricité"** (2018-2020) contract number: SI/501993-01, **Contribution à l'IEA EBC Annex 72** (2018-2021) contract number: SI/501632-01 and **S-DSM "Sustainable Demand Side Management"** (2021-2024) contract number: SI/502165-01).

Schweizerische Eidgenossenschaft
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Swiss Federal Office of Energy SFOE

- More information of EcoDynElec research works & programming tool :

SFOE EcoDynBat final report:
https://www.aramis.admin.ch/Dokument.aspx?DocumentID=68220

GitHub : https://github.com/LESBAT-HEIG-VD/EcoDynElec

Code paper:
https://www.sciencedirect.com/science/article/pii/S2352711023001814#fig1

Thank you for your attention!

Any questions ?

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