HIGH-RESOLUTION MODELING OF HEATING-COOLING DEMAND IN BUILDINGS UNDER FUTURE CLIMATE CHANGE SCENARIOS

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DLR

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Agenda

1. Context and modeling baseline

2. Methodological workflow

3. Heating demand modeling

4. Climate Change projection

5. Conclusions

Modeling Context

"Exploring Energy Demand Dynamics"

Energy system design –

long term perspective:

- ▪ Requirements, concepts and technical solutions for the future operation of climate-neutral energy systems.

- ▪ Feasibility of a sustainable and resilient overall energy system over different scenarios.

- • **Climate change** can have an effect on energy demand for heating and cooling caused by more intense temperature conditions.

- • **Demand for heating and cooling** is a key aspect when analyzing the effects of climate change in future scenarios.

Modeling Baseline

WHAT:

- High resolution time series of heating and cooling demand under different climate change scenarios

  - Germany
  - Residential and Commercial sectors
  - ~~Regional spatial resolution (NUTS2)~~
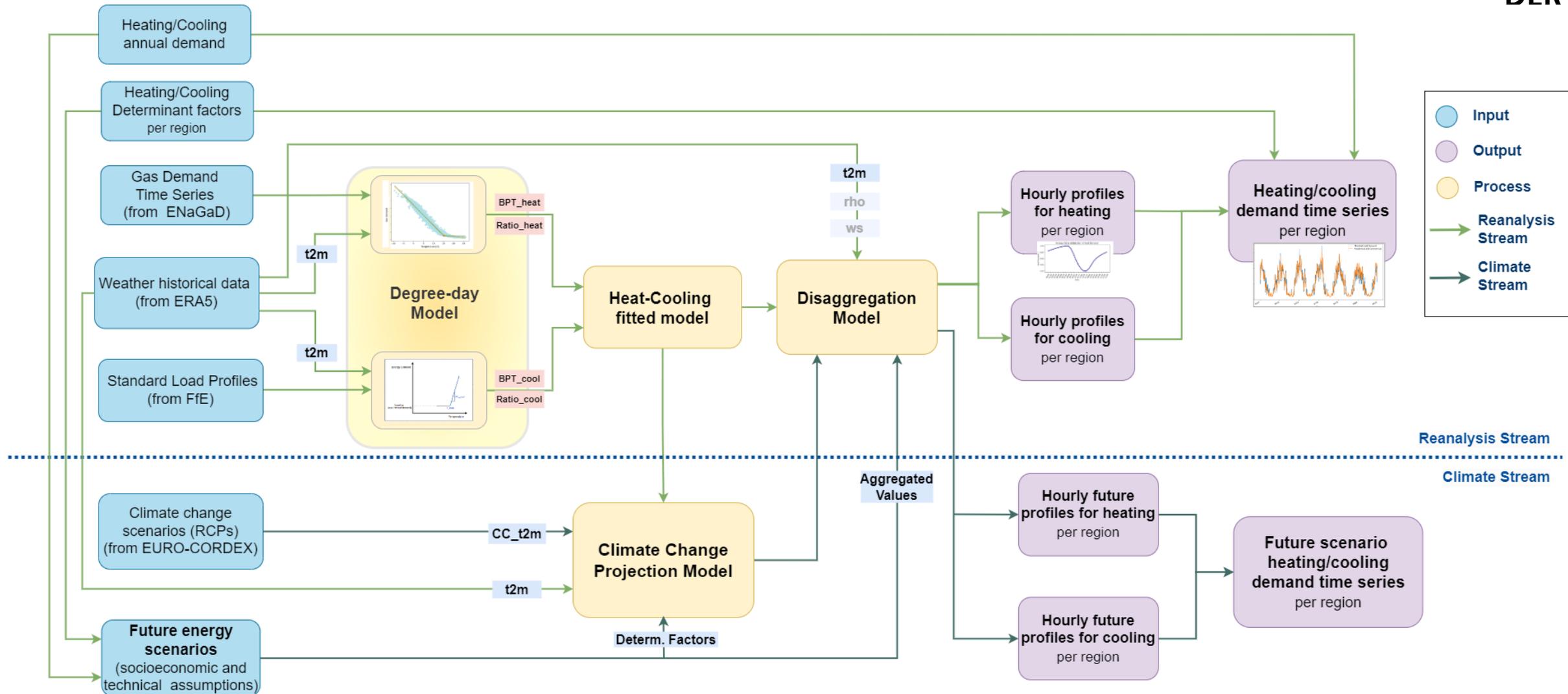
Heat Modeling

National Level

WHY:

- Enrichment and flexibility of tools for energy systems analysis

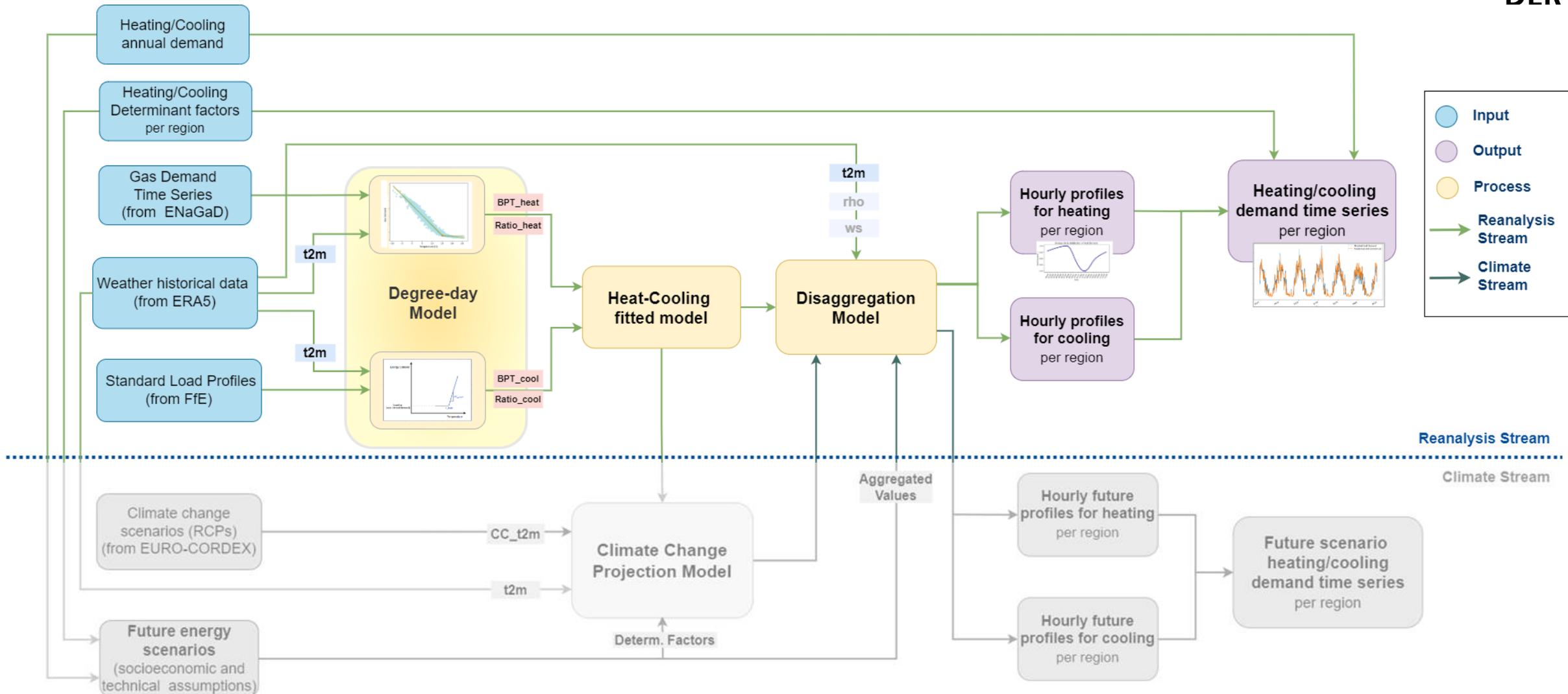- Impact on modeling of long-term future sustainable energy system and climate change mitigation

WHO:

- Scientific community
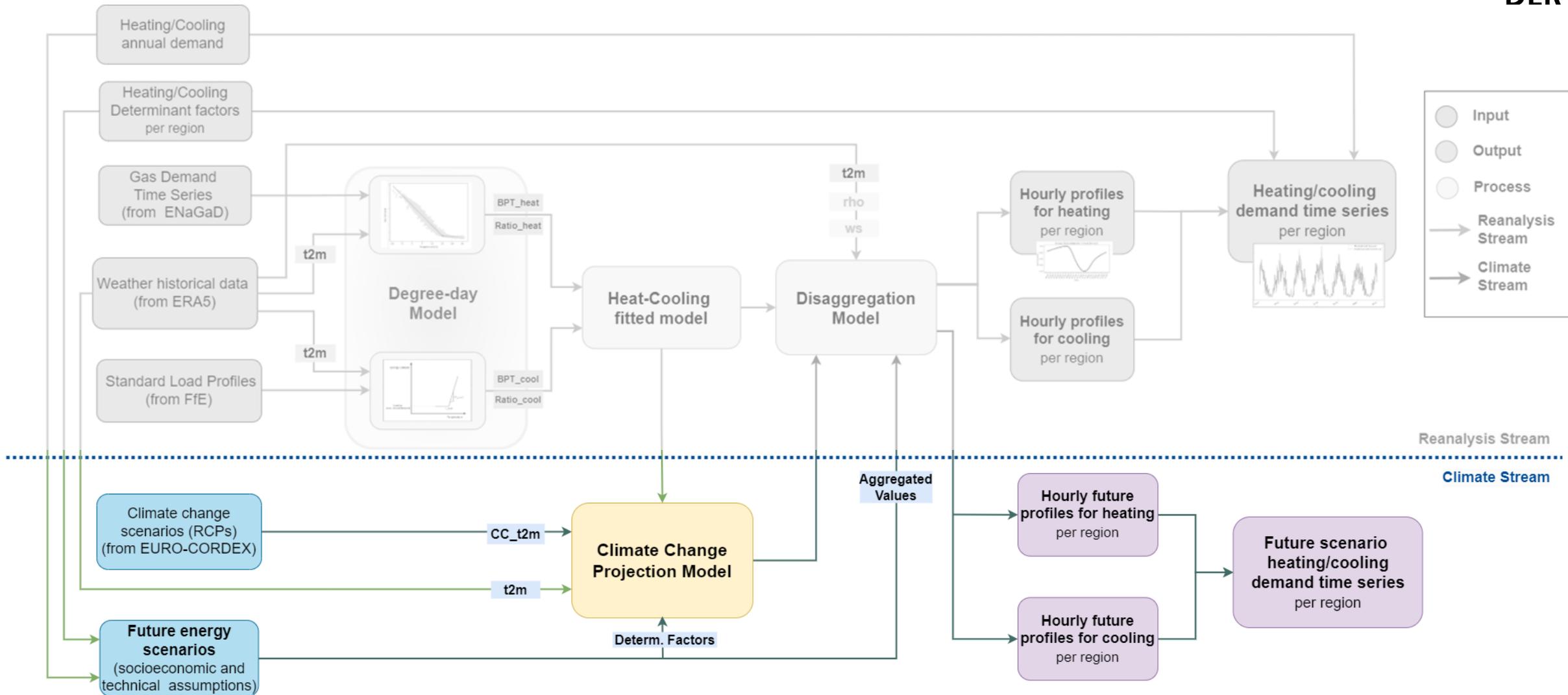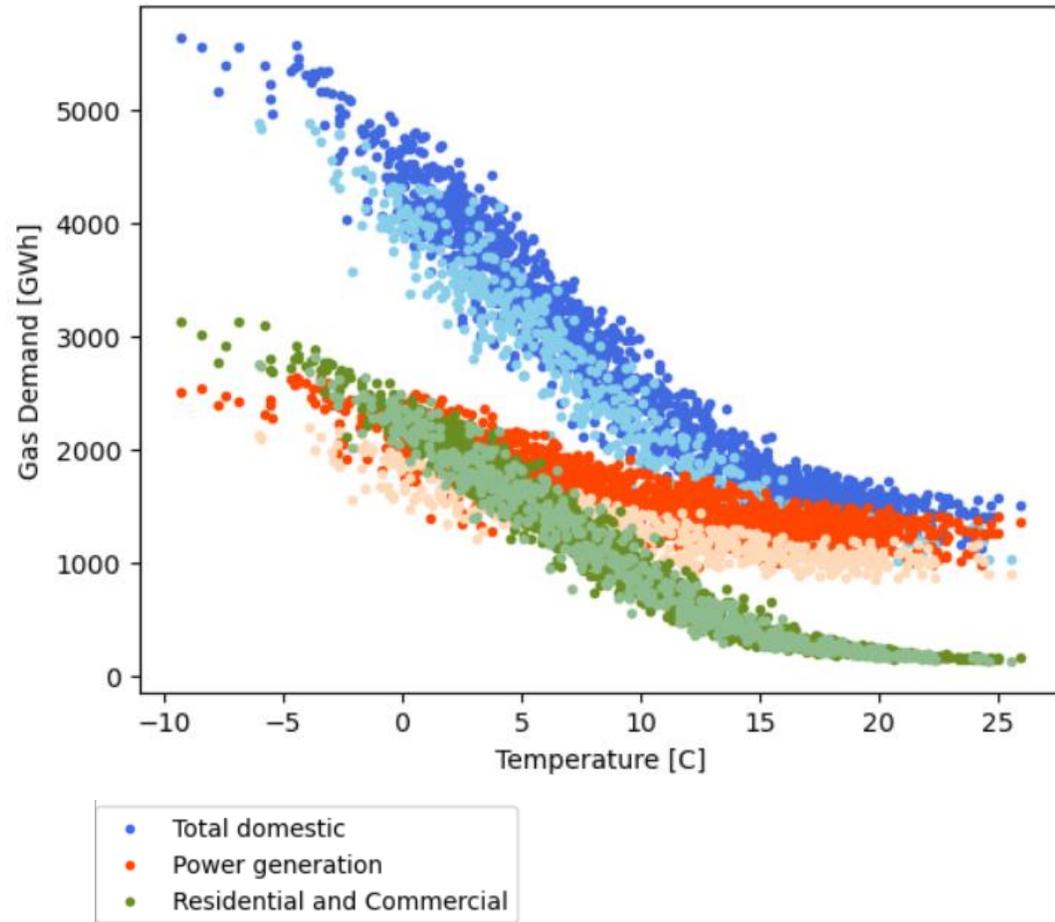
- Energy system and market modeling

Modeling Workflow

Modeling Workflow

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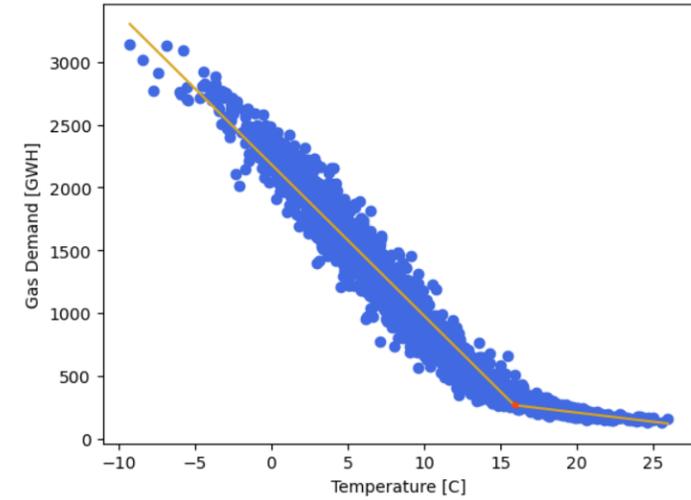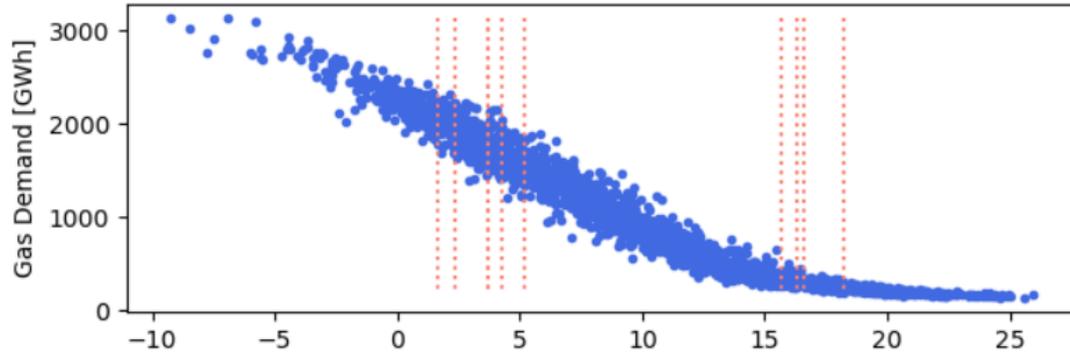# Modeling Workflow

Heating Demand Modeling

- The European Natural Gas Demand database (ENaGaD)
- Federal Network Agency from Trading Hub Europe (THE)

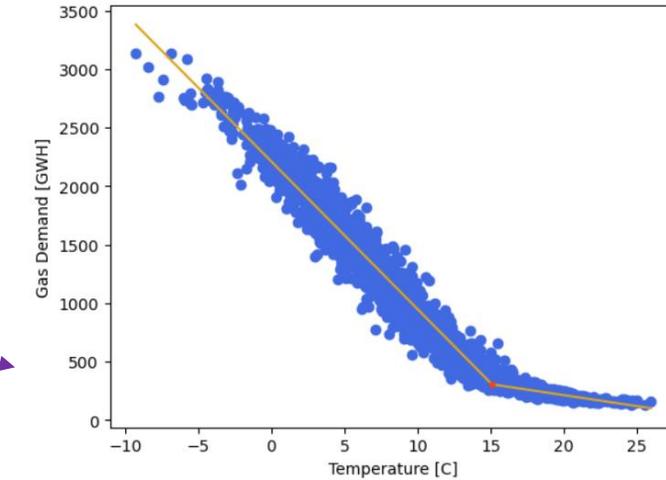- Daily time series from Jan 2015 until Dec 2023

→ *Residential and Commercial sectors.*

Heating Demand Modeling
Preliminary results

Balance-point Temperature = 15.911598733316852
Combined RMSE = 191.2019183022229
Heating RMSE = 151.92314613610787
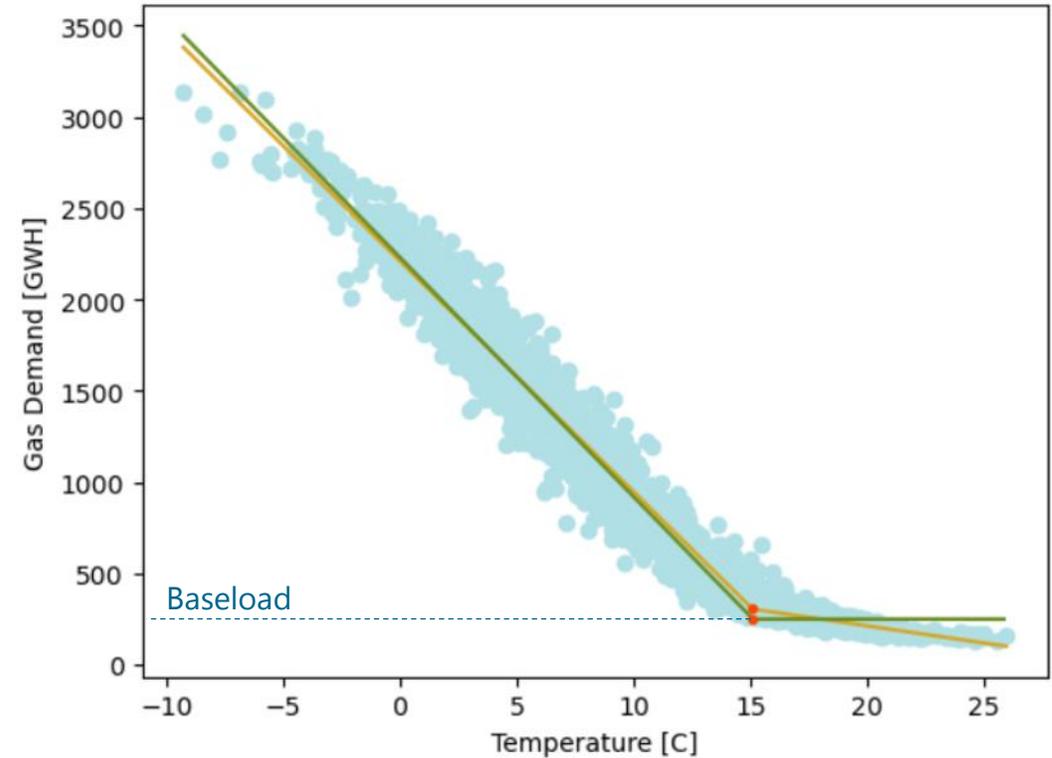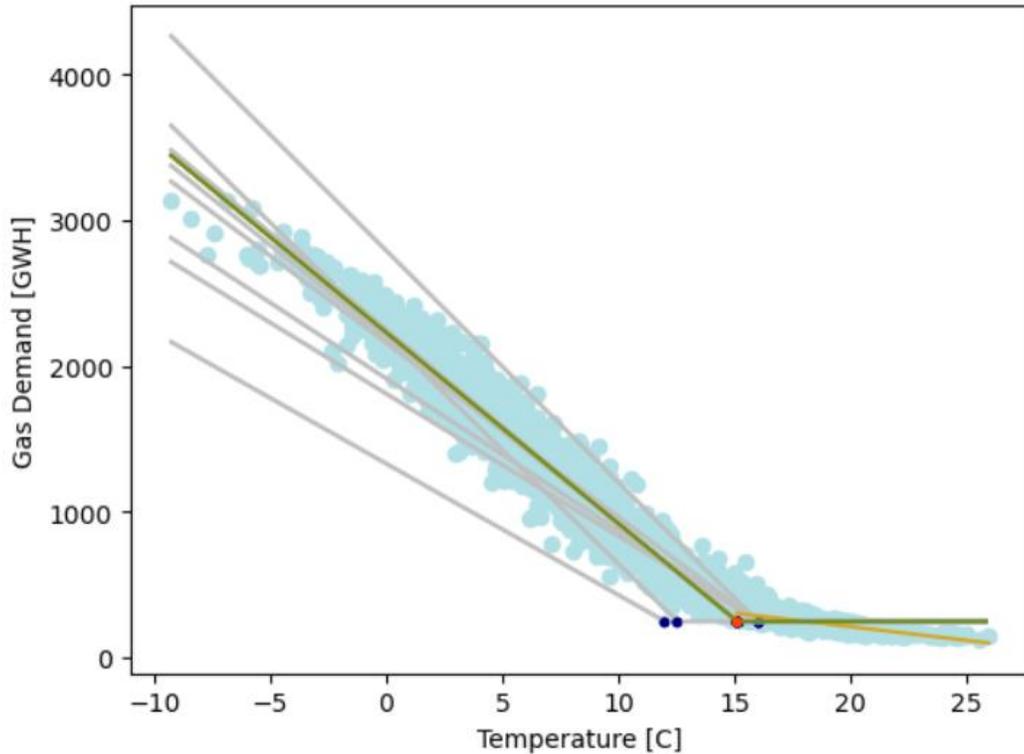Pearson for Heating Demand = 0.9530609461372641

Balance-point Temperature = 15.101043731486843
Combined RMSE = 188.6704850996533
Heating RMSE = 146.60852074027525
Pearson for Heating Demand = 0.9546024997060157

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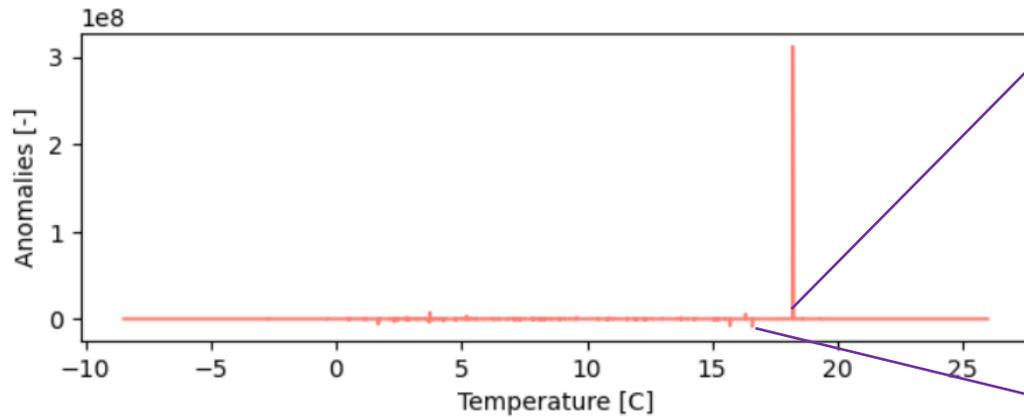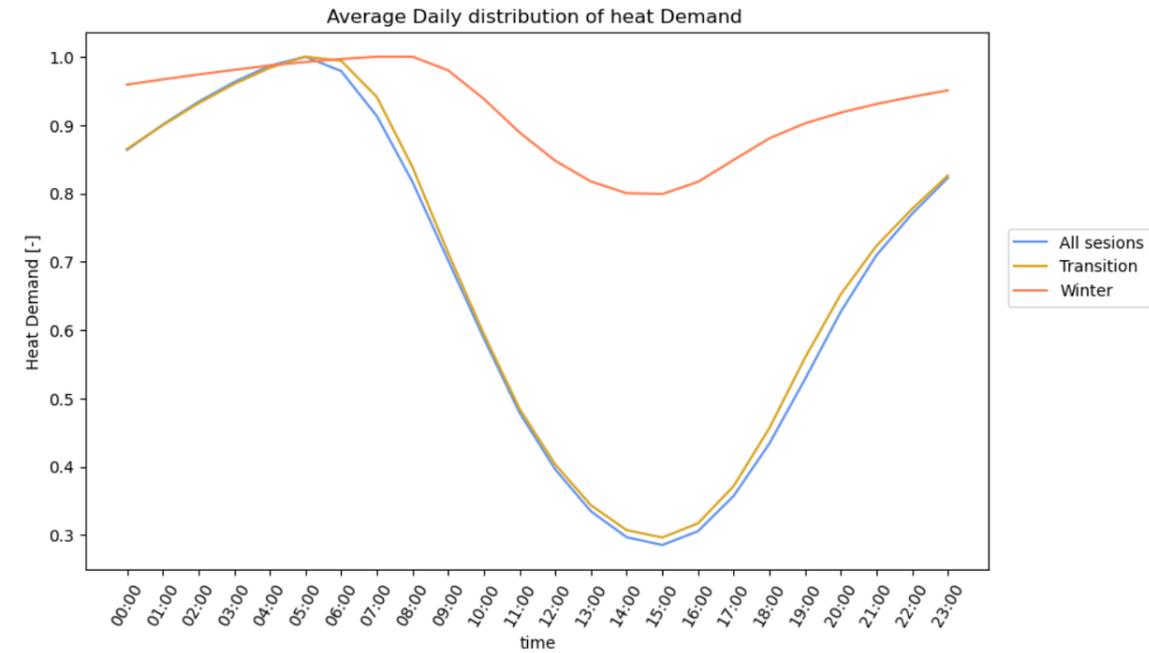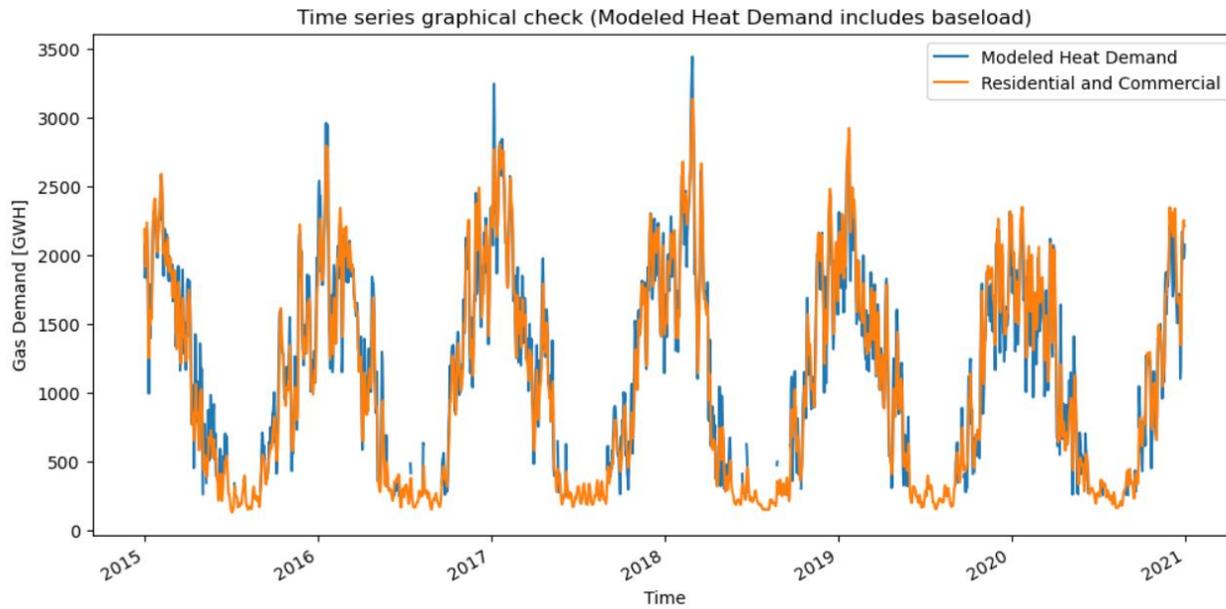
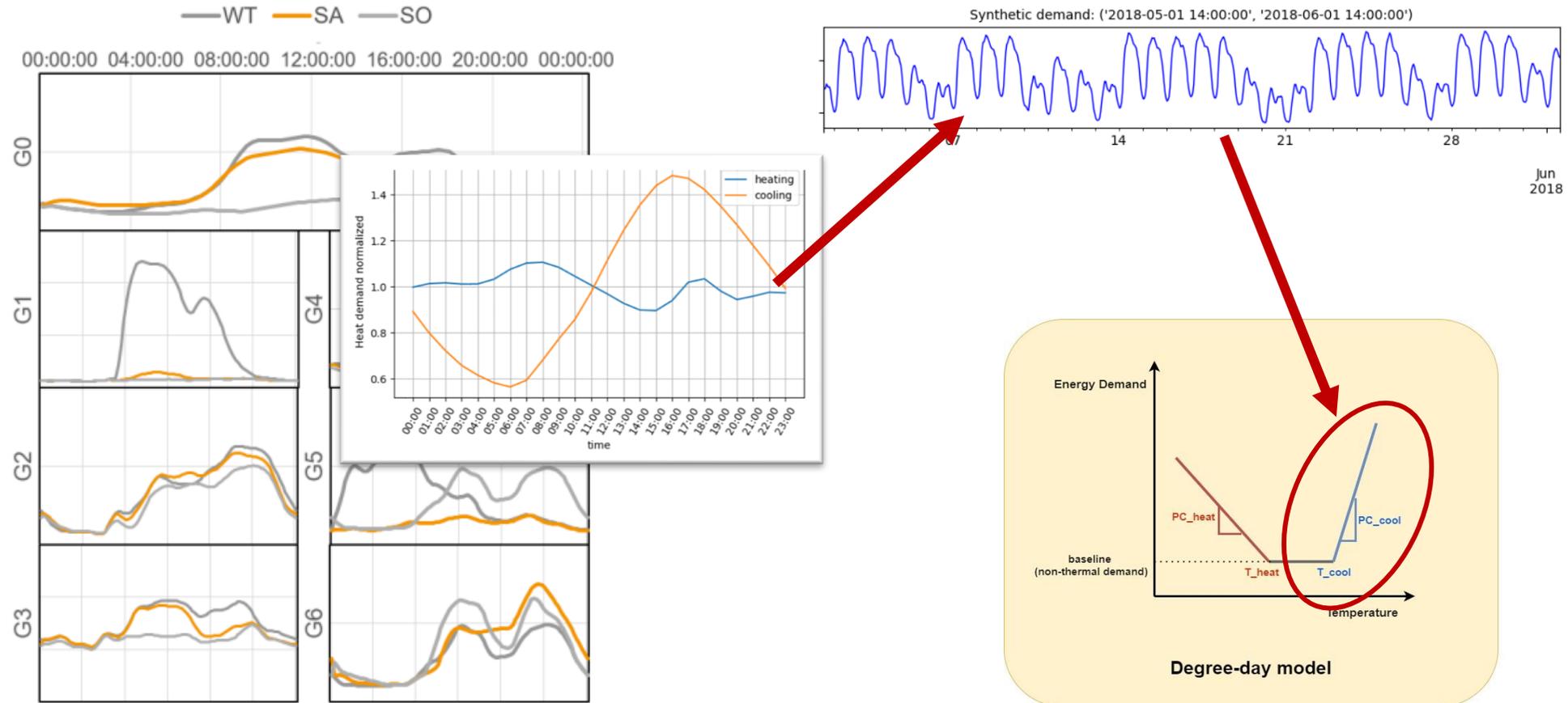# Heating Demand Modeling
Preliminary results

Balance-point Temperature = 14.489042846406267
PC_Heat = -136.59758250461664
Heating RMSE = 108.83231874186761
Baseload RMSE = 65.42715250773533
Pearson for Heating Demand = 0.9649625072099979

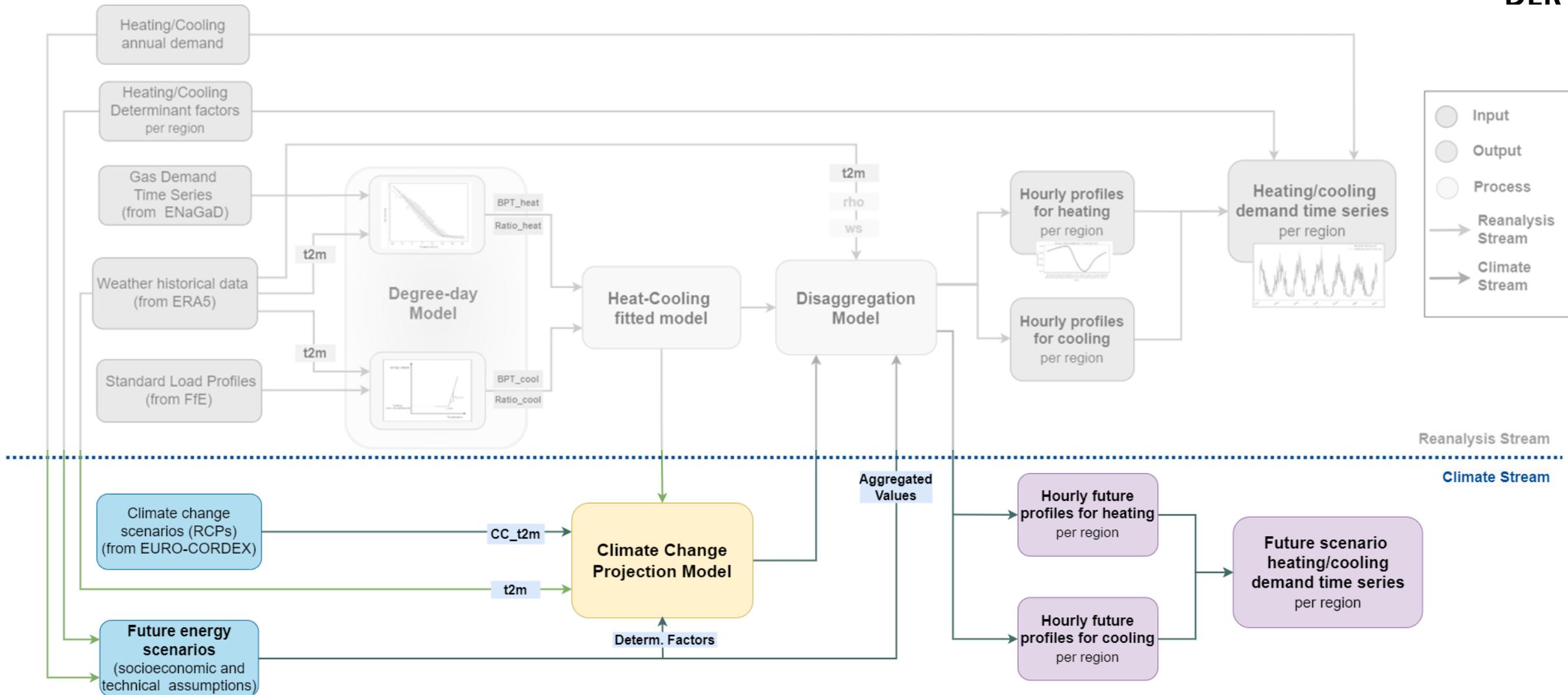# Heating Demand Modeling
Preliminary results

Time series graphical check (Modeled Heat Demand includes baseload)

Average Daily distribution of heat Demand

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Modeling Workflow

Climate Change Scenarios

Future period 2031-2060 with RCP4.5
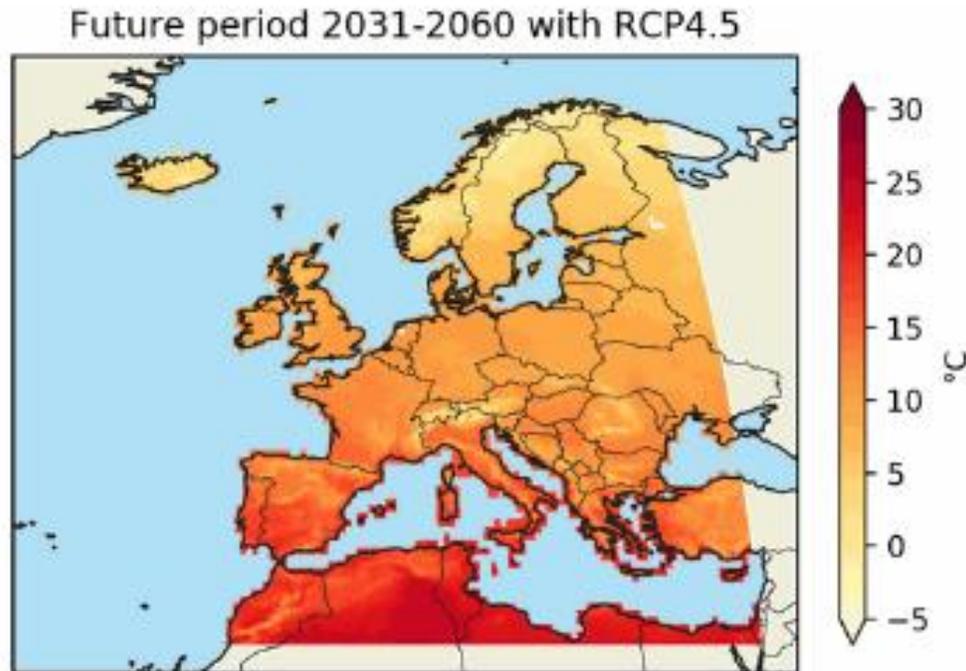
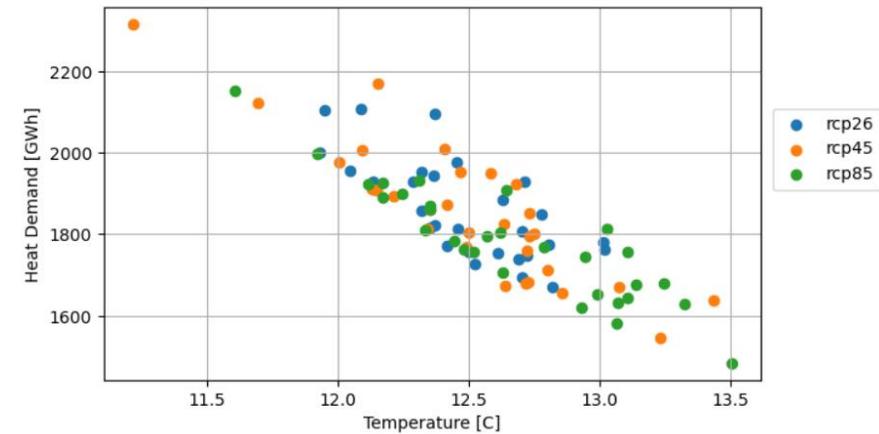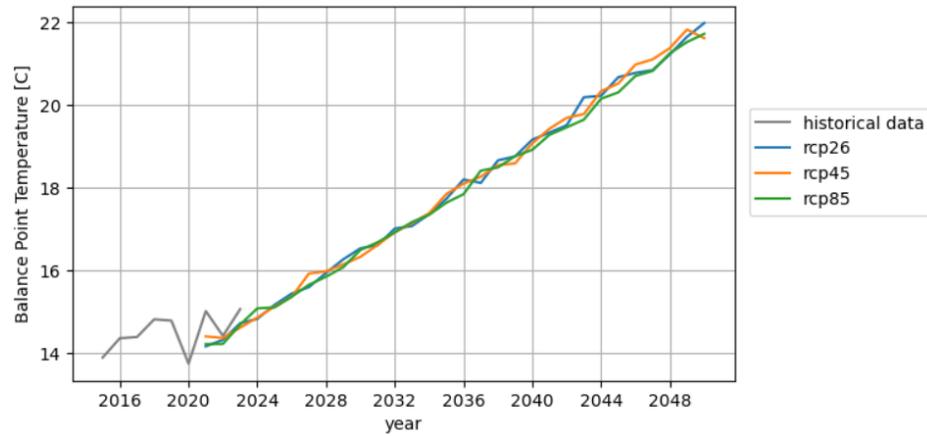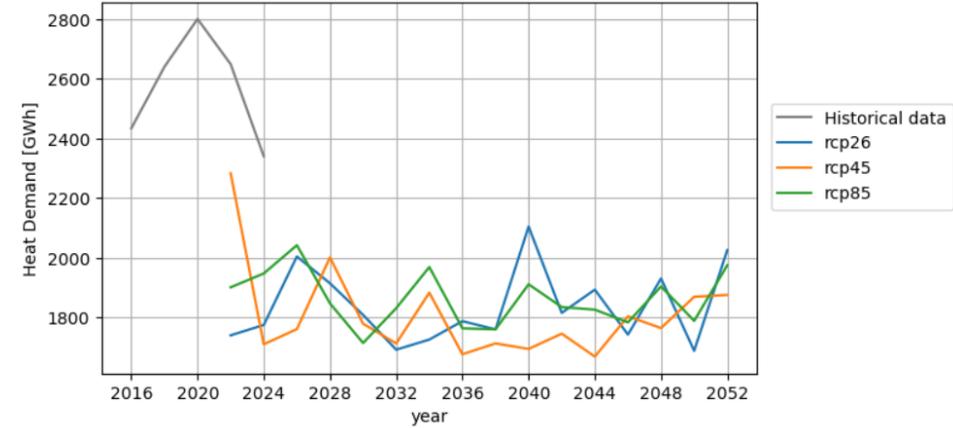- EURO CORDEX - Representative Concentration Pathways (RCP2.6 , RCP 4.5, RCP8.5)

- Demand projection from 2020 until 2050

- Multiregression analysis considering:
  - Socio-economic factors
    (Population Density and GDP)

  - Seasonal patterns change
    (Winter – Sommer - Transition)

  - Energy system adaptation
    (future share of energy matrix)

  - ~~Building stock thermal and technical characteristics~~

Climate Change Scenarios
Preliminary results

Climate Change Scenarios Preliminary results
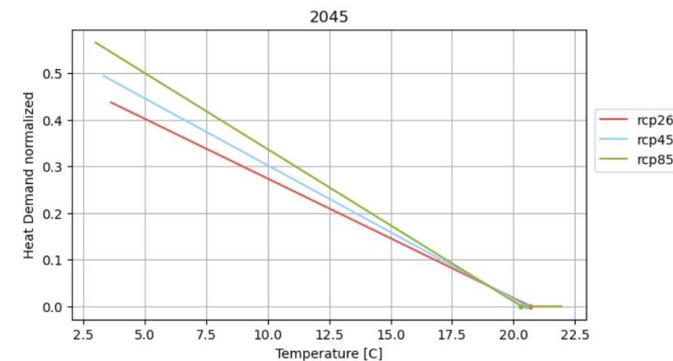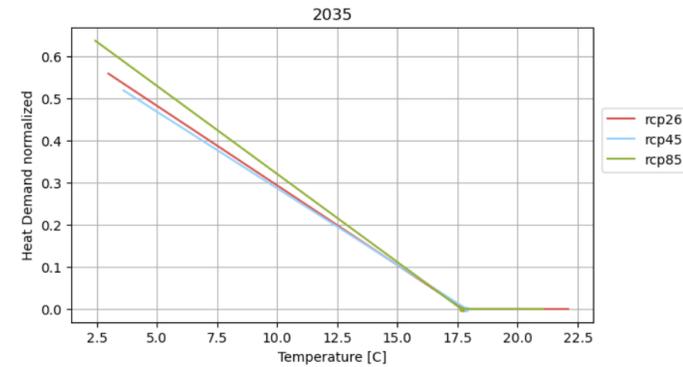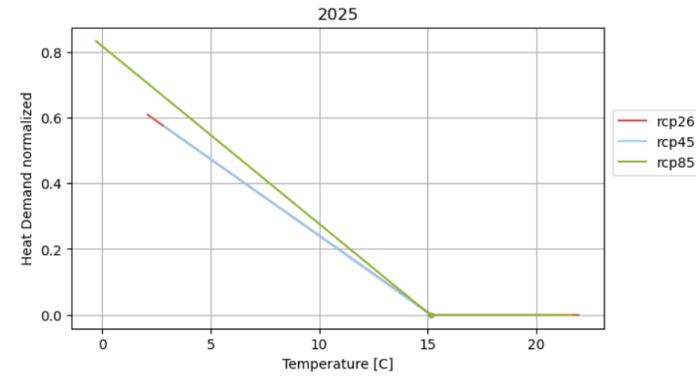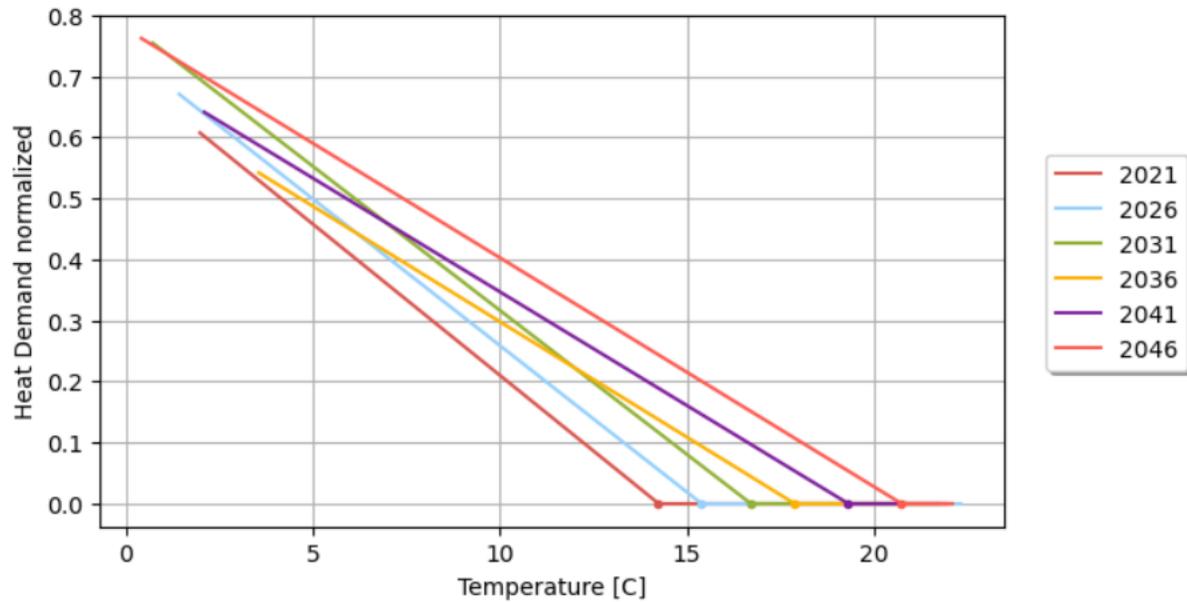
RCP8.5

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Outcomes
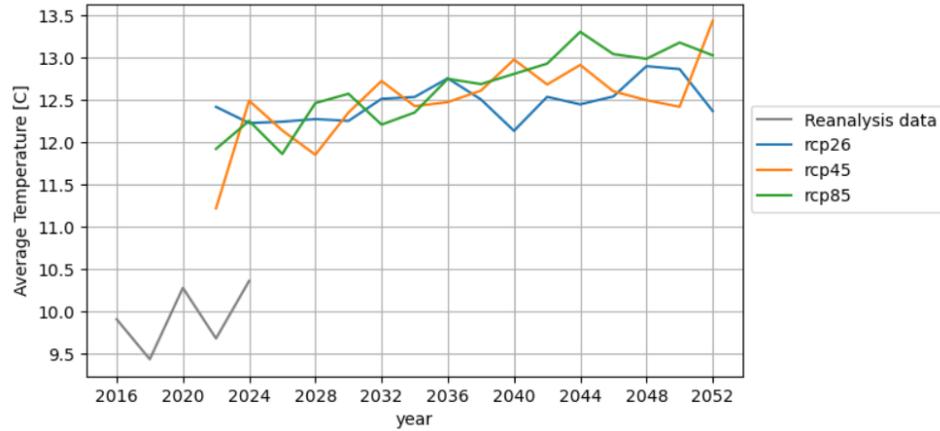
Modeling:

- Demand for heating and for cooling must be treated and modeled separately *(Parametrization by differentiating between main energy sources, season, calendrical patterns.)*

- Day of the week seems not to have an impact on heating demand

- Seasonal patterns is the main factor driven by changes on temperature for thermal modeling

- Developing of building stock and it thermal capacities is crucial but still missing in the modeling.

- Parametrization of degree-day model using year distinction is valuable for future climate change projections

- Socio-economic aspects and their future development are relevant to the future climate change projection model

Preliminary results

- Increase in average annual temperatures and a increase in max temperature might lead to a decrease of heating requirements but an start/increase of the use of air conditioning.

- In Germany, the tendency is towards a decrease in heating requirements in residential and commercial buildings and its consumption rate.

- Projection of future BPT values present increasing values, which is surprising if improvements to thermal isolation in residential and commercial buildings are expected. Therefore, it is meaningful to include the thermal characteristics of building stock.
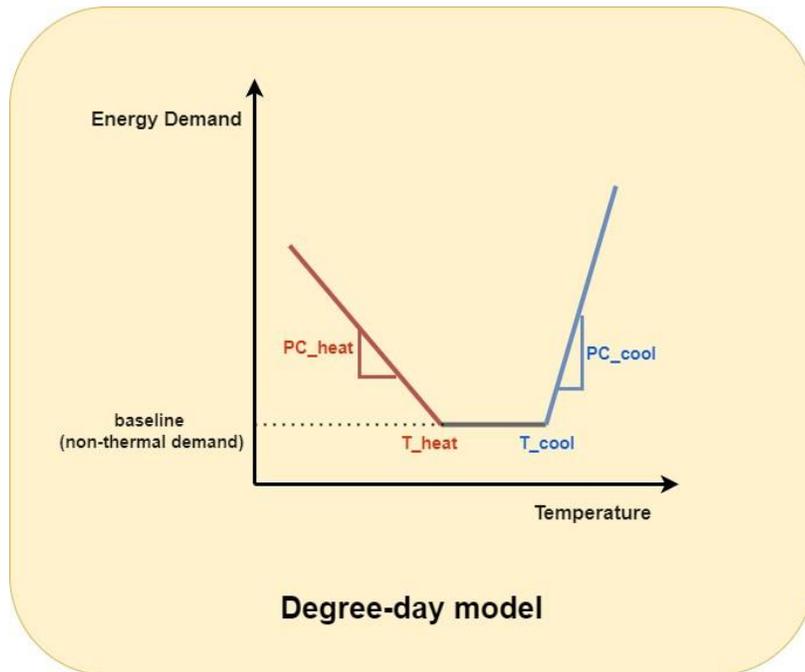
References

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[2] Fumo, N., & Biswas, M. R. (2015). Regression analysis for prediction of residential energy consumption. *Renewable and sustainable energy reviews*, *47*, 332-343.

[3] Fotis, P., Karkalakos, S., & Asteriou, D. (2017). The relationship between energy demand and real GDP growth rate: The role of price asymmetries and spatial externalities within 34 countries across the globe. *Energy Economics*, *66*, 69-84.

[4] Palacios-Garcia, E. J., Moreno-Munoz, A., Santiago, I., Flores-Arias, J. M., Bellido-Outeirino, F. J., & Moreno-Garcia, I. M. (2018). A stochastic modelling and simulation approach to heating and cooling electricity consumption in the residential sector. *Energy*, *144*, 1080-1091.

[5] Falchetta, G., Pavanello, F., & Wing, I. S. (2023). Inequalities in global residential cooling energy use to 2050.

[6] Isaac, M., & Van Vuuren, D. P. (2009). Modeling global residential sector energy demand for heating and air conditioning in the context of climate change. *Energy policy*, *37*(2), 507-521.

[7] Households' adaptation in a warming climate. Air conditioning and thermal insulation choices

[8] Yueksel-Erguen, I. (2021). *Gas supply and demand: Forecasts and historical data* [Data set].

[9] Gasverbrauch der Bundesnetzagentur von der Trading Hub Europe (THE)

[10] ENTSO – E Transparency Plattform - https://www.entsoe.eu/data/transparency-platform/

[11] eurostat Energy balances - https://ec.europa.eu/eurostat/data/database

THANK YOU

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BackUp

Modeling Workflow: Degree-day Model
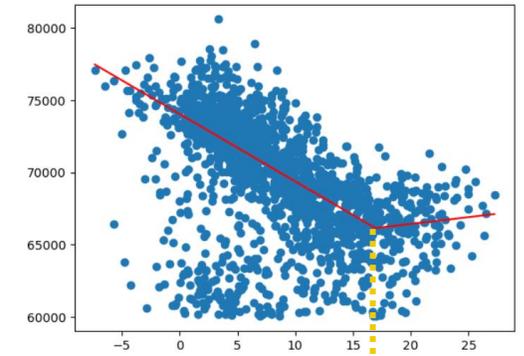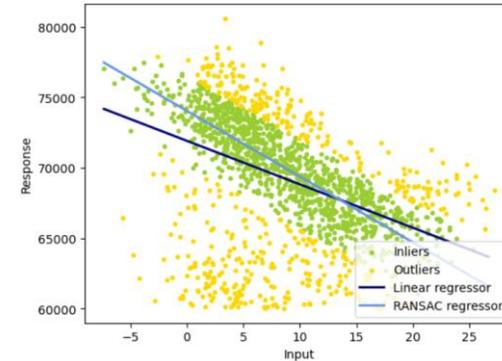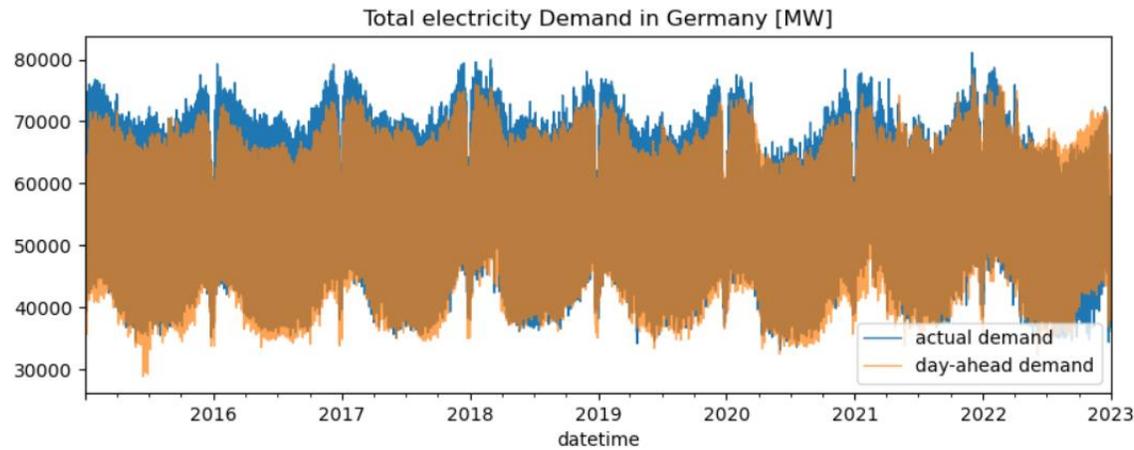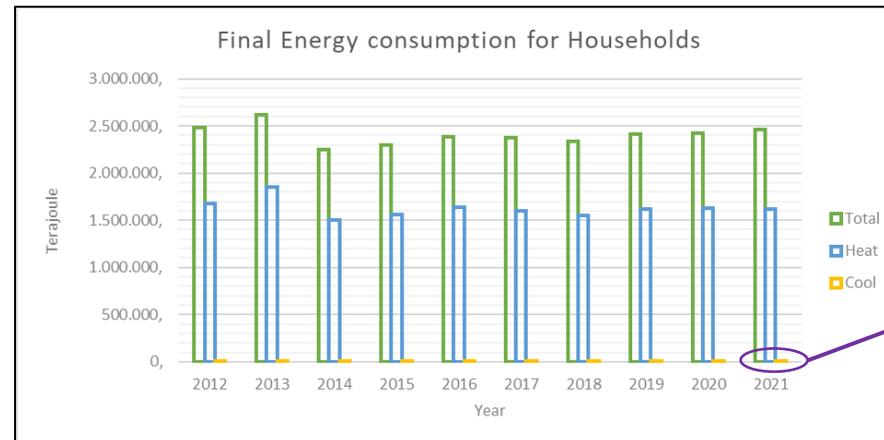

Degree-day model

Challenges:

- Proper determination of heating/cooling power coefficients

- Demand for heating and for cooling must be treated separately *(Identification by differentiating between energy sources, season, calendrical patterns.)*

Modeling Workflow: Degree-day Model for Cooling

Balance-point Temperature

≈ 0.2% of total energy consumption (GER)