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Deliverable report

Deliverable n°	1.2.1
Deliverable name	Model code and software infrastructure for thermal-ESM (tool)
Authors The authors bear the entire responsibility for the content of this report and for the conclusions drawn therefrom.	Jonathan, Chambers, UNIGE, Jonathan.chambers@unige.ch Guidati Gianfranco ETHZ, gianfranco.guidati@esc.ethz.ch
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sweet swiss energy research for the energy transition

Summary

The deliverable consists of open-source modules related to published works on thermal energy systems. The focus is on local or "mesoscale" systems, such as city and district scales. A series of modules were developed based on several research outputs from the SWEET DecarbCH project. It includes algorithms for generating load curves based on annual heating and hot water demands, generating a District Heating Network (DHN) layout, and evaluating the renovation potential of buildings. The data used includes building stock heat and cooling demands, derived from regional and national energy demand statistics and various measurement campaigns. The computing infrastructure is built using Python and Jupyter notebooks, with a Postgres database for storage. This system has been successfully replicated with other research groups. The infrastructure provides shared CPU and RAM resources, multiple storage tiers, SQL and GIS capabilities, Python environments, and interactive computing through Jupyter notebooks.

1 Introduction

This deliverable summarises the availability of software code implementing published aspects of the thermal energy system modelling work and documenting the computing hardware and software developed to run the code. Note that where suitable documentation for an element is available in the form of paper article or research archive, we refer the reader to those documents. Priority is given to links available in the SWEET CROSS project which aims to store model and dataset metadata relating to SWEET project outcomes. We exploit synergies with the Swiss Energy Scope by providing local understanding of potentials and costs and cross referencing use of various resources (e.g. providing limits on use of biomass).

2 Deliverable content

2.1 Local scale thermal energy system model

This section references the thermal energy system modelling at the "mesoscale", e.g. city and district scale. The deliverable content for this section consists of references for model data and code for model components.

2.1.1 Model code

The model integrates several research outputs from the SWEET DecarbCH project. An overview of the project may be found in the relevant Conference article [1]. It integrates modules and data for heat demand estimation and thermal network feasibility and evaluation, for further documentation see deliverable 1.2.2 and references for heat demand load curves [2], renovation potential of buildings [4], and thermal network layout [3]. Public code is available in the UNIGE gitlab repository (https://gitlab.unige.ch/energy-and-buildings/tessa-public).
As a basis for calculation was used an atlas of the annual heat demand of the buildings, with decomposition in terms of space heating and domestic hot water, based on a large sample of real measurements (by typology and construction period). Further description of methods can be found in the relevant conference article [6], while the data has been published on the SWEET-CROSS platform. The data used are:

- Build stock heat demand (data-driven). This data derived heating demands from regional and national energy demand statistics and an aggregation of data from different measurement campaigns.
    - **https://sweet-cross.ch/data/swiss-heat-demand-building-stock/2021-06-01/**
- Building stock cooling demand for service sector (data-driven). This data derived cooling demand from cooling system certificates and a data-driven modelling of cooling system adoption in this Swiss service sector.
    - **https://sweet-cross.ch/data/swiss-cooling-demand-service-sector/2021-06-01/**
- Heating and cooling demand for building archetypes (simulation). This data simulated heating and cooling profiles using bottom-up building physics models of the building stock run using EnergyPlus.
    - **https://yareta.unige.ch/archives/ea0cdaa8-f25e-42a1-8a49-4bdd3844fbbd**

2.1.2 Software infrastructure

The models are developed in the Python programming language using "Jupyter notebooks" for coding and working interactively with the models mentioned above, while Postgres database is used for storage. Figure 1 shows the system infrastructure design to support the modelling system for interactive computing. This infrastructure allows different users to access and share the model code and computing resources behind and has been successfully replicated with other research groups. It provides:

- Shared CPU and RAM resources.
- Multiple storage tiers (small storage with high performance, large storage with slow performance).
- SQL and GIS capability with PostgreSQL database.

- Python environments using “conda” package manager.
- Interactive computing through Jupyter notebook, which allows to combine code and text in a live coding environment.

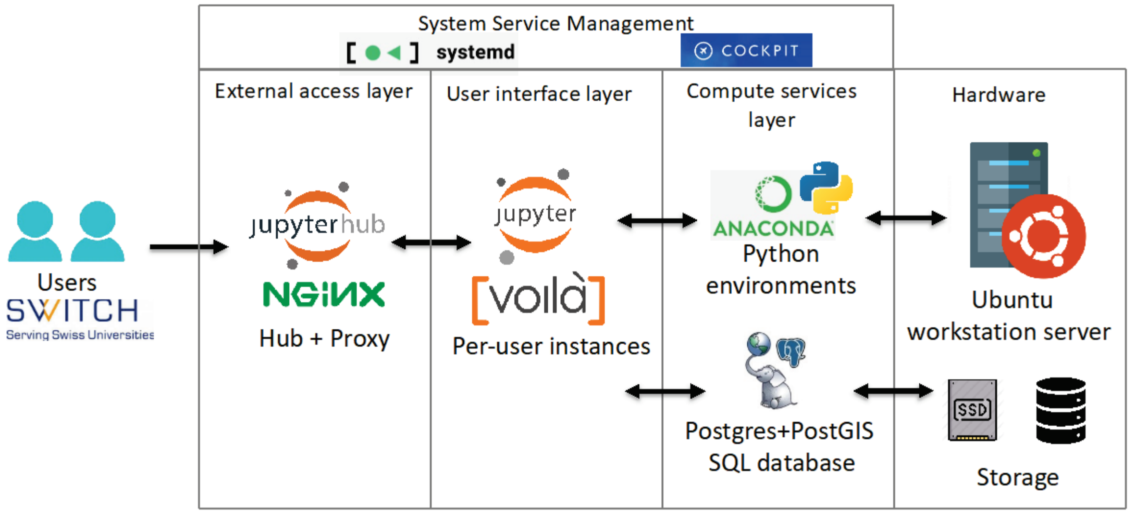

Figure 1 Software system architecture overview.

The setup is as follows:

Hardware layer:

Server hardware provided by institution with specification oriented towards interactive jobs (relative to batch-oriented jobs normally used in HPC environments). This relates in particular to fast local storage (rather than networked storage or Lustre clusters) and high RAM-to-CPU ratio to support working on live/in memory datasets with low latency.

System Service management:

Services are configured using local (Systemd) service manager. This represents a tradeoff by reducing scalability (suitable only for single node configuration) but increasing local reliability and reducing overhead (assumption of reliable local service without possible network disruption). System administration is done using the Cockpit web-based server administration tool.

Compute services:

Python and R kernels provided by the Conda package manager for scientific computing. Users can install their own packages. A Postgres SQL database with PostGIS plugin is also provided for local SQL data processing and Geospatial data storage and processing.

User interface layer:

A Jupyter server is started by JupyterHub for each connected user, see Jupyter documentation for details (**https://jupyterhub.readthedocs.io/en/stable/**).

External access layer:

Implements the JupyterHub configuration to enable multi user access to the service together with Nginx server to provide system security. Documentation for setting up the JupyterHub infrastructure in this manner. has been contributed to the Open Source project and can be found on GitHub at the following location: **https://github.com/jupyterhub/jupyterhub-the-hard-way/**

Users Identities:

User identities are provided from the SwitchAAI Swiss universities OpenID service (**https://help.switch.ch/aai/**), allowing cross-institution access and collaboration.

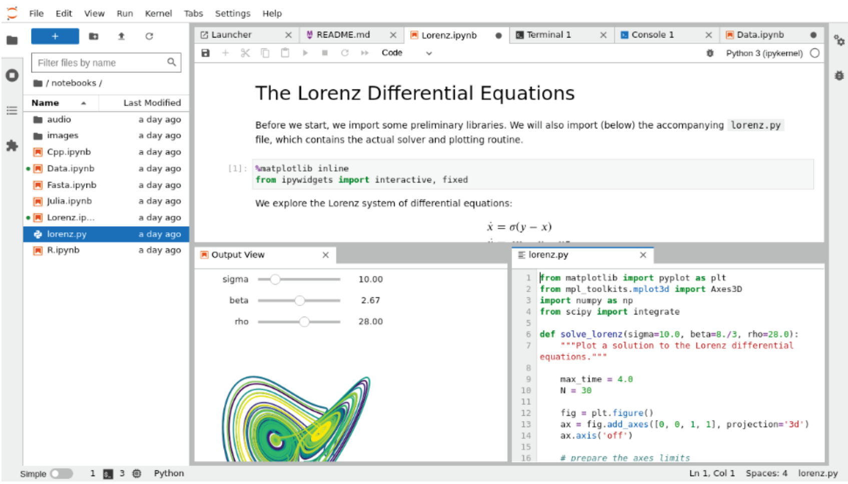

Figure 2 Example of Jupyter environment showing mix of code, text documentation, and interactive visualisations.

3 Conclusion

An overview of the model source code with references to the relevant papers for which the code is published is provided. An overview of the computing infrastructure developed to support this code is given. Further model documentation is provided in deliverable 1.2.2.

4 References

[1] J. Chambers, S. Cozza, and M. Patel, "The GENEAP project: digitalising and automating planning of district heating and cooling," *J. Phys. Conf. Ser.*, vol. 2600, no. 8, p. 082003, Nov. 2023, doi: 10.1088/1742-6596/2600/8/082003.

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[3] J. D. Chambers, "Computationally scalable geospatial network and routing analysis through multi-level spatial clustering," *MethodsX*, p. 101072, Sep. 2020, doi: 10.1016/j.mex.2020.101072.

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[5] F. Sasso and M. K. Patel, "Thermal performance of residential and non-residential sectors: describing differences and understanding underlying reasons," *J. Phys. Conf. Ser.*, vol. 2600, no. 2, p. 022003, Nov. 2023, doi: 10.1088/1742-6596/2600/2/022003.

[6] J. Chambers, M. Rittman-Frank, and M. Patel, "Presentation of new geospatial datasets for renewable thermal energy systems modelling in Switzerland," *J. Phys. Conf. Ser.*, vol. 2042, no. 1, p. 012003, Nov. 2021, doi: 10.1088/1742-6596/2042/1/012003.