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AN INTERACTIVE TOOL FOR OPTIMIZING SUSTAINABLE BUILDING ENERGY SYSTEMS

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Summary

A graphical user interface for energy system modelling (EnSys) was developed. The EnSys-tool consists of a frontend and a backend. In the frontend, the energy system model is created on a digital whiteboard and then transferred to the backend. In the backend, the energy system is transferred to oemof.solph (Krien et al., 2020) and solved. The results are then processed and visualised. The EnSys-tool has proven to be extremely suitable for people who do not have extensive programming experience. The browser-based solution offers the advantage that no software needs to be installed for the development of energy systems in the building sector.

Keywords: Decision making–Mathematical models, energy modelling, building sector, graphical user interface, oemof

Field of application for the findings: Optimization and decarbonization of energy systems in the building sector

Addressed audience: Engineers and building designers

1. Introduction

The transition to a climate-neutral energy system poses a significant challenge. One way to support this transition is through the use of energy system models. The open-source modelling framework oemof is one example of a generic modelling environment. Oemof.solph (Krien et al., 2020) is a programme developed with Python, which requires certain programming skills to use. As a result, access to such systems is difficult for a large number of users. This problem has been recognised by several institutes, which have developed appropriate solutions. The EnSys-tool (Lubojanski et al., 2025) enables the mapping of energy systems and optimisation in terms of costs and CO_2 emissions. Since a significant proportion of energy demand is attributable to the heating sector, there is considerable potential for optimising systems in this area. In view of this, the EnSys-tool can be considered a potentially valuable instrument for supporting the process of converting energy supply in buildings.

2. Methology

The tool developed is a browser-based application divided into a frontend and a backend. A key advantage of the browser-based approach is that no additional software needs to be installed on users' computers. It should also be noted that the computing capacity of the user devices is not a significant factor.

2.1 Frontend

The frontend of the platform acts as the primary interface for modeling and simulating energy systems. The tool enables users to create, configure, and evaluate energy scenarios in an interactive, graphical environment. In this context, the computational complexity is abstracted for users.

The angular framework (Jain et al., 2014) based frontend is designed to ensure optimum user-friendliness while maintaining technical completeness. It simplifies complex modelling processes through structured configuration forms, predefined system components and guided scenario management, while still supporting advanced parametric and investment-based modelling approaches. The separation of user interaction from backend calculation ensures responsiveness, scalability and efficient handling of simulation processes through the frontend.

2.2 Backend

The backend is based on a modern microservice-oriented architecture, using the FastAPI framework (Ramírez, 2018) to provide REST functionality.

The implementation follows the model-view-controller pattern, with a clear separation between routing, data models and logic. The technological basis of the system is Python with type hints, which serve to optimise code quality. FastAPI is used as a powerful, asynchronous web framework with automatic OpenAPI documentation. SQLModel (Ramírez, 2025) is used as the ORM (object-relational mapping) layer for data persistence. This enables typesafe database interactions based on Pydantic (Colvin et al., 2025) and SQLAlchemy (Bayer, 2006). The relational database allows flexible storage of complex energy system configurations.

The entire system is containerised using Docker Compose. So it is easy to start the project on own hardware, known as on-premise. The code itself is stored in a public GitHub-repository under the aGPLv3 License.

3. Building-Template

The generic approach of the tool presented proves to be extremely suitable for developing a general approach to modelling energy systems, such as buildings. These can comprise sources, sinks, converters, storage devices and buses, which can be connected via drag-and-drop. The general approach is characterised by the fact that it has no technology-limiting restrictions. However, a thorough examination of the oemof-documentation is necessary for a precise description of the components. To simplify working with the tool, various templates have been provided that can be used to preconfigure energy systems. This makes it easier to get started with simulation using the tool. In this context, a template for building simulation has been developed, which will be presented in detail below.

The frontend is set up on a project basis. You can either create a new, empty project or use an existing template as a basis. At the project level, you can define global settings, including the project name, the units used and the location. Within a project, you can generate and manage different scenarios. For example, an existing scenario and various technology scenarios were created for the building project template.

3.1 Szenarios

Three comparative scenarios were drawn up for the building model:

- existing scenario
- renewable energy scenario
- sector coupling scenario

The **existing scenario** describes the current state of the technology. This scenario is based on conventional electricity and heating requirements. Electricity can only be supplied via the grid. A gas boiler, which uses natural gas from the gas network, is provided to supply space heating and domestic hot water.

The **renewable energy scenario** expands on the existing scenario to include renewable energy technologies (in this case, exclusively rooftop photovoltaic systems) and an electricity storage system. It also offers the option of feeding surplus energy into the electricity grid.

In the **sector coupling scenario**, the model is expanded to include a heat pump and a thermal storage tank. All the components described are shown schematically in figure 1.

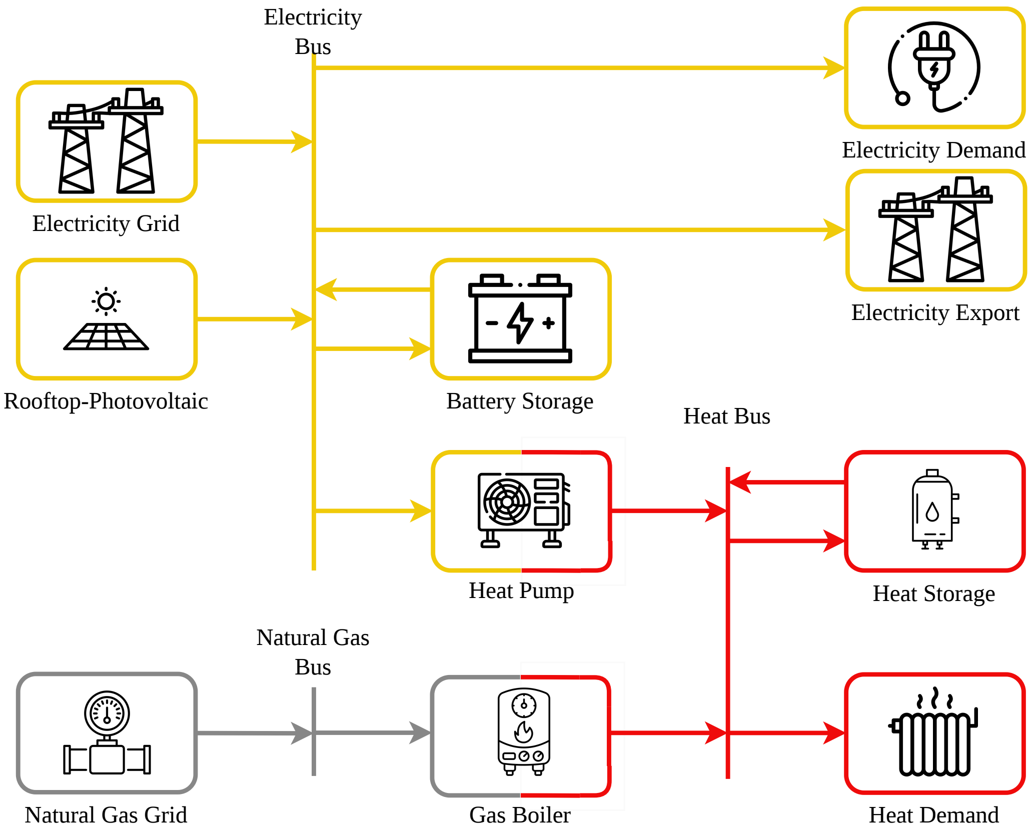

Fig. 1: Schematic representation of the Energy System model

Various assumptions and boundary conditions must be defined for the energy system model. These are described in the section below.

3.2 Assumptions

The model can be applied to buildings of any size. For the purposes of this specific example, we will assume a single-family house. For this model, we will assume an electricity consumption of 3 500 kWh_{el} and a thermal energy consumption of 20 000 kWh_{th}. Electricity and heat demand is not constant over time. The hourly load profiles are taken from the input data for the ZO.RRO II model (Schmidt et al.).

The fluctuating feed-in from the rooftop photovoltaic system is modelled using an hourly feed-in profile generated by the ZO.RRO II model (Schmidt et al.). The output of the photovoltaic system can be freely selected by the optimiser, but is limited to 20 kW_p by the size of the roof area.

For electricity and natural gas supplies, fixed energy prices of 0.3 Eur/kWh_{el} and 0.165 Eur/kWh_{gas} respectively are assumed. The feed-in of electricity to the local grid is paid at a rate of 0.03 Eur/kWh_{el}.

CO_2 emission factors are applied to electricity and natural gas supplies, which were also taken from the ZO.RRO II model (Schmidt et al.) and amount to 269 g_{CO_2}/kWh_{el} and 202 g_{CO_2}/kWh_{gas} respectively.

To describe the photovoltaic source block, techno-economic parameters must be specified in addition to the feed-in profile. Table 1 lists the data used. These data are also taken from the ZO.RRO II model (Schmidt et al.). Several assumptions must also be made regarding the storage systems; these are summarized in table 2. The assumptions for converters are summarized in table 3. The required data were taken from Sterchele et al..

Air is to serve as the source medium for the heat pump. In this regard, the heat pump's efficiency depends heavily on the ambient temperature T_a and the flowout temperature T_{fo} of the heating circuit. The outdoor

Tab. 1: Techno-economic parameters for photovoltaic rooftop powerplant.

Parameter	Investment Costs	Operating Costs	Lifetime	Interest Rate
Unit	Eur/kW_{el}	$\%_{Invest}$	a	%
Value	895	2	25	5

Tab. 2: Techno-economic parameters for storages.

Parameter	Investment Costs	Operating Costs	Lifetime	Interest Rate	Efficiency
Unit	Eur/kWh	$\%_{Invest}$	a	%	%
Battery	900	1	15	5	86.5
Heat Storage	28	1	25	5	81.0

temperature was also taken from Schmidt et al.. A value of 313.15 K was set for the flowout temperature. Using the temperatures and a performance factor ν of 0.4, the hourly Coefficient of Performance $COP(t)$ of the heat pump can be calculated as follows:

$$COP(t) = \frac{T_{fo}}{T_{fo} - T_a(t)} \cdot \nu \tag{1}$$

The results of the optimisations, based on the assumptions described, are examined in more detail in the following section.

4. Simulation results

A linear system of equations is derived from the energy system model developed for the building, which can be solved using so-called solvers. As a result, both the energy flows and the storage states can be examined at hourly resolution. As an example, Figure 2 shows the energy flow on the electricity bus in the sector coupling scenario during a typical summer and winter week.

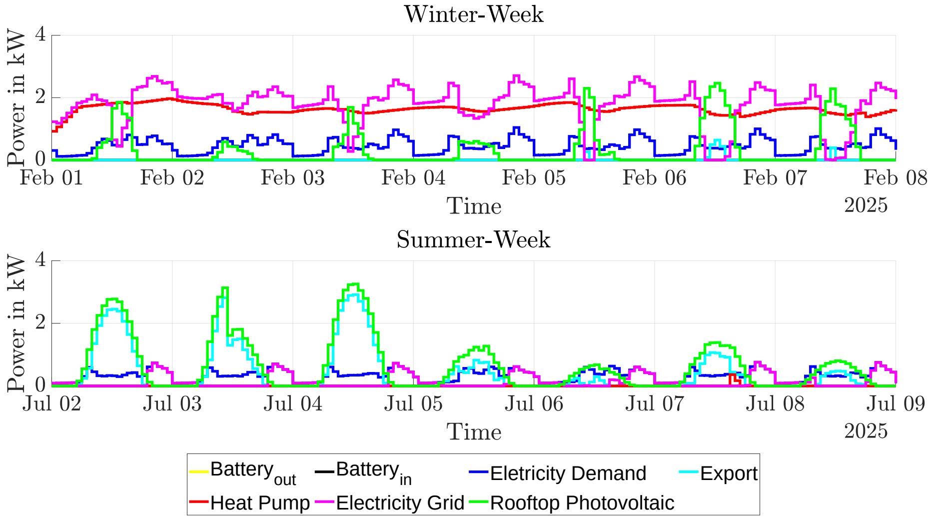

Fig. 2: Illustration of the flow of services during a winter and a summer week in the sector coupling scenario.

Figure 2 shows that significantly more power is drawn from the electricity grid (magenta) during the winter week. Electricity demand for standard electrical applications (blue) varies only slightly between summer and winter. During the summer week, electricity demand (blue) is largely met by the photovoltaic system (green). Electricity only needs to be drawn from the grid during the night. The higher grid consumption during the winter week is also due to the power required to run the heat pump (red). This requires significantly more

Tab. 3: Techno-economic parameters for converter.

Parameter	Investment Costs	Operating Costs	Lifetime	Interest Rate	Efficiency
Unit	Eur/kW_{th}	$\%_{Invest}$	a	%	%
Gas Boiler	97	2	20	5	98.0
Heat Pump	857	1	20	5	$f(T_a)$

energy during the winter months than it does for domestic hot water heating during the summer months. The electrical storage system (yellow/black) is not used in this scenario.

Furthermore, the 'Results' section provides an overview of the power and capacities to be installed. The installed power/capacities are summarised in Table 4.

Tab. 4: Optimised performance and capacities of the various technologies for the building model.

Parameter	Photovoltaic	Battery	Heat Pump	Gas Boiler	Heat Storage
Unit	kW_p	kWh_{el}	kW_{th}	kW_{th}	kWh_{th}
existing scenario	0	0	0	8.5	0
renewable energy scenario	2	0	0	8.5	0
sector coupling scenario	4.5	0	4.9	2.8	4.9

Table 4 shows that coupling the electricity and heating sectors enables better integration of photovoltaics (up to 4.5 kW). Unlike electrical storage, heat pumps and thermal storage are included in the optimisation calculations. The use of a heat pump reduces the output of the natural gas boiler to 2.8 kW.

The performance and capacity figures for the various scenarios also result in different emissions and total costs. Table 5 summarises the values for the three scenarios.

Tab. 5: Optimised performance and capacities of the various technologies for the building model.

Parameter	total costs	emissions
Unit	Eur/a	kg_{CO_2}/a
existing scenario	4 500	5 064
renewable energy scenario	4 318	4 777
sector coupling scenario	2 968	2 068

Using a photovoltaic system can reduce costs by approximately 180 Eur/a. Emissions fall by approximately 290 kg_{CO_2}/a. In the sector coupling scenario, costs can be reduced by 1 500 Eur/a and emissions by 3,000 kg_{CO_2}/a compared with the existing scenario.

5. Conclusion

It is evident that, with the help of the EnSys tool (Lubojanski et al., 2025), a building's energy system can be modelled at a high temporal resolution (hourly values). Depending on how the scenarios are used, the results provide guidance on reducing overall costs and emissions. Furthermore, the cost-optimal outputs and capacities of the components are presented clearly.

The results obtained are heavily dependent on the input constraints and serve as an example of how the EnSys tool can be used. The building model described is available as a template in EnSys and can therefore be easily used and expanded. Thanks to the generic approach in EnSys, it is straightforward to incorporate further technologies such as solar thermal systems.

In future, the template is also to be expanded to include room cooling and building renovation.

6. Acknowledgements

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References

Michael Bayer. The Architecture of Open Source Applications (Volume 2) SQLAlchemy, 2006. URL `https://aosabook.org/en/v2/sqlalchemy.html`.

S. Colvin, E. Jolibois, H. Ramezani, A. Garcia Badaracco, T. Dorsey, S. Matveenko, and D. Montague. Pydantic Validation., 2025. URL `https://pydantic.dev/docs/validation/latest/get-started/#_top`.

Nilesh Jain, Priyanka Mangal, and Deepak Mehta. AngularJS: A Modern MVC Framework in JavaScript. *Journal of Global Research in Computer Sciences*, 5:17–23, 2014.

Uwe Krien, Patrik Schönfeldt, Jann Launer, Simon Hilpert, Cord Kaldemeyer, and Guido Pleßmann. oemof.solph—A model generator for linear and mixed-integer linear optimisation of energy systems. *Software Impacts*, 6:100028, 2020. ISSN 26659638. doi: 10.1016/j.simpa.2020.100028.

Andreas Lubojanski, Mahammad Hossein Ganjyar, Viktor Wesselak, and Christoph Schmidt. EnSys: Model local energy system, 2025. URL `https://ensys.hs-nordhausen.de/`.

Sebastián Ramírez. FastAPI framework, high performance, easy to learn, fast to code, ready for production, 2018. URL `https://fastapi.tiangolo.com/`.

Sebastián Ramírez. SQLModel, SQL databases in Python, designed for simplicity, compatibility, and robustness., 2025. URL `https://sqlmodel.tiangolo.com/`.

Christoph Schmidt, Andreas Lubojanski, Theresa Reinhardt, Rohith Krishnan Bala Krishnan, Viktor Wesselak, and Nordhausen University of Applied Sciences. Input research data on the Thuringia energy system (ZO.RRO II).

Philip Sterchele, Julian Brandes, Judith Heilig, and Daniel Wrede. Wege zu einem klimaneutralen Energiesystem: Die deutsche Energiewende im Kontext gesellschaftlicher Verhaltensweisen: Anhang zur Studie.