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AN ENERGY MODELLING TOOL FOR MUNICIPAL NET-ZERO PLANNING

Summary

Municipalities are key to achieving Switzerland's net-zero target by 2050, yet local energy planning is increasingly difficult as it is shaped by sector coupling, electrification, and renewable integration. Emission reductions therefore require an integrated system perspective. We present a municipal energy system model embedded in a publicly available energy tool. Based on public building-level data, the model is automatically parametrized and simulates hourly energy balances and enables parametric implementation of transformation measures such as heating system replacement and renewable expansion. CO_2 emissions are consistently allocated across sectors, allowing transparent evaluation of marginal and cumulative impacts. Using three municipalities as illustrative cases, we show how the model supports structured pathway exploration and provides municipalities with an accessible basis for system-consistent energy planning.

Keywords: Municipal energy system planning, Net-zero districts

Field of application for the findings: Municipal energy planning

Addressed audience: Energy planners, Municipal officers, Utilities, Researchers

1. Introduction

Switzerland aims to achieve net-zero greenhouse gas emissions by 2050. Substantial responsibility is placed on municipalities through motivating building retrofits, district heating expansion, renewable deployment, and the deployment of charging infrastructure for the mobility sector. Increasing sector coupling requires emission reductions to be assessed at the integrated system level. However, energy planning is often complex or costly when it relies on external consultancy, which limits accessibility for smaller municipalities. To address this gap, the Recommender Tool (Meyer et al., 2023) was developed within the Swiss-wide SWEET EDGE project (*Sweet EDGE*, 2026). It combines municipal energy data with a sector-coupled district energy model that simulates hourly energy balances across the sectors heat, electricity, and mobility. Transformation measures such as heating system replacement, renewable expansion, thermal storage integration, and mobility electrification can be implemented parametrically. CO_2 emissions are consistently allocated across sectors. Using three municipalities, Sirnach (Swiss plateau), Basel (urban), and Lauterbrunnen (alpine), we demonstrate how sequential pathway analysis quantifies marginal and cumulative emission impacts to support informed municipal decision-making.

2. Methods

The presented study is based on the Recommender Tool (*Recommender Tool*, 2026) and its underlying District Energy Model (DEM) (Schilt, 2026). DEM is a municipal-scale multi-energy system model openly available as a Python package or via Github (HSLUDEM, 2026). In the following, a concise overview is provided; detailed documentation and references of the modeling framework and datasets can be found in (HSLU CC TES, 2025).

Heat and electricity demands are estimated at building level based on typology and usage (Schneeberger et al., 2025). The model includes data on existing heating technologies, district heating networks, installed PV systems, rooftop solar potential (Frischholz, 2025), projected EV electricity demand (Herrera and Hug, 2025), and wind power potential (Dujardin and Lehning, 2022). Sector coupling between heat, electricity, and mobility is explicitly represented, enabling consistent tracking of energy flows and CO_2 emissions.

In this study, DEM is operated in deterministic, hourly-resolved simulation mode. Transformation measures are implemented parametrically: (i) heat pump retrofit (100%) replaces all oil and gas boilers with heat pumps;

(ii) rooftop PV (100%) exploits all remaining suitable rooftop potential; (iii) wind (100%) deploys the remaining technically available wind potential; (iv) thermal energy storage (TES) installs storage capacity equal to 20% of annual municipal heat demand; and (v) EV electrification (100%) replaces all fossil-fueled passenger cars with electric vehicles. Although DEM includes an optimization module, it is not applied here; the focus is on pathway-based scenario evaluation.

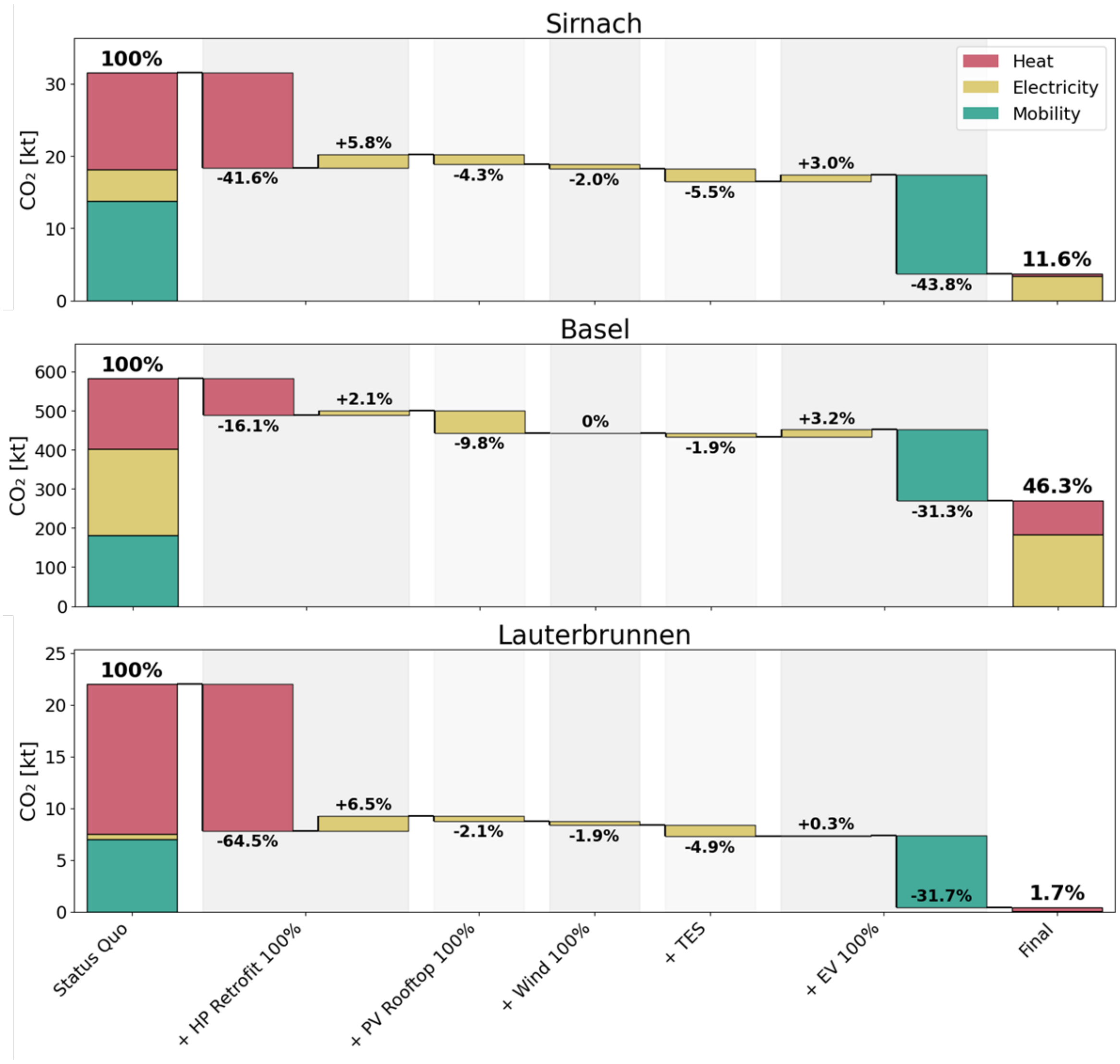

Figure 1: Impact of pathway-based scenarios on the carbon emissions of three Swiss municipalities: Sirnach (Swiss plateau), Basel (urban), and Lauterbrunnen (alpine). Scenarios include replacement of fossil heaters with heat pumps (HP) (+HP Retrofit 100%), expansion of rooftop-based photovoltaic (PV) system (+PV Rooftop 100%), expansion of wind power (+Wind 100%), implementation of thermal energy storage (TES) systems (+TES), and expansion of electric vehicles (+EV 100%).

3. Results

To illustrate the applicability of the Recommender Tool and the relevance of local system characteristics, sector-disaggregated waterfall plots were generated for three Swiss municipalities: Sirnach (Swiss plateau), Basel (urban), and Lauterbrunnen (alpine) (Figure 1). The sequential implementation of transformation measures reveals how baseline structure and sector coupling shape transition pathways.

In Sirnach, emissions are dominated by heating and mobility. Retrofitting fossil heating systems and electrifying mobility together reduce total emissions by almost 80% relative to the status quo. Renewable electricity expansion (PV, wind) largely compensates for the increased demand induced by electrification. The case shows that municipalities with large shares of fossil heating and mobility have a high emission mitigation potential.

In Basel, a large share of buildings is already connected to district heating with comparatively low carbon intensity, limiting large reduction potential in the heating sector. The mobility sector therefore provides the largest remaining mitigation potential. However, constrained local renewable generation and reliance on grid imports (assumed to reflect the national electricity mix) restrict overall emission reductions unless upstream electricity supply is further decarbonized.

In Lauterbrunnen, nearly two-thirds of baseline emissions originate from the heating sector. Accordingly, heat pump retrofitting delivers the dominant reduction effect. Combined with mobility electrification, emissions are reduced to less than 2%. This case demonstrates how municipalities with high fossil heating and mobility shares can achieve substantial decarbonization through electrification.

Across all cases, electrification shifts emissions from heat and mobility to the electricity sector, underscoring the importance of integrated, sector-coupled analysis. The magnitude and distribution of reduction potentials differ between municipalities, highlighting the need for locally specific pathway evaluation.

4. Conclusion

This study demonstrates the capability of the Recommender Tool and its underlying District Energy Model to support municipal energy planning and monitoring of the transition pathway toward Switzerland's net-zero target. By integrating local demand, renewable potentials, infrastructure constraints, and sector coupling, the tool enables transparent evaluation of transformation measures and their system-wide emission impacts. The pathway-based representation facilitates identification of high-impact interventions under municipality-specific conditions.

The quantitative results depend on the quality and resolution of the underlying datasets and assumptions regarding technology performance and electricity carbon intensity. Since most used data are estimations based on past surveys, incorporation of locally measured data and refined parameterization can further improve accuracy. Overall, the approach offers an accessible and structured basis for informed decision-making in municipal energy transition planning.

5. References

Dujardin, J., Lehning, M., 2022. Wind-Topo: Downscaling near-surface wind fields to high-resolution topography in highly complex terrain with deep learning. Quarterly Journal of the Royal Meteorological Society, 148(744), 1368–1388. https://doi.org/10.1002/qj.4265

Frischholz, Y., 2025. CH-POA300—Hourly Plane-of-Array Solar Irradiance at High Resolution for Switzerland. International Journal of Retina and Vitreous, 11(1). https://doi.org/10.16904/envidat.632

Herrera, M. P., Hug, G., 2025. Modeling Charging Demand and Quantifying Flexibility Bounds for Large-Scale BEV Fleets. 2025 IEEE Kiel PowerTech, 1–6. https://doi.org/10.1109/PowerTech59965.2025.11180551

HSLU CC TES, 2025. District Energy Model (DEM) Documentation. https://demdocumentation.readthedocs.io/

HSLUDEM, 2026. HSLUDEM/District_Energy_Model. GitHub. https://github.com/HSLUDEM/District_Energy_Model/tree/main/config/config_files

Meyer, M., Linder, E., Schilt, U., Schneeberger, S., Melillo, A., Gökgöl, E. K., Schuetz, P., 2023. Tool for evaluation of energy system options for municipalities. Journal of Physics: Conference Series, 2600(2), 022010. https://doi.org/10.1088/1742-6596/2600/2/022010

Recommender Tool, 2026. prototype.recommendertool.ch

Schilt, U., 2026. District Energy Model (DEM): Version 0.1.0-rc2 [Software]. Zenodo. https://doi.org/10.5281/zenodo.18154581

Schneeberger, S., Meister, C., Schuetz, P., 2025. Estimating the heating energy demand of residential buildings in Switzerland using only public data. Energy and Buildings, 347, 116371. https://doi.org/10.1016/j.enbuild.2025.116371

Sweet EDGE, 2026. https://www.sweet-edge.ch/