District Energy Model (DEM): An open-source model for local energy system simulation and optimisation.

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Summary

The transition from centralised to decentralised energy systems for achieving net-zero emission targets requires the evaluation of potential future scenarios on various spatial scales [ref]. The *District Energy Model (DEM)* is a Python-based multi-energy system model designed to simulate scenarios from neighbourhood to regional scale with a focus on the integration of decentralized renewable energy technologies (e.g., solar, wind, biomass). DEM runs simulation and optimisation studies in hourly resolution using a "snapshot-year" approach [ref Marechal]. DEM is deployed as an open-source Python library, available as a PyPi package. Once installed, it can be run with command-line interface, not requiring any Python programming knowledge. Alternatively, a Python API is also provided so that it can be used programmatically. Two types of input files are required to run simulations: *configuration files* and *data files*. *Configuration files* specify the simulation metrics (e.g., buildings to consider, simulation timeframe, output to generate) and define the energy system configuration (e.g., scenarios, technologies, selected year). These are provided in YAML format [ref]. When running DEM programmatically in Python, configuration input can be passed directly to DEM without the need of configuration files. *Data files* provide information about energy demand, generation potential, and ambient conditions. These are provided to DEM in FEATHER format [ref]. For selected regions (e.g., Switzerland), data files have been compiled from public data sources and made available to be used with DEM. This lets users run simulation studies without the need of collecting and compiling such data.

The DEM comes with a detailed documentation providing step-by-step instructions, explaining the modelling approaches and methods, and listing information about publications and research related to DEM.

Statement of need

Many open-source energy system modelling frameworks exist, such as e.g., SESMG [ref], EHTOS.FINE [ref], REHO [ref], (..find more). Each model has strengths and weaknesses and specific scopes of application. While these models provide valuable frameworks for evaluating multi-energy systems on various spatial and temporal scales, they require the user to provide input data such as demand profiles, cost information, or technology specifications. A large portion of the work when creating simulation studies using a modelling framework goes into the collection and generation of such data. DEM eliminates the need for this work as it already provides this type of data for selected regions and therefore greatly reduces the workload for the modeller. The provided data has been collected from various public sources and pre-processed for use in simulation studies. Therefore, simulation and optimisation studies can be run in

42 DEM with only minimal configuration requirements (e.g., which buildings to consider), while
43 still maintaining maximum flexibility of substituting any of the pre-configured data with custom
44 data and configurations if the need arises.

45 While an optimisation study is very useful to determine optimal technology design and operation,
46 many energy provision scenarios can be simulated without applying optimisation. Therefore,
47 DEM can also be run as a simulation without optimisation for various scenarios. This allows
48 for short computation times and fast result generation.

49 - What stands out from a research perspective? Flexibility considerations; local boundaries,
50   while also considering national electricity provision (as an interface model between local,
51   regional, and national energy planning)
52 - Availability of open-source data: pulling it together in one model
53 - Bottom-up demand consideration of individual buildings
54 - Focus on integration of local, decentralized energy sources and technologies
55 - Energy-planning on neighbourhood-scale
56 - No extensive modelling required, yet flexible in scenario creation.
57 - Pre-configured with standard values for the Swiss energy system
58 - Automated parametrisation: Provided for Switzerland; Other countries to be added
59   can also be added by users, as the required data structure is provided
60 - Selection of custom district
61 - Optimisation optional

Modelling Approach

63 DEM simulates the energy flows in a district, combining bottom-up with top-down modelling.
64 A district in this context can refer to anything from a small group of buildings to an entire
65 municipality or city. Several characteristics are obtained for each individual building (e.g.,
66 building type, location, size, age, heat and electricity demand, heating system, solar energy
67 resources), while other data is assessed on district-level (e.g., wind power resources, biomass
68 resources, ambient conditions, mobility demand). The basis for any simulation are a set of
69 resources (e.g., wind, solar, biomass, hydro), a set of generation, conversion, and storage
70 technologies, and a set of demand profiles for heat, electricity, and mobility. An exemplary
71 energy system layout is shown in Fig. Figure 1. Any list of buildings can be passed to DEM
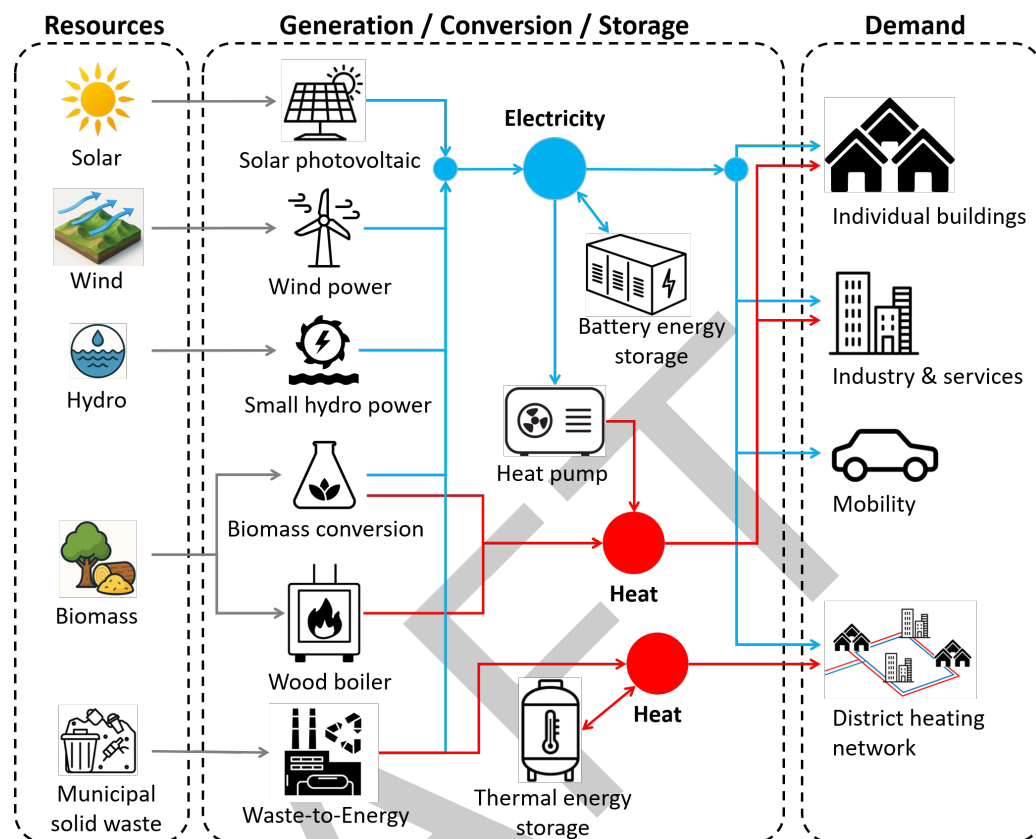72 for simulation of a district energy system.

Figure 1: Example of a district energy system with resources, generateion, conversion, and storage technologies, and various energy demands. The full list of available resources and technologies can be found on the documentation website.

Acknowledgements

References