CESAR-P: A dynamic urban building energy simulation tool

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Software

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Summary

Buildings are responsible for a large share of energy consumption and carbon dioxide emissions. With the challenge of reducing energy consumption and integrating renewable energy sources in buildings and neighbourhoods, an understanding of energy consumption patterns is needed at different temporal and spatial scales. CESAR-P (Combined Energy Simulation And Retrofitting - Python) is a bottom-up building stock modelling software to evaluate energy consumption and retrofitting strategies for individual buildings and neighbourhoods. CESAR-P is used to parameterize models for the dynamic building energy simulation tool EnergyPlus (Crawley et al. (2001)). It computes hourly energy demand profiles and indoor temperatures at the building level and takes into account shading and reflections of surrounding buildings. After the current energy demand is computed, retrofitting measures for individual buildings can be evaluated in terms of energy savings, embodied emissions and costs. The default library of CESAR-P is based on Swiss archetypal buildings created from standards and statistics about the Swiss building stock; however, users are able to define their own constructions and internal conditions for their buildings. CESAR-P is written in Python and is a further development of the tool CESAR (Wang et al. (2018)). The building model generator of CESAR-P creates EnergyPlus input data files (.IDF) for each building within a specified extent, and can process geo-referenced input data as shapefiles (ESRI .shp format) for geometry. Building usage type and construction information is used to populate the building model. The EnergyPlus files are executed with a weather file (EnergyPlus epw weather data format) of the geographic location which provides the necessary climatic context for the building. The results consist of a configurable set of yearly demand values and hourly resolved times series for each building from EnergyPlus and additional operational costs and emissions. The retrofit module can be used to update the building models according to a specified retrofit strategy. Retrofit strategies specify the frequency of retrofits to the main building elements such as walls, windows and roofs across the building stock. The output of the retrofit module include, in addition to the above-mentioned operational indicators, costs and embodied emissions of retrofitting interventions. All simulation steps can also be run in parallel on multiple cores. The code is platform-independent and is tested to run on Linux and Windows. The source code for CESAR-P has been archived to Zenodo: (Fierz & UrbanEnergySystemsLab, 2021)

Statement of need and Key features

Building energy simulation is required and compelling, as current energy demand profiles of buildings are often not readily available or the building performance needs to be studied for varying conditions (e.g. building retrofit, changing climate). CESAR-P simplifies the process of building simulation model generation by automatically generating input files for the open-source

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building simulation tool EnergyPlus with only a few key input parameters needed. Key features of CESAR-P include:

- The modelling of indoor temperatures, heating and cooling loads, domestic hot water consumption, electricity consumption, comfort parameters, operational costs and emissions, embodied emissions and investment costs of retrofitting solutions and solar irradiance on external surfaces.
- Geo-referenced data sources (shp) as input for building geometries
- The archetypes used to parameterize the building models are stored to a graph database. The data is structured according to an urban energy simulation ontology (Allan et al. (2021))
- Evaluation of retrofitting options and strategies
- Simulate and compare energy demand for scenarios with different building parametrization, for example to evaluate passive cooling potential (Silva et al. (2022))
- Since CESAR-P uses EnergyPlus, which is a continually developed energy simulation tool within the research field, the capabilities of CESAR-P can be extended to accommodate future developments and improve modelling accuracy.
- The tool can be applied at various scales and can be used for predicting the energy consumption of a single building, of whole neighbourhoods with thousands of buildings (Wang et al. (2018)) or, in combination with clustering approaches, for calculating national building energy demands ((**MURRAY_ET_AL_2020?**), Eggimann et al. (2022)).

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