Estimating latent energy demand of buildings

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This abstract was accepted to the Academic Track of the State of the Map 2019 Conference in Heidelberg after peer-review.

Buildings are responsible for a quarter of energy-related greenhouse gas emissions, making them a substantial driver of climate change; heating and cooling in buildings in particular are the biggest contributors to their energy demand [1]. Strategies that reduce energy demand in the building sector also need to be socially just by ensuring that minimal thermal comfort is accessible to all. Of particular concern is the energy use of cooling, as deadly heat waves are expected to become more frequent in many regions of the world, making cooling necessary to ensure basic wellbeing [2].

In order to develop mitigation solutions at scale, a key challenge is to understand the energy demand across the large and heterogeneous building stock. However, building energy data are often proprietary or do not even exist – which hinders large scale studies. Current methods are well-equipped to model individual buildings but do not scale up easily, or they model the overall building sector – leaving out much of the local context. This confines impactful climate action to a limited group of cities, where data exists. There are many regions with pressing climate change mitigation and development challenges that are often overlooked, in particular rapidly-urbanizing urban areas in the Global South [3].

Our project aims at leveraging the increasing availability of spatial data, such as OpenStreetMap (OSM) data, and machine learning techniques, to estimate the minimum – latent – energy demand for heating and cooling in a larger building stock. Our framework is data-driven and modular so that it can be made more complex as more data become available. We use first-order factors influencing latent energy demand, which are more easily available at scale.

The outer wall surface is particularly important and requires a 3D model of the building stock. The coverage of 2D building footprints in OSM is rapidly increasing. Even though some issues remain, in many cities the data quality is likely to be sufficient for our purpose. However, the height information is sparsely populated in OSM data, and with large imbalances between regions: only ~10 million buildings worldwide have values for the height key in July 2019. This corresponds to about 20 cities of the size of Berlin fully mapped. Best

Milojevic-Dupont et al. (2019). Estimating latent energy demand of buildings
In: Minghini, M., Grinberger, A.Y., Juhász, L., Yeboah, G., Mooney, P. (Eds.). Proceedings of the Academic Track at the State of the Map 2019, 25-26. Heidelberg, Germany, September 21-23, 2019. Available at https://zenodo.org/communities/sotm-2019
DOI: 10.5281/zenodo.3387711

available height data is provided either by cadaster data, or by an expensive aerial sensing technique – LiDAR – which is only openly available for very few cities in developed countries.

Our overall workflow is divided into two main models: (i) a building height prediction model and (ii) a model of the energy demand for heating and cooling individual buildings to a given temperature.

Here, we present the concept for the building height prediction model. We predict buildings heights using supervised machine learning techniques that map the relationships between buildings and urban tissue features from OSM to building heights from ground truth LiDAR data. While a similar approach has been taken for two Dutch cities by [4], here we aim at developing a model that can predict buildings heights from OSM data only in order to scale to a larger building stock.

Preliminary results show that OSM data alone are predictive of building heights. We are currently developing our model on a set of European cities where open 3D data are available. From preliminary results for Berlin data, we find that heights can be predicted with a mean average error of ~3 meters using a random forest regression with 5-fold cross-validation. To improve the prediction, we are investigating deeper architectures and further inclusion of the surroundings of the building under scrutiny. This includes engineered features like street connectivity, and rasterized OSM building and street layers.

One of the main challenges of this model is to generalize to new cities, especially in different geographical regions. It can be expected that the relationship of certain building features with height is fairly similar across the world, while that of others differ widely. Transfer learning with local retraining may enable to take advantage of those regularities, while adapting to local specificities.

The building height attribute in OSM data provides crucial information for climate solution research in cities. Machine learning can partly infer missing data, but algorithms need training data to learn from. OSM mappers can help provide this data, or other relevant predictors like the number of floors in a building. Information about only a limited amount of buildings could be enough, if those data points are well distributed across cities and regions. We further emphasize the general need for detailed infrastructure data: by better supporting municipal policy makers, data-driven urban planning strategies have a great potential to mitigate climate change in cities.

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