Siamak Sheykhha and Reinhard Madlener

SPECIFYING ENERGY GRIDS DEVELOPMENT NEEDS IN SAMPLE LIVING QUARTERS

Siamak Sheykhha, Institute for Future Energy Consumer Needs and Behavior (FCN), School of Business and Economics / E.ON Energy Research Center, RWTH Aachen University, Aachen, Germany, +49 241 80 49841, siamak.sheykhha@eonerc.rwth-aachen.de
Reinhard Madlener, Institute for Future Energy Consumer Needs and Behavior (FCN), School of Business and Economics / E.ON Energy Research Center, RWTH Aachen University, Aachen, Germany, +49 241 80 49820, RMadlener@eonerc.rwth-aachen.de

Overview

In order to develop a decision-making tool for the development of regional energy grids, a conceptual framework has been established in the form of sample living quarters. These have certain characteristics that are pertinent to their description. The objective of the study presented here is twofold: firstly, to provide a comprehensive definition of sample living quarters that takes into account both spatial and socio-economic aspects, along with the evolution over time, while also explicitly considering local resource endowments, energy management options, and technological requirements. Such a definition can help to foster consistency in urban planning and enabling renewable energy and sectoral integration, acceptable resilience, and sufficient flexibility within the energy system. Secondly, to outline the primary prerequisites for creating an algorithm that factors in various aspects of development, including emerging challenges and trends in the development of living quarters, as well as specific data-related constraints.

Methods

The study establishes heuristics and strategies to identifying distinguished quarters that have specific characteristics. In the first step, a qualitative and quantitative assessment of attributes and model assumptions is conducted. As a result, the characterization and definition of relevant sample living quarters, as well as a conceptual delineation system, are defined. Then, a critical review of the characteristics and applicability of sample living quarters and their impact on energy grids infrastructure, is undertaken. Anticipation and adoption for future changes of socio-economic structures of regions are also explicitly considered. In the second step, the study investigates the usefulness of a clustering approach that harvests geospatial, socio-economic, and energy infrastructure data. To do so, a (K-means) clustering algorithm is developed to identify clusters that can be distinguished based on the aforementioned attributes, and to provide some guidance on the optimal number of clusters and sample living quarters to be considered.

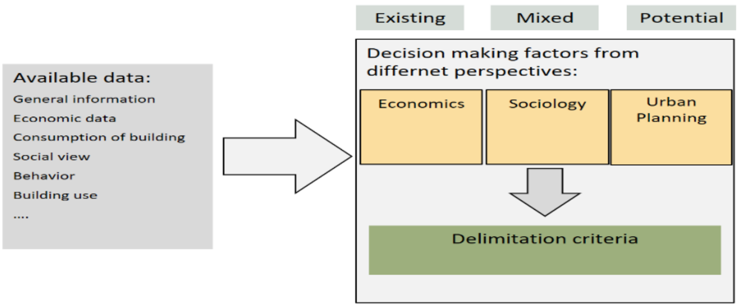

Figure 1: Approach adopted for the classification of the data used

Results

The proposed heuristics enable the assessment of the socio-economic and spatial indicators that should be taken into account, and which ones can be ignored. Having analyzed around 120 indicators, we find the location of buildings, building characteristics and specifically the age of the buildings as appropriate spatial indicators. Furthermore, two socio-economic indicators are defined: power to change and habit of change. Power to change is the ability of people to change towards more sustainable energy technologies. It is constructed based on the purchasing power and age of the building occupants. Habit of change indicates the propensity of building occupants to upgrade their energy technologies adopted, which is constructed as a combination of price sensitivity, ownership and environmental consciousness of the inhabitants.

The proposed quarters are determined based on energy infrastructure indicators such as electric vehicle (EV) potential, solar photovoltaics (PV) potential, heating system status, socio-economic factors, and building types. We identify the energy characteristics of clusters for both current and future scenarios. Our analysis reveals, as an example, that there are ten meaningful clusters in Essen, Germany. These clusters encompass a range of distinguished quarters from the ones with low energy infrastructure potential (EV, PV), such with low power to change and habit of change (Table 1 (a)), to those quarters with high potential for sustainable energy options and a high power to change and habit of change (Table 1 (b)). Visual inspection and statistical analysis of clusters validate the robustness of the results.

Table 1: Sample cluster profiles

(a): Cluster with low future development of energy infrastructure

Socio-Economic	Low power to change Very low habit of change	
Spatial	Local site, multi family houses	
Energy	NOW	FUTURE DEVELOPMENT
PV	Very low	Very low
EV	Very low	Very low
Heat options	District heating, central heating	District hating

(b): Cluster with high future development of energy infrastructure

Socio-Economic	Very high power to change Very high habit of change	
Spatial	Local site, terraced or semi-detached house	
Energy	NOW	FUTURE DEVELOPMENT
PV	Very high	Very high
EV	Mid	Very high
Heat options	Central heating, single multi chamber ovens	Heat pump

Conclusions

This study defines sample living quarters in a comprehensive manner that integrates socio-economic and spatial dimensions of quarters over time, considering the development of energy technologies and specific local requirements. The implementation of the clustering method reveals that the optimal number of clusters depends on several parameters, such as the set of indicators used, the clustering algorithm, the aim of the clustering, and the number of key required outputs. The main takeaway of the research is that there is no fixed number of clusters that applies to all cities/regions. However, the proposed heuristics and search strategy can help to determine the most adequate number of clusters for any given region.

References

De Jaeger, I., Reynders, G., Callebaut, C., & Saelens, D. (2020). A building clustering approach for urban energy simulations. Energy and buildings, 208, 109671.

Madlener R., Sunak Y. (2011). Impacts of Urbanization on Urban Structures and Energy Demand: What Can We Learn for Urban Energy Planning and Urbanization Management? Sustainable Cities and Society, 1(1): 45-53.

Schnur, Olaf (2008): Quartiersforschung. Zwischen Theorie und Praxis. VS Verlag für Sozialwissenschaften. Wiesbaden.