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Comparison of individual and microgrid approaches for a distributed multi energy system with different renewable shares in the grid electricity supply

Boran Morvaj[a]*, Ralph Evins[b], Jan Carmeliet[c]

[a]*Urban Energy Systems Laboratory, Empa, Switzerlandl,* [b] *Department of Civil Engineering, University of Victoria, BC, Canada*
[c]*Chair of Building Physics, ETH Zurich, Switzerland*

Abstract

The transition to 100% renewable energy systems is an important factor in the transition to sustainable energy systems. A top-down approach is often used to study the design of such energy systems on a country or continental scale. Results of these studies are useful for developing energy roadmaps but they lack the details about how distributed multi energy systems should be designed and operated at local level. An optimisation model of distributed multi energy systems is applied in order to investigate how urban districts should be optimally designed in the (near) future when the goals of energy roadmaps are achieved. The impact of individual and microgrid approaches on distributed multi energy systems is analysed on an urban district level for scenarios with different levels of renewable energy in the electricity grid supply.

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Keywords: multi energy systems, optimization, distribution grid, district heating

1. Introduction

The transition to 100% renewable energy systems is an important factor in making energy systems sustainable. The transition path towards 100% renewable electricity supply has been analysed for many countries such as Denmark [1], Portugal [2], Macedonia [3], Croatia [4], China [5], and New Zealand [6]. A top-down approach is often used to study

* Corresponding author. Tel.: +41 58 765 6024, *E-mail address:* Boran.Morvaj@empa.ch

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the design of energy systems with 100% renewable electricity supply on a country or continental scale. Results of such studies give the optimal energy mix of different energy sources and are useful for developing roadmaps and energy policies for the cost effective transition to decarbonized energy systems. However, it lacks the information about how energy systems in urban areas should be designed and operated, and their impact on the low level networks such as distribution grid and district heating.

In most of the studies, the customers are assumed to be *individual* (passive) users where they only satisfy their individual demand. However, the future of power systems likely lies in the implementation of *microgrid* concepts which will additionally increase the complexity of designing and operating distribution grids. A *microgrid* is defined as a network structure based on the control of all aspects related to the network operation (distributed generators, storage devices, controllable flexible loads, etc.) at the distribution level, which allows the network to coordinate efficiently all its resources as if it was a single energy system [7]. With customer involvement it can improve the overall energy efficiency and reliability of the grid, and decrease energy consumption [8].

In this paper the impact on energy systems of different levels of renewable energy in the electricity grid supply is analysed on district scale (at the low voltage distribution grid level). We examine how urban districts should be optimally designed in the (near) future when the goals of energy roadmaps are achieved. The main goal of the analysis is to compare the differences in the design and operation of distributed multi energy systems for two approaches – individual and microgrid.

2. Model and case study

The optimisation model used for the analysis can simultaneously determine the optimal design and operation of a multi energy system (with district heating network layout and electrical distribution grid upgrades needed) while ensuring that the solutions are within the distribution grid limits using linearized AC power flow. The considered technologies are combined heat and power (CHP), photovoltaics (PV), heat pump (HP), gas boiler and heat storage. The model is based on the energy hub modelling approach [9] extended and applied to buildings, and coupled with electrical distribution grid and district heating model. The optimisation is performed for two objectives– cost (investment plus operational) and carbon emissions for a given electricity renewable share. For more details about the model, the reader is referred to Morvaj et al. [10].

The optimisation is carried out for the current individual and the future microgrid approaches as shown in Fig. 1. In the individual approach the buildings are owned by different owners, and minimize their own individual objective(s). The electricity demand is met at the building level and the buildings cannot share directly electricity between each other. In the microgrid approach all buildings are owned by the same owner and buildings have common objective(s). The electricity demand is summed over the whole district and only the flows leaving the microgrid boundary are accounted for. In this way buildings can share the electricity between each other and utilize it more efficiently.

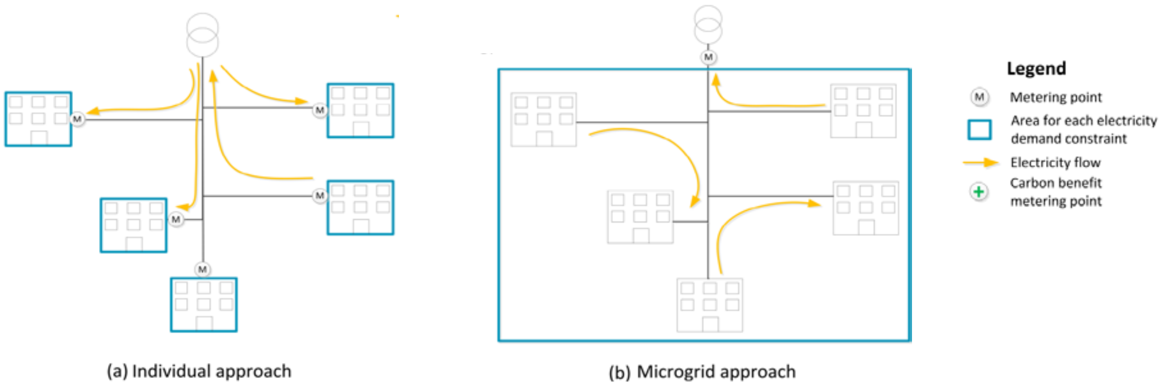

Fig. 1 Graphical representation of (a) individual and (b) microgrid approach

The model was applied to a large urban case study which is based on the IEEE Low Voltage Test Feeder case [11]. It consists of 55 residential buildings and a radial network with 4 branches. In order to reduce the computational complexity, buildings that are connected to the same grid connection point were aggregated. As a result the case study has been reduced to 37 residential buildings connected by a three phase low voltage (0.4 kV) radial distribution grid. The grid is assumed to be balanced and the mutual impedances are taken as zero.