Neighborhood Energy Flexibility Demand Management Systems

A bottom-up system integration of energy infrastructures

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***Abstract*—**Climate agreements, EU policies to reduce CO2 emissions express the need for more sustainable energy systems. The necessary energy transition leads to drastic changes within the current energy system; new market structures and players (e.g. local (independent) multi-carrier micro-grids, energy generation and storage at community level and smart buildings/homes), changing end-user involvement and new technologies (e.g. storage and conversion between energy carriers). The Netherlands has around 7.6 mln houses and around 370.000 building [RVO 2016]. This leads to a fundamental change from separated centralized systems with electricity and gas production to a more decentralized system based on renewable energy production with as much local sources e.g. solar, wind or geothermal sources. Other changes include the ongoing growth of electricity consumption caused by electrification of transport (EV), heat pumps and data centres. Furthermore the now dominant use of natural gas as energy carrier has to diminish and partly filled by electricity. This all leads to the need of the integration of the different energy carriers into a multi-energy grid and behind the smart meter an increasingly complex home/building energy system is needed. A sophisticated control of all components and energy flows is required to effectively and efficiently make use of the energy. Instead of treating the energy actors and different subsystem as one big integrated energy systems we proposed a modular approach. This approach is based of the existing urban and energy infrastructure combined with the local future characteristics (planned renovation of buildings and energy grids) and its possibilities to use renewable energy sources. In this way all possibilities to reduce or flexibly energy demand can be considered.

Traditionally top down organized energy supply electricity networks now have to cope with decentralized renewable energy production. Though weather and energy consumption predictions have improved over the years ensuring large power plants are able to pre-schedule their power generation, the increasing share of energy generation at building level does however introduces further operational complexities and uncertainties. It is also noted that the current infrastructure and auxiliary services are all designed and built to support the traditional power grid system. This adds to other challenges and complexities of the smart grid; the challenge of integrating distributed generations, dynamically changing technologies and diminished interoperability of systems. Furthermore, with the changing role of users from mere passive to active participants, planning of electricity supply becomes a rather increasingly challenging task. Traditional simulation methods have reached their limits and new approaches have to be developed to deal with this growing complexity particularly as it relates to buildings and users. The real user and building behavior is leading the energy supply processes. However it is not effective enough to just optimize one building. Buildings' energy use should be optimized in relation to other buildings and the existing energy distribution networks of Electricity, Gas, Heat or Cold. A new coordination framework is therefore being proposed for the physical coupling of buildings to the Smart Grid and a virtual coupling with the Gas and or heat distribution network. For such integrated system, it is necessary to develop Neighborhood Energy Management Systems that are capable of interacting with existing BEMS as well as the SCADA systems of the Grid operators. Contrary to the top-down approach of the traditional electrical system, (centralized energy generation/distribution through the Smart grid) this framework is based on a middle-out (control on building level by the Building Energy Management Systems BEMS) as well as a bottom-up (demand driven by the human behavior) approach, see Fig. 1.

Due to their significant energy demand, buildings are critical in efforts towards attaining the required future operational flexibility in energy grids occasioned by increased decentralized renewable energy integration. The traditional consumers of energy become prosumers who can generate and store their own renewable energy, this changes the interaction with the utilities completely, see Fig. 2 below. Also beside energy there is a need for new and more ICT services, Home Automation systems and Building Energy Management Systems. This all leads to a need for more integration instead of the traditional top-down single direction oriented approach, with new roles for all stakeholders. Using the principle of Open Bouwen urban planning, different functional levels will be distinguished, with connecting links e.g. energy and data hubs on neighbourhood level. Based on the necessary integration of multi-energy grids, decentralized renewable energy generation, ICT technologies and energy flexible buildings, a new level of integrated energy management becomes necessary which will also offer possible additional synergetic effects.

A functional bottom-up data clustering and transformation based on data of smart meters is assisted by building energy management systems. This will offer an in site view of the building's energy flexibility for energy management by Multi-agent SCADA systems. This is used to control data or physical energy hubs on neighbourhood level as modules towards the future integrated energy infrastructure of districts, cities and regions.

This concept is developed from the general systems theory. The general systems theory is a useful tool for conceptualizing phenomena which did not lend themselves to explanation by mechanistic reductionism of classic science. One approach to a supportive orderly framework is the structuring of a hierarchy of levels of complexity for basic elements in the various fields of inquiry. A hierarchy of levels can lead to a systematic approach to systems that have broad application. This method therefore uses an hierarchical functional decomposition and division to cope with the complexity of the energy infrastructure of the built environment and its different functions. The open building concept developed by Habraken [1, 2] approached the built environment as a constantly changing product caused by human activity, with the central features of the environment resulting from decisions made at various levels, which is also typically the case with the energy infrastructure of the built environment. The principal tool used by those working in an open building way [3] is the organization of the process of designing and building on environmental levels. In this way, an urban planning approach can be integrated to a system engineering bottom-up approach to be used to transfer the existing energy infrastructure into a flexible demand driven neighborhood with its own energy management. Turning the distribution grid from a passive system into a more active system, see Fig. 2, also means that the intelligence of the building and its user behavior becomes more important for the energy planning process and should be included in the planning of energy grid control. The fluctuations of demand from customers as well as possibility for the intelligent buildings to generate their own electricity through decentralized energy supply, would otherwise result in unstable process control situations.

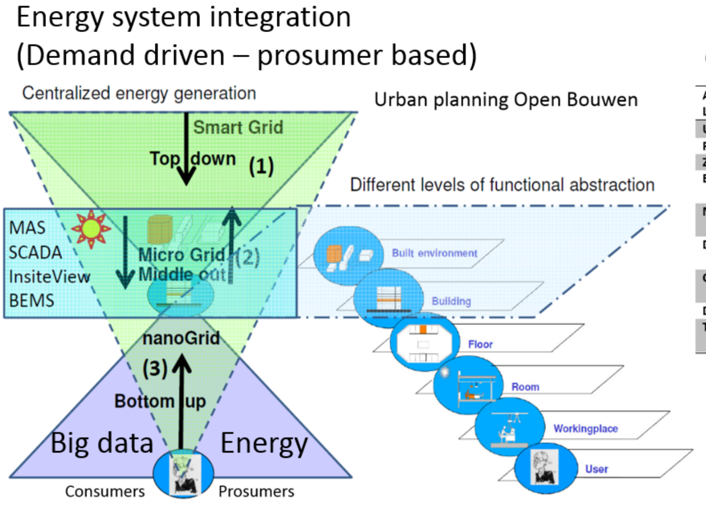
This research therefore mainly aims to improve Building and Smart Grid functional interaction on neighborhood level taking into account the flexibility of occupant's energy demand and need of energy for comfort.

Keywords—demand driven; energy flexibility; bottom-up; energymanagement;neighborhood

[1] Habraken N.J., 1998, The Structure of The Ordinary: Form and Control in the Built Environment, MIT Press.

[2] Habraken N.J., Open Building; brief introduction, accessed 28 February 2017, http://www.habraken.com/html/introduction.htm

[3] Kendall S., Open Building Concepts, CIB W104, accessed 28 February 2017, http://open-building.org/ob/concepts.html



Different roles of stakeholders/actors depending on hierachy level

Actor/Hierarchy Level	Role
User	Registers comprehensive user preference, associated comfort and energy profile.
Room	Aggregate comfort and energy profile inside the room.
Zone	Aggregate comfort and energy profile for all spaces associated with a zone.
Building	Aggregate energy use and available power flexibility for the whole building dynamically.
Neighborhood	Dynamically aggregates available power flexibility for buildings in a neighborhood.
District	Dynamically aggregates available energy flexibility for a number of neighborhoods at medium level of the network.
City	Dynamically aggregates available energy flexibility of connections at high level of the network.
DSO	Ensure network reliability and integrity of the energy distribution networks.
TSO	1. Operates & manage market 2. Ensures network reliability & integrity power transmission network.

Figure 1. Hierarchical representation of the built environment and the role of actors

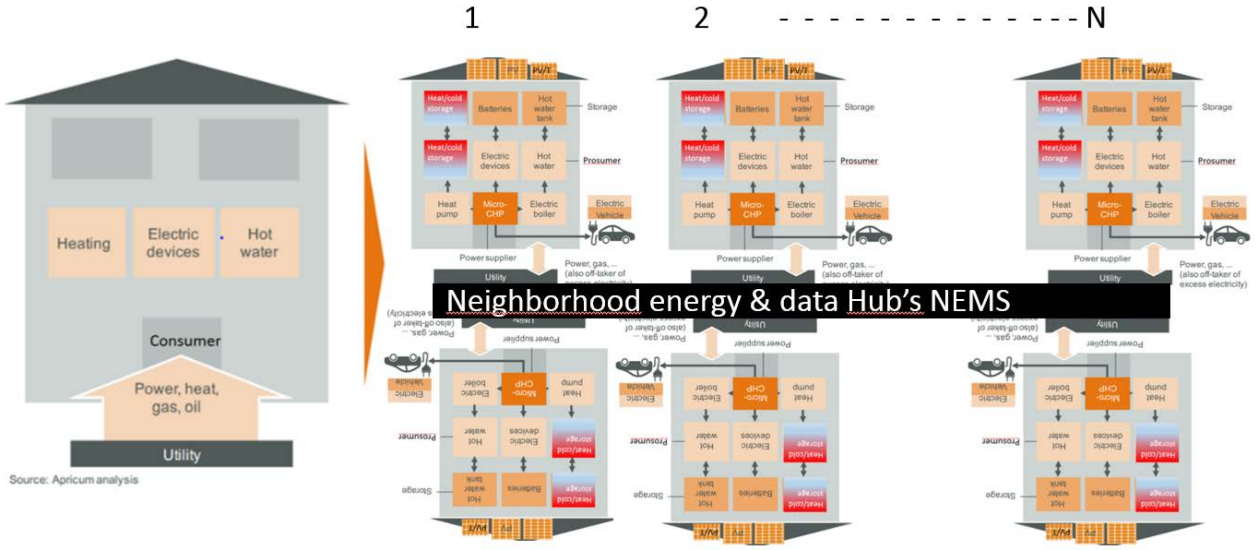


Figure 2. The change from simple energy consumption towards complex prosumers in the built environment