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IEA EBC Annex 67 Energy Flexible Buildings

Søren Østergaard Jensen[#1], Anna Joanna Marszal-Pomianowska [*2]

[#]*Energy and Climate Division, Danish Technological Institute*
Gregersensvej 2, DK-2730 Taastrup, Denmark
[1]sdj@teknologisk.dk
[*]*Department 6, Department of Civil Engineering, Aalborg University*
Sofiendalsvej 11, DK-9200 Aalborg SV, Denmark
[2]ajm@civil.aau.dk

Abstract
The foreseen large deployment of renewable energy sources may seriously affect the stability of energy grids. It will be necessary to control energy consumption to match instantaneous energy production. The built-in Energy Flexibility in buildings may be utilized for stabilizing the energy grids, allowing for a larger roll out of renewable technologies.
The Energy Flexibility of a building is the ability to manage its energy demand and generation according to local climate conditions, user needs and grid requirements. Energy Flexibility of buildings will thus allow for demand side management and load control and thereby demand response based on the requirements of the surrounding grids.
Currently there is, however, no overview or insight into how much Energy Flexibility different building types and their usage may be able to offer to future energy systems. Three is thus a need for increasing knowledge on and demonstration of the Energy Flexibility Buildings can provide for the energy grids as well af to identify critical aspects and possible solutions to manage this Energy Flexibility.
The paper discusses the background, the aims and the work plan of IEA (International Energy Agency) EBC (Energy in Buildings and Communities programme) Annex 67. The working phase of IEA EBC Annex 67 started in June 2015 and will last until June 2019.
The paper outlines the scene for a session with papers related to IEA EBC Annex 67 written by participants of IEA EBC Annex 67.

Keywords: *Energy Flexible Buildings, load control, demand response*

1. Introduction

The last decades' increasing global energy demand, a foreseen reduction of available fossil fuels and an increasing evidence for global warming have generated a high interest in renewable energy sources. However, energy sources, such as wind and solar power, have an intrinsic variability that can seriously affect the stability of the energy system, if they account for a high percentage of the total generation. Therefore, future high penetration of variable renewable energy sources forces a transition from generation on demand to consumption on demand in order to match the instantaneous energy generation. In practice this means that the energy consumption needs to become flexible.

The end use of e.g. electricity is not located in the high voltage transmission level, but in the low voltage parts of the grid, which have different requirements and constraints than at the transmission level. Traditionally, only the power demand has guided the design of grids. The challenge with large scale application of buildings which not only consume, but also generate energy - commonly called prosumers - is that the grid has to be designed with respect to the power demand (both heat and electricity) as well as the local energy generation and to the way these coincide in order to avoid creating stress on the grid. If not considered, it may result in limits on the amount of exported energy for building owners to avoid power quality problems, e.g. Germany has already enforced restrictions on private PV generation exported to the grid. Furthermore, today the distribution grid is often dimensioned based on houses heated by sources other than electricity e.g. oil or gas burners. However, the transition to a renewable energy system will in many areas lead to an increase in electrical heating - e.g. by heat pumps or resistance heaters – even if the foreseen reduction in the space heating demand via energy renovation is realized. The expected penetration of electrical vehicles may further increase the loads in the distributed grids, but they may also be used for peak shaving using their batteries. All these factors will in many distribution grids call for major reinforcement of the existing grids or a more intelligent way of consuming electricity. The intelligent way is Smart Grid (or Smart Energy Networks, when energy carriers other than electricity are considered as well) where both demand and local production in the distribution grid are controlled in order to stabilize the grid. Buildings are expected to have an important role in future Smart Grids/Energy networks.

In most developed countries, the energy use in buildings accounts for 30-40 % [1] of the total energy consumption, and it is used for space heating, heating of domestic hot water, cooling, ventilation and lighting of rooms as well as for appliances used by occupants. A large part of the energy demand of buildings may be shifted in time, and it may thus significantly contribute to increasing flexibility of the demand in the energy system. In particular, the thermal part of the energy demand, e.g. space heating/cooling, ventilation, domestic hot water, but also hot water for washing machines, dishwashers and heat to tumble dryers, can be shifted. A Danish study [2] on large-scale implementation of heat pumps in individual homes outside areas with district heating showed an increased utilization of excess power generation from wind turbines and a reduced use of fuels during periods with low electricity production by utilizing storage, e.g. in the constructions of buildings or in water tanks. The study showed that excess power generation could be reduced by up to 20% - excess power that otherwise would be wasted or sold at a low or even negative price. The most cost-effective solution was to utilize the thermal mass of the buildings as heat storage, even if only a small part of the total thermal capacity can be exploited by existing technologies. A similar approach may be used in communities with district heating or community heating (common heating system for a limited number of buildings). Excess renewable energy generation (e.g. wind power) may be utilized for heating in the district/community heating plant. However, in order to be able to store sufficient heat the thermal mass of the buildings connected to the district/community heating grid may be utilized in the same way as in buildings with heat pumps or resistance heaters.

All buildings have thermal mass embedded in their constructions, which makes it possible to store a certain amount of heat. Depending on the amount, distribution, speed of charging/discharging, etc. of the thermal mass it is possible to postpone heating or cooling for a certain period of time without jeopardizing the thermal comfort in the building. Moreover if a building is excess pre-heated/cooled within the comfort range of the room temperature prior to a shutdown of heating/cooling, it is possible to prolong the shutdown period. The time constant of buildings varies - depending on the amount and exploitability of the thermal mass together with the heat loss, internal gains, user pattern and the actual climate conditions - typically between a few hours to several days. Many buildings may also contain different kinds of discrete storages (e.g. water tanks and storage heaters) that may add to the energy demand flexibility of the buildings. One such typical storage is the domestic hot water tank, which might be excess pre-heated before a low energy level situation. The excess heat may be utilized for space heating but may also be used for white goods such as hot-fill dishwashers, washing machines and tumble dryers in order to decrease and shift their electricity need.

Figure 1 shows an example of how the flexibility of houses with heat pumps may decrease the need for reinforcement of the local 0.4 kV, where the houses are situated.

Although various investigations of buildings in the Smart Grid context have been carried out, research on how Energy Flexibility in buildings can help stabilize the future energy system and thereby facilitate large penetration of renewable energy sources, is still in its early stages. The investigations have mainly focused on how to control a single component – often simple on/off controlled - and not on how to optimize the Energy Flexibility of the buildings themselves.

There is currently no overview or insight into how much Energy Flexibility different types of building and their usage may be able to offer to the future energy systems. This is the reason why IEA EBC Annex 67 Energy Flexible Buildings was initiated.

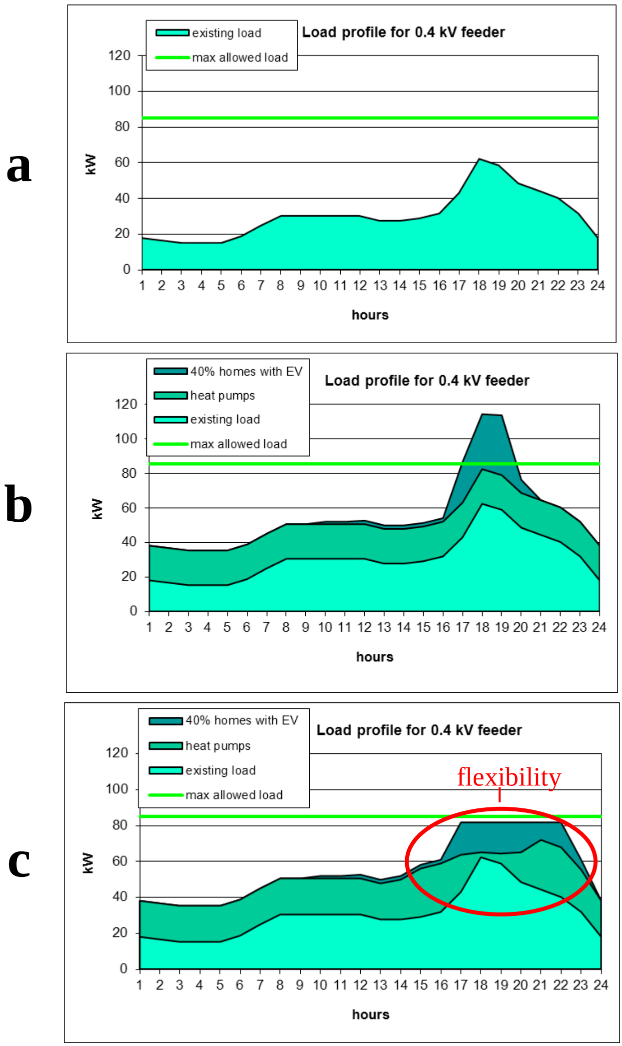

Fig. 1 The graphs show an example of introduction of heat pumps and electrical vehicles in a 0.4 kV outlet/feeder:

a) the existing situation
b) business as usual: heat pumps and EVs in the system will demand a reinforcement of the grid as the demand exceeds the max allowed load
c) a Smart Grid solution where the buildings prior to the cooking peak (17:00-20:00) are excess heated within the comfort band of the room temperature. The buildings are mainly free floating during the cooking peak but need extra heat after the cooking peak. The charging of the EV's is controlled in order to keep the demand below the max allowed load.

2. IEA EBC Annex 67 Energy Flexible Buildings

The aim of IEA EBC Annex 67 is to increase knowledge, and to identify critical aspects and possible solutions concerning the Energy Flexibility, which buildings can provide and the means to exploit and control this flexibility. This knowledge is important in order to be able to incorporate the Energy Flexibility of buildings in the future Smart Energy systems and thereby facilitate energy systems being entirely based on renewable energy sources. The obtained knowledge is also important when developing business cases that will utilize building Energy Flexibility in future energy systems – including that the utilization of Energy Flexibility in buildings may reduce costly upgrades of distribution grids.

2.1. Objectives

To fulfil the aims of the Annex and to facilitate future Energy Flexible Buildings the Annex focuses on the following specific objectives:

- Development of common terminology and definition of "Energy Flexibility in buildings" and a classification method (Subtask A)
- Investigation of user comfort, motivation and acceptance associated with the introduction of Energy Flexibility measures in buildings (Subtask A and C)
- Investigation of the Energy Flexibility potential in different buildings and contexts, and development of design guidelines, control strategies and algorithms (Subtask B)
- Investigation of the aggregated Energy Flexibility of clusters of buildings and the potential effect on energy grids (Subtask B)
- Demonstration of Energy Flexibility in buildings through experimental and field studies (Subtask B and C)

2.2. Scope and Demarcation

The Annex will focus on analyzing the potential Energy Flexibility in buildings and on how to control this flexibility without loss of comfort for the users in the buildings. The building technologies with special focus will be storage of heat in building constructions and in water tanks (e.g. DHW tanks), control of HVAC systems (e.g. heat pumps, air conditioning and ventilation) but also the interaction between the building load and the on-side energy production based on renewable energy will be investigated. Other electricity loads (e.g. lighting) and storage in batteries may also be included in the work within the Annex.

The Annex will address both residential and non-residential buildings. However, these two sectors will be treated separately because the issues, challenges and possible solutions differs for the two sectors. The Annex will address both new constructions and renovation of buildings. Renovation of buildings is of special importance because the majority (75 %) of buildings existing today will still be there by 2050, and it is important from a cost point of view to consider Energy Flexibility as part of a renovation process.

All energy demands of and storage possibilities in buildings are in principle included in the scope of the Annex. However, only demands, which can be controlled and can contribute significantly to the Energy Flexibility in buildings, will be included in the investigations. Different ways of storing energy in buildings will be investigated, especially focusing on storage methods that are considered to already be or soon may become economical feasible.

The Annex will focus on both single buildings and clusters of buildings as the grids are mainly influenced by buildings at an aggregated level. It is, therefore, also important to investigate the aggregated flexibility given by pooling of several buildings within the same distribution grid.

Although interoperability is mandatory when deploying Energy Flexibility of buildings for stabilization of energy grids, this is not a direct focus area of the Annex, but will be considered where important.

The knowledge generated by the Annex is important when trying to develop business cases that will include the utilization of Energy Flexibility in building in future energy systems. Business cases and the future interaction between buildings and the grid are briefly dealt with in the Annex.

3. Content of IEA EBC Annex 67

The Annex comprises the following subtasks:

- Subtask A: Definitions and Context
- Subtask B: Analysis, Development and Testing
- Subtask C: Demonstration and User Perspectives

3.1. Subtask A: Definitions and Context

As Energy Flexibility in buildings for grid stabilization is a new research area the subtask will develop a terminology and definition of the term Energy Flexibility in buildings that can be understood not only within the building sector but also at the grid managing level. Furthermore, a methodology for characterization of Energy Flexibility in buildings will be developed in order to make the potential flexibility operational for both the building and grid side, especially for the aggregators, who will aggregate the flexibility of many buildings and offer this on a flexibility market. However, as buildings are occupied it is also important to understand how the behavior and acceptance of the users of the buildings will influence the actual obtainable Energy Flexibility in buildings. The work will among others take offset in earlier work on flexibility indicators from the IEA SHC Task 40/EBC Annex 52 Towards Net Zero Energy Solar Buildings [3], [4] and [5].

The subtask is divided into the following research activities:

- Activity A.1. Common terminology and definition of Energy Flexibility in buildings
- Activity A.2 Methodology for characterization of Energy Flexibility in buildings
- Activity A.3. User needs, motivation and barriers for application of Energy Flexibility in Buildings
- Activity A.4. Market analysis

3.2. Subtask B: Analysis, Development and Testing

In this subtask, different storage, generation and control options for achieving and optimizing Energy Flexibility in buildings will be investigated and documented. The investigations in the subtask will be carried out using both simulations and laboratory tests. Control strategies and algorithms will be developed and together with components and systems these will be tested in controlled environments. Based on the investigations and input from Subtask C, example cases will be selected and documented. Simulations will be carried out for the example cases under realistic energy prices, weather conditions, user behavior and load profiles.

The subtask is divided into the following research activities:

- Activity B.1. Simulation of Energy Flexibility in single buildings and clusters of buildings
- Activity B.2. Control strategies and algorithms
- Activity B.3. Laboratory tests of components, systems and control strategies
- Activity B.4. Example cases and design examples

3.3. Subtask C: Demonstration and User Perspectives

The work in Subtask A and B is mainly theoretical work. However, in order to be able to convince policy makers, energy utilities, grid operators, aggregators, the building industry and consumers about the benefits of buildings offering Energy Flexibility to the future energy systems, proof of concept based on demonstrations in real buildings is crucial. A number of real buildings will be selected and provided with equipment for controlling the flexibility of the buildings. The measurements will provide important input to Subtask B on the actual accessible flexibility in real buildings under real use. The subtask will also provide real load profiles and monitored data on storage and generation systems. This knowledge will be utilized for calibration of the simulation models of the example cases in Subtask B. The demonstrations will also deliver important knowledge on user motivation and acceptance of Energy Flexibility in buildings.

The subtask is divided into the following research activities:

- Activity C.1. Measurements in existing buildings
- Activity C.2. Demonstration of Energy Flexibility in real building

Activity C.3. User motivation and acceptance

4. Results and Deliverables

The results of the Annex will be documented example cases, definition of Energy Flexibility in buildings, a methodology for characterization of Energy Flexibility, control strategies and algorithms for optimizing Energy Flexibility, user perspectives and test procedures.

The resulting knowledge is important when developing business cases that will benefit from the utilization of Energy Flexibility in building in the future energy systems.

Recommendations for future work on labeling of Energy Flexibility in building will be given.

The planed deliverables are shown in table 1 together with the target groups:

Table 1. Deliverables from Annex 67. All deliverables will be published electronically.

Deliverables	**Target group**
Source Book: Principles of Energy Flexible Buildings	Research community and associates. DSOs, TSOs and aggregators, building industry, policy makers
Technical report: Terminology, definition and Flexibility indicators for characterization of Energy Flexibility in buildings	Research community and associates.
Technical report: Guidelines on modelling of Energy Flexibility in buildings	DSOs, TSOs and aggregators, Building industry, architects, consulting engineers. Policy makers
Technical report: User perspectives	Research community and associates. Building industry, consulting engineers, ICT industry and aggregators
Technical report: Control strategies and algorithms	Building industry, architects, consulting engineers, ICT industry, aggregators, Policy makers
Technical report: Test procedures and results	Building industry, consulting engineers, ICT industry
Technical report : Design examples on optimization of Energy Flexibility in buildings	Building industry, consulting engineers, DSOs, TSOs and aggregators, ICT industry

5. Participants

The participants of Annex 67 are currently 30+ institutes from universities and technological institutes plus two companies. The participating countries are Austria, Belgium, Canada, Denmark, Finland, France, Germany, Italy, The Netherlands, Norway, Portugal, Spain, Switzerland and UK. The large number of participants underlines the importance of the tasks taken up by Annex 67. Figure 2 shows the participants of the first working meeting of Annex 67 in Lisbon, September 30-October 2, 2015.

Fig. 2 the participants of the first working meeting of Annex 67 in Lisbon.:

The work of IEA EBC Annex 67 is still in the early beginning and, therefore, open for more participants. Especially private companies are welcome as they may ensure that the outcome of the work is closer to the market.

For more information, please contact the Operating Agent of Annex 67: Søren Østergaard Jensen or Anna Joanna Marszal-Pomianowska (authors of this paper).

Acknowledgment

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