IEA EBC Annex 67

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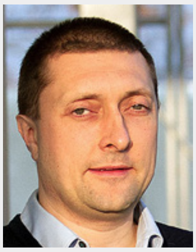
Annex 67 – Energy Flexible Buildings



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Annex 67 is an ongoing research project of the Energy in Buildings and Communities programme (EBC) of the International Energy Agency (IEA) that aims at gaining knowledge on and demonstration of the energy flexibility buildings, and clusters of buildings, can provide to energy networks. This article gives a brief overview of the project and highlights some of its results.

Keywords: energy flexibility, demand side management, aggregated flexibility, grid requirements

Introduction

Large-scale integration of electricity production from renewable energy sources is often suggested as a key technology striving towards a sustainable energy system, mitigating fuel poverty and climate change. In many countries, the growing share of renewable energy sources (RES) goes in parallel with the extensive electrification of demand, e.g. replacement of traditional cars with electrical vehicles or displacement of fossil fuel heating systems, such as gas or oil boilers, with energy efficient heat pumps. At the same time, supporting the operation of (low temperature) district heating grids supplied by different renewable sources. These changes on both the demand and supply side impose new challenges to the management of energy systems, such as the variability and limited controllability of energy supply from renewables or increasing load variations over the day. Consequently, managing the energy transition following the traditional energy system viewpoint would lead to a grid operation closer to its limits, with a possible consequent increase of the energy use at peak periods, requiring more complex control problems with shorter decision times and smaller error margins.

As buildings account for approximately 40% of the annual energy use worldwide, they are likely to play a significant role in providing a safe and efficient operation of the future energy system. Buildings are able to deliver significant flexibility services to the system by intelligent control of their energy loads, both thermal and electric.

Buildings can supply flexibility services in different ways, e.g. utilization of thermal mass, adjustability of HVAC system use (e.g. heating/cooling/ventilation), charging of electric vehicles, and shifting of plug-loads. **Figure 1** illustrates a buildings capability to shift loads and thus using its flexibility.

Although various investigations of buildings in the Smart Grid/Smart Energy context have been carried out, research on the relationship between Energy Flexibility in buildings and future energy grids is still in its early stages. There is a need for increasing knowledge on and demonstration of the energy flexibility buildings can provide to future energy networks. At the same time, there is a need for identifying critical aspects and possible solutions to manage this energy flexibility, while maintaining the comfort of the occupants and minimizing the use of non-renewable energy. For these reasons, the research project Annex 67 [1] was launched in 2014.

PROJECT DURATION
2014 – 2019

OPERATING AGENT
Søren Østergaard Jensen, Danish Technological Institute, Denmark

PARTICIPATING COUNTRIES
Austria, Belgium, Canada, P.R. China, Denmark, Finland, France, Germany, Ireland, Italy, The Netherlands, Norway, Portugal, Spain, Switzerland, UK

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Objectives

The project objectives are:

- the development of a common terminology, a definition of 'energy flexibility in buildings' and a classification method,
- investigation of user comfort, motivation and acceptance associated with the introduction of energy flexibility in buildings,
- investigation of the energy flexibility potential in different buildings and contexts, and development of design examples, control strategies and algorithms,
- investigation of the aggregated energy flexibility of buildings and the potential effect on energy grids, and
- demonstration of energy flexibility through experimental and field studies.

Deliverables

The following project deliverables are planned:

- Principles of Energy Flexible Buildings,
- Characterization of Energy Flexibility in Buildings,
- Stakeholders' perspective on energy flexible buildings,
- Control strategies and algorithms for obtaining energy flexibility in buildings,
- Experimental facilities and methods for assessing energy flexibility in buildings,
- Examples of Energy Flexibility in buildings,
- Project Summary Report.

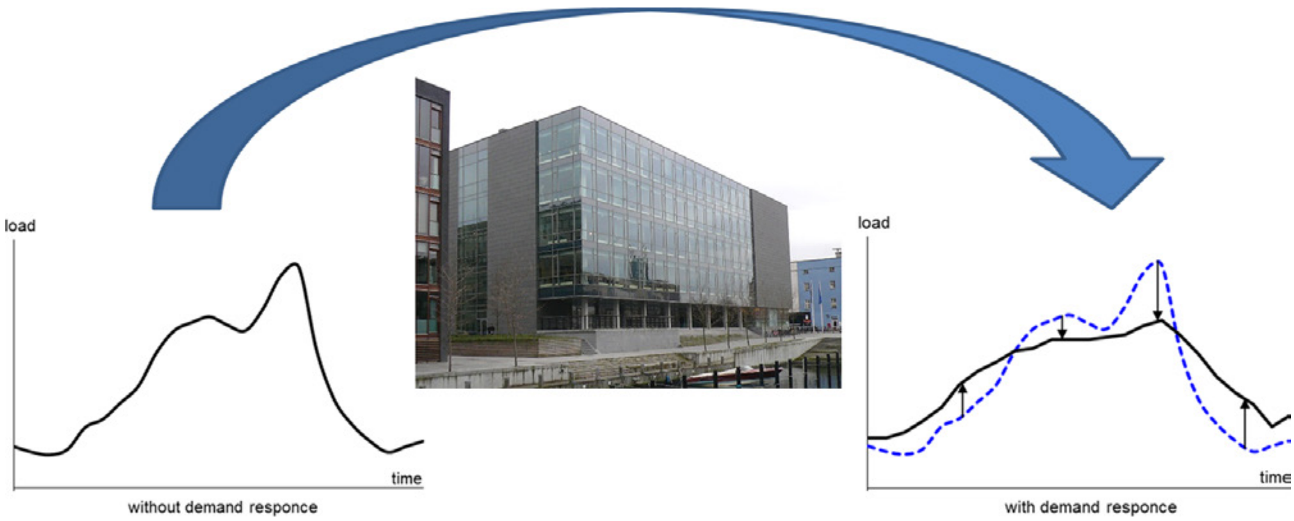


Figure 1. Load shifting and peak shaving using the flexibility available in a building.

Flexibility options

A large part of the energy demand of buildings – such as the energy for space heating/cooling or white-goods – may be shifted in time, and, thus, it may significantly contribute to increase the flexibility of the demand in the energy grids.

One option for generating flexibility is to make use of the thermal mass, which is embedded in all building structures. Depending on the thermal mass properties, such as the amount, the distribution, the speed of charging/discharging, etc. of the thermal mass it is possible to shift the heating or cooling demand in time for a certain period without jeopardizing the thermal comfort in the building. Typically, the time constant of buildings varies between a few hours to several days depending on the amount and exploitability of the thermal mass together with the heat loss, internal gains, user pattern and the actual climate conditions. In addition, many buildings use different types of distributed energy storages (e.g. water tanks, and electrical batteries), which may influence the Energy 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 used 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.

When referring to Energy Flexibility in terms of consumer demand, there are two main approaches, which meet the need to shift the energy demand: storage of electrical energy/heat and demand flexibility. Storage of heat (as mentioned above) is based on the utilization of the structural thermal mass (building inertia) or on water tanks, whereas storage of electrical energy relies on dedicated batteries or electric vehicles. The storage of heat can be done efficiently in a number of ways, most commonly used are the heat pump technology and hot water tanks. On the other hand, demand flexibility (response) is achieved when the electricity consumption of controllable devices (HVAC, washing machines, dishwashers, tumble dryers, electric vehicles, etc.) is shifted from its normal consumption patterns in response to changes in the price of electricity or to meet periods of high renewable generation.

Energy Flexibility definition

One of the first priorities of Annex 67 was to establish a clear definition of Energy Flexibility. After an intensive literature review, following definition was adopted [2]:

- The Energy Flexibility of a building is the ability to manage its demand and generation according to local climate conditions, user needs and grid requirements.
- Energy Flexibility of buildings will thus allow for demand side management/load control and thereby demand response based on the requirements of the surrounding grids.

Characterization methodology for Energy Flexibility

Another main deliverable from Annex 67 is to determine a methodology for characterization and labeling of Energy Flexibility in buildings.

Two approaches have been introduced to compute the flexibility characteristics: a data-driven approach whereby system identification techniques are used to identify the response function based on time series data of the system output (e.g. energy use) and the penalty signal; and a simulation-based approach whereby the flexibility characteristics are derived from simulating the system response to respectively a flat penalty and a step penalty.

The methodology [3] is based on the fact that the Energy Flexibility of a building is not a fixed value but varies with the daily and seasonal weather conditions, the use of the buildings, the requirements of the occupants e.g. comfort range, the requirements of the energy networks, etc.

Figure 2 shows an example of the aggregated response of buildings when receiving some sort of control signal – in the following called **penalty signal**.

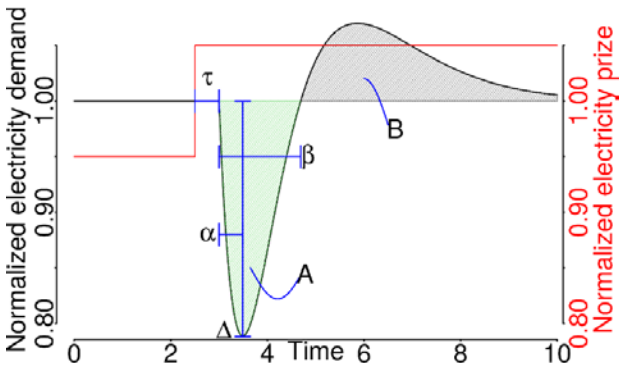


Figure 2. Example of aggregated response when some buildings receive a penalty signal – here a price [2]. The parameters in Figure are: τ is the time from the signal is submitted to an action starts, α is the period from start of the response to the max response, Δ is the max response, β is the duration of the response, A is the shifted amount of energy, and B is the rebound effect for returning the situation back to the "reference".

The penalty signal can be chosen according to specific conditions: often the penalty signal is a price signal, but can also be a signal based on the actual level CO_2 or actual level of energy from renewable energy sources (RES). For these signals the controller should minimize the price or CO_2 emission or maximize the utilization of RES.

The penalty signal can either be a step response (e.g. a sudden change of the price of energy) as in **Figure 2** in order to test different aspects of the available Energy Flexibility in a building or clusters of buildings, or it can be a temporal signal varying over the day and year (example see **Figure 3**) according to the requirements of the energy networks. A step response test may e.g. be utilized in simulations to test the capacity of e.g. a thermal storage. Temporal signals will typically be used when utilizing the energy flexibility in an area of an energy network and will concurrently feedback knowledge on the available energy flexibility in this area.

Due to the variation of the conditions for obtaining Energy Flexibility the focus is on a methodology rather than a number. However, using the methodology numbers may be obtained for the parameters mentioned **Figure 2** and for comparison with a reference case, where no flexibility is obtained. The latter refers to labelling, where buildings including their energy systems may be rated by their share of reduction on price/consumption/CO_2 -emissions etc. (depending on the target of the labelling) when using penalty-aware control instead of penalty-ignorant control.

Position paper on Smart Readiness Indicator (SRI)

Based on the above described methodology, Annex 67 has given input to the EU study on a Smart Readiness Indicator for implementation in EPBD [4]. Annex 67 has written a Position Paper explaining the view of Annex 67 regarding how to consider Energy Flexibility – also in the Smart Readiness Indicator. There is a need for an approach that takes in to account the dynamic behaviour of buildings rather than a static counting and rating of control devices. It is further important to minimize the CO_2 emission in the overall energy networks rather than optimize the energy efficiency of the single energy components in a building.

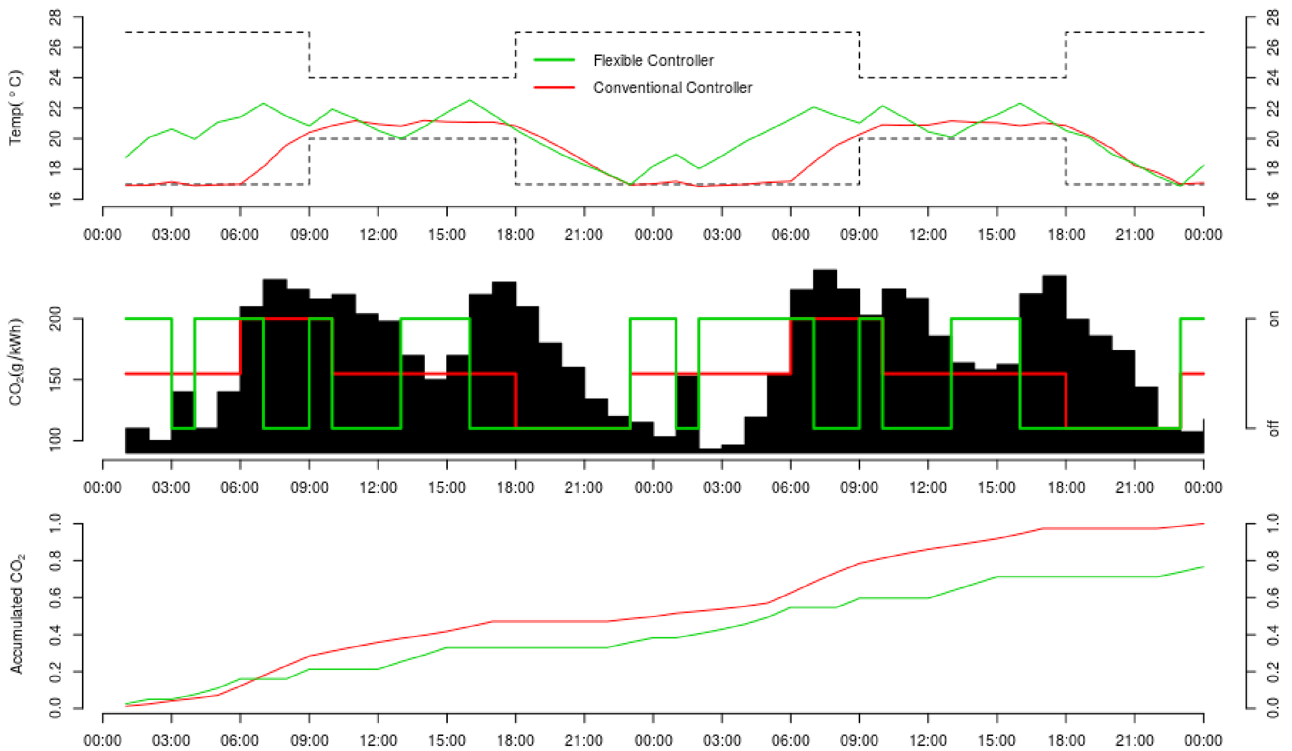
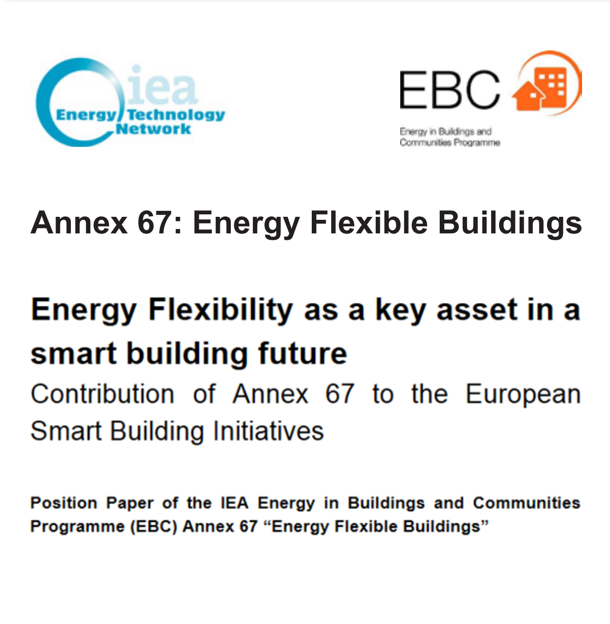


Figure 3. Top plot: the room temperature in a building is controlled by a penalty-aware controller (green line) or a conventional controller (red line). Both controllers are restricted to stay within the dashed lines. Middle plot: The black columns give the penalty, while the green and red lines show when the two controllers calls for heat. Bottom plot: the accumulated penalty for each of the controllers. The penalty-aware controller results for the considered period in 20 % less emission of CO_2 compared to the traditional controller [3].

The position paper can be downloaded from the Annex 67 website.



Annex 67: Energy Flexible Buildings

Energy Flexibility as a key asset in a smart building future

Contribution of Annex 67 to the European Smart Building Initiatives

Position Paper of the IEA Energy in Buildings and Communities Programme (EBC) Annex 67 "Energy Flexible Buildings"

Figure 4. Position paper of Annex 67 on SRI.

Building stakeholders

When utilizing the Energy Flexibility in buildings the comfort and economy of the buildings are influenced. If the owner, caretaker and/or users of a building are not interested in delivering Energy Flexibility to the surrounding energy grids, it does not matter how energy flexible the building is as the building will not be an asset for the surrounding energy grids. It is, therefore, very important to investigate and understand which barriers exist for the stakeholders of buildings and how the stakeholders may be motivated to allow their buildings to contribute with Energy Flexibility to stabilize the future energy grids. Strategies to benefit both the total energy system and the customers are, therefore, investigated.

Concluding Remarks

Annex 67 is tackling the very challenging topic of Energy Flexibility in buildings. This topic will become ever more important with the growing share of RES in sustainable energy systems. So far, the project has been very productive. For all available articles, conference papers, reports and other results, see www.annex67.org. ■

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[1] IEA EBC Annex 67 "Energy Flexible Buildings". http://www.annex67.org.

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