ANNEX 67 NEWS

Newsletter 1 | April2016

Content

[Photo of Living Lab, Katrine Peck Sze Lim]

Brief description of IEA Annex 67

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. This can be done by several means i.e. thermal mass, charging of electrical cars and use of appliances. 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. The aim of the Annex is thus to increase knowledge on and demonstrate the Energy Flexibility buildings can provide for the energy grids, and to identify critical aspects and possible solutions to manage this Energy Flexibility.

In-depth knowledge of the Energy Flexibility that buildings may provide is important for the design of future Smart Energy systems and buildings. The knowledge is, however, not only important for the utilities it is also necessary for companies when developing business cases for products and services supporting the roll out of Smart Energy networks. Furthermore, it is important information for policy makers and government entities involved in the shaping of future energy systems.

IEA EBC Annex 67 Energy Flexible Buildings was officially started in June 2016 and will last until June 2019. The annex is divided into three subtasks with several activities beneath:

Subtask A: Definitions and Context

Activity A.1. Common terminology and definition of Energy Flexibility in buildings

Activity A.2 Methodology for characterization of Energy Flexibility in buildings

Subtask B: Analysis, Development and Testing

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 guidelines

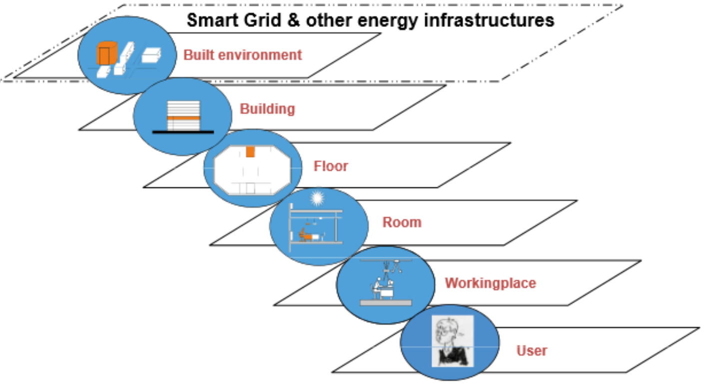
Subtask C: Demonstration and User Perspectives

Activity C.1. Measurements in existing buildings

Activity C.2. Demonstration of Energy Flexibility in real building

Activity C.3. User motivation and acceptance

For further information please see www.annex 67.org, which soon will be lanced as the web page of IEA EBC Annex 67. The following countries participate in the annex: Austria, Belgium, Canada, Czech Republic, Denmark, Finland, Germany, Italy, The Netherlands, Norway, Portugal, Spain, Switzerland and UK.



The objectives of IEA EBC Annex 67

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.

IEA EBC Annex 67 deliverables

The following project deliverables are planned:

- source book: Principles of Energy Flexible Buildings,
- technical report: Terminology, definition and Flexibility indicators for characterization of Energy Flexibility in buildings,
- technical report: Guidelines on modelling of Energy Flexibility in buildings,
- technical report: User perspectives,
- technical report: Control strategies and algorithms,
- technical report: Test procedures and results,
- technical report: Design examples on optimization of Energy Flexibility in buildings.

Brief from the two first working meetings

IEA Annex 67 1st experts meeting

The 1st working meeting took place in Lisbon, Portugal September 30th - October 2nd, 2015 and was attended by 31 participants from 13 countries. It was hosted by Faculty of Science and Technology / Universidade Nova de Lisboa (FCT/UNL). Aside of the finalization of administrative issues related to project management, the main aim of this meeting was to give project participants a chance to present their work related to Energy Flexible Buildings, and how it can contribute to the work planned within the Annex 67. There were all together 26 presentations, which indicated that there is already significant amount of research done on describing and modeling flexibility. However, the work is very fragmented and case related hence there is lack of common approach / understanding. Therefore, first common exercise, led by Glenn Reynders, KU Leuven, with the goal to initiate and streamline an in-depth discussion on the (subtle) differences between definitions and quantification methods for the energy flexibility in buildings was started. You can read more about the common exercise can be found later in the newsletter.
Moreover, number of test facilities in different locations, i.e. Spain, Italy, Finland, Denmark, UK, and Norway are available for Annex 67 use in order to test components, systems, and new control strategies etc.

IEA Annex 67 2nd experts meeting

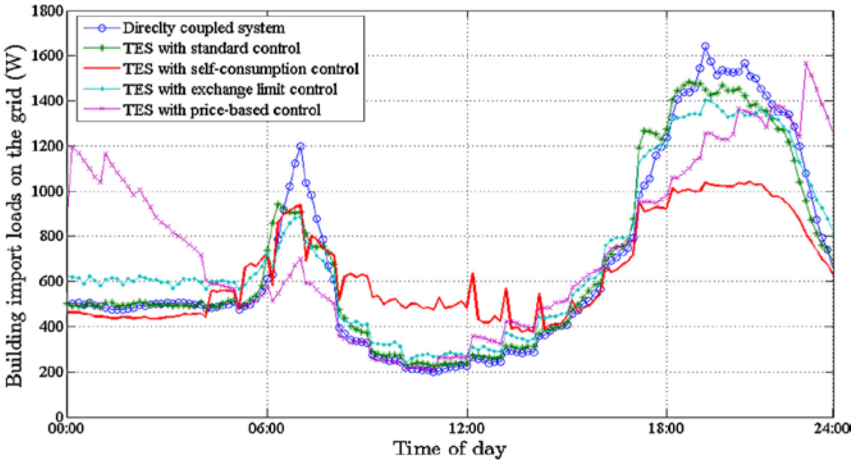
The 2nd working meeting took place in Trondheim, Norway March 16th – March 18th, 2016 and was attended by 43 participants from 14 countries. It was hosted by Norwegian University of Science and Technology (NTNU) and SINTEF. The first day was used to report update on the work progress within individual subtasks, e.g. the ongoing literature reviews of i) terminology and methodologies applied to characterized flexibility (STA), ii) users' needs and barriers for application of flexibility (STA), and iii) control strategies (STB); and common exercise. The participants had also a chance to visit a Living Lab, a multipurpose experimental facility, designed to carry out experimental investigations at different levels, ranging from envelope to building equipment components, from ventilation strategies to action research on lifestyles and technologies, from technologies for solar energy conversion to building-grid interaction. You can read more about the preliminary results from common exercise and the Living Lab later in the newsletter. The day ended with session dedicated to presentations of research work that is not part of Annex 67 but is related to the flexibility topic. The second and third day was used to coordinate the work structure of individual actions and to involve interested participants in particular actions. Finally, it was agreed to hold the Annex 67 meeting in autumn 2016 in Bolzano, Italy.

Norwegian perspective on energy flexibility

Source:Dar, U.I., Sartori, I., Laurent, G. and Novakovic, V. (2014) Advanced control of heat pumps for improved flexibility of Net-ZEB towards the grid, Energy and Buildings, 69(2014) 74-84.

ZEB need to be flexible to be grid friendly, and therefore environmental friendly; 'zero' just ain't enough

The ZEB (Zero Energy/Emission Building) concept promotes buildings that use the grid as the virtual energy storage medium. They exchange a large amount of energy with the grid and rely heavily on these energy exchanges to fulfill their yearly zero balance. Nevertheless, grid hosting capacity is limited and due to these large energy exchanges several investigations have pointed out that the large-scale application of such buildings is a challenging task considering the grid stability issues.



Annual mean import profiles for different control strategies (hourly resolution). TES = Thermal Energy Storage (hot water tank in this case)

Hence, large scale application of ZEBs in the building stock can only be realized if well-designed energy solutions are in place.

As current market trends shows strong growth in heat pump (HP) and photovoltaic (PV) applications, this article investigates the flexibility that such combination could offer to the grid. An HP-PV combination leads to an all-electric building that uses electricity as the sole energy carrier. The focus is on the opportunities associated with the heating system and the flexibility linked with such all-electric ZEB. For the purpose, the study investigated four different control strategies using a common hot water tank as thermal energy storage (TES) as the flexible energy medium within the building.

The building conforms to the Norwegian passive house requirements and is simulated for the Oslo climate. Statistically representative occupancies, appliance and lighting loads are obtained from a stochastic load model.

Results shows that with a proper control: self-consumption of the building could be improved by almost 40%, the annual import bills could be reduced by 20% and hours of peak exchanges with the grid could be reduced by 30%. However, it is observed that the objectives are mostly contradictory, and optimizing one objective degrades the others.

The price-based control shifts most of the HP loads to night-time and has a significant influence on reducing the cost and shifting the load, but it worsens both the peak exchanges as well as the self-consumption of the building. The self-consumption control, on the other hand, shifts most of the HP loads to day-time and maximizes the onsite consumption as well as reduces the interaction with the grid. Nevertheless, it worsens the import bill due to large heating loads shifted to day-time and not entirely covered by the PV. Overall, significant flexibility of the energy demand in ZEB is found achievable if proper control is in place.

Literature review on methodologies for quantification of energy flexibility

Rui Amaral Lopes

Having into consideration local climate conditions, user needs and grid requirements, the energy flexibility of the building stock can be used to improve the overall energy system. In order to use such flexibility, e.g. through demand response programs, tools to proper quantify it are needed. Researchers worldwide have developed several methodologies to quantify the energy flexibility of different system, as further described.

Six et al. [1] first proposed a methodology to quantify energy flexibility, which was then extended by Nuytten et al. [2]. These researchers consider the flexibility of a specific system as the ability to shift the consumption, associated to a certain amount of electrical power, in time. These studies quantify the energy flexibility as the number of hours that energy consumption can be delayed or anticipated.

The methodology was applied to quantify the flexibility of residential heat pumps combined with thermal energy storage [1] and to quantify the flexibility of a Combined Heat and Power (CHP) system with thermal energy storage [2].

De Conick and Helsen developed a methodology based on cost functions [3][4]. Their work is focused on heating systems that use buildings' thermal properties to provide energy flexibility. The referred cost functions are composed by at least three different data points. They comprise information regarding (i) the amount of energy that can be shifted to or from a specific time slot and (ii) the associated cost when comparing to a reference plan

This reference plan results from an optimal control problem that already minimizes the monetary costs associated with the operation of the controlled devices while preserving the building's indoor temperature within the comfort boundaries. Hence, in this case, other control strategies using system's flexibility to deviate the energy consumption from the reference plan result in an additional cost. Different curves can be aggregated to quantify the flexibility provided by a system composed by several subsystems. Additionally, if a cost curve is calculated at each time step, then the resulting information can be aggregated to obtain a time dependent energy flexibility profile. If the flexibility of the respective system is used at a specific point in time, the cost curves should be revaluated as this will affect the availability of flexibility on future time slots.

Without specifically using the term energy flexibility, Oldewurtel et al. developed a methodology to quantify the shifting potential of a specific system (in practice these two terms refer to the same concept) [5]. They defined shifting potential as the amount of power a building can shift from the baseline power consumption, if needed. To quantify it, the authors use efficiency curves where the maximum possible power increase or decrease during a time interval is depicted against the power shifting efficiency. This efficiency refers to the ratio between the amount of power consumption modified during the mentioned time interval and the additional energy consumption of the system over a test period. To develop the efficiency curves they perform distinct control strategies to predict the amount of power the building can shift from the reference power consumption profile during a certain time span, and the respective power shifting efficiency.

In line with Oldewurtel et al. [5] and De Coninck and Helsen [3][4], Reynders et al. [6] present a generic quantification method for energy flexibility by representing a demand response technology as a virtual storage capacity. These researchers quantify the energy flexibility by computing the available storage capacity, the storage efficiency and the power shifting capability. The available storage capacity is then defined as the maximum amount of energy that can be added to the virtual storage capacity during the duration of a demand response event. This storage efficiency is used to quantify the energy losses associated to the activation of the storage capacity. The power shifting capability is defined as an additional indicator that expresses the relation between the (i) level to which a system can deviate its power demand (or output) from the reference scenario and (ii) the duration this shift can be maintained without affecting normal behavior. Reynders et al. [7] applied the three indicators to analyze the relation between the demand response potential of structural thermal energy storage and building design parameters.

Thereby all indicators are strongly affected by the dynamic boundary conditions and the energy flexibility of thermal mass itself is thus a dynamic property.

D'hulst et al. quantified the flexibility offered by five different types of domestic electrical devices (washing machines, dishwashers, tumble dryers, electric hot water buffers and electric vehicles) based on measured data [8]. D'hulst et al. defined the energy flexibility of an electrical device as the power increases or decreases which are possible within functional and comfort limits, combined with how long these changes can be sustained. Another generic quantification process was proposed by Laurynas Siksnys et al. [9]. They developed a detailed methodology based on the concept of flex-object which is a multidimensional representation capturing two aspects: 1) the time flexibility interval (i.e. the difference between the earliest and latest possible starting times) and 2) the amount profile (i.e. the consecutive sequence of possible amounts that the object can assume). Solutions to aggregate and disaggregate the flexibility provided by different objects are also proposed.

Although not focusing on energy flexibility, this generic methodology could be used to quantify the energy flexibility of electrical devices. Additionally, it could be used by small energy consumers and/or producers to offer their aggregated flexibility on markets that would not be accessible to them otherwise.

The current literature review was conducted with the objective of establishing a knowledge base for future works in energy flexibility quantification. A number of studies can already be found in the literature focusing specific methodologies to quantify the energy flexibility of particular devices. However, it can be concluded that a detailed and generic framework, developed to quantify the energy flexibility of distinct individual or aggregated systems, is still lacking in the literature.

Such literature gap is to be addressed under the scope of IEA EBC Annex 67. Nevertheless, interested readers may refer to [10] for an extended version of this literature review.

References

[1] – D. Six, J. Desmedt, D. Vanhoudt, J. Van Bael, Exploring the flexibility potential of residential heat pumps combined with thermal energy storage for smart grids. In: 21st International conference on electricity distribution; 2011. p. 0442–0442.

[2] – T. Nuytten, B. Claessens, K. Paredis, J. Van Bael, D. Six, Flexibility of a combined heat and power system with thermal energy storage for district heating, Applied Energy, Volume 104, April 2013, Pages 583-591.

[3] – R. De Coninck, L. Helsen, Bottom-up quantification of the flexibility potential of buildings, in: Building Simulation, 13th International Conference of the International Building Performance Simulation Association, IBPSA, Aix-les-Bains, France, 2013.

[4] – R. De Coninck, L. Helsen, Quantification of flexibility in buildings by cost curves – Methodology and application, Applied Energy, Volume 162, 15 January 2016, Pages 653-665.
[5] – F. Oldewurtel, D. Sturzenegger, G. Andersson, M. Morari, R. S. Smith, Towards a standardized building assessment for demand response, in: Proceedings of the IEEE Conference on Decision and Control, IEEE, Firenze, Italy, 2013, pp. 7083–7088.
[6] – G. Reynders, J. Diriken, and D. Saelens, A generic quantification method for the active demand response potential of structural storage in buildings, in 14th International Conference of the International Building Performance Simulation Association, 2015.
[7] – G. Reynders, J. Diriken, and D. Saelens, "Quantifying the active demand response potential: impact of dynamic boundary conditions," in 12th Rehva world congress: clima 2016.
[8] – R. D'hulst, W. Labeeuw, B. Beusen, S. Claessens, G. Deconinck, K. Vanthournout, Demand response flexibility and flexibility potential of residential smart appliances: Experiences from large pilot test in Belgium, Applied Energy, Volume 155, 1 October 2015, Pages 79-90.
[9] – L. Šikšnys, E. Valsomatzis, K. Hose and T. B. Pedersen, Aggregating and Disaggregating Flexibility Objects, IEEE Transactions on Knowledge and Data Engineering, vol. 27, no. 11, pp. 2893-2906, Nov. 1 2015.
[10] – R. A. Lopes, A. Chambel, J. Neves, D. Aelenei, J. Martins, A literature review of methodologies used to assess the energy flexibility of buildings, in SHC 2015.

Preliminary results from common exercise

Glenn Reynders

In order to facilitate and streamline an in-depth discussion on the – sometimes subtle – differences between the definitions and quantification methods for the energy flexibility in buildings that are reviewed in Subtask A.1 and A.2, a first common exercise has been setup. While a step-wise increase of complexity is aimed for in follow-up exercises, the subject of the first exercise was limited to the definition and quantification of the flexibility of a simple single zone dwelling.

Follow-up exercises will extend the scope by including additional storage and demand response technologies (e.g. domestic hot water tanks or batteries) and by increasing the model complexity (including non-linear system efficiencies, multi-zone building). As such, the common exercises will also support model and control development in subtask B.

In the first common exercise participants are asked to quantify the "energy flexibility" of a grid-connected, single-zone residential building equipped with structural thermal mass,

Sketch of the detached single-zone dwelling

an air-to-water heat pump, low temperature radiators and photovoltaic system.

Thereby no clear definition(s) nor quantification method(s) are proposed. In contrast, participants are asked to define and quantify flexibility based on literature or own experience. Evidently, the definitions and processes to quantify the flexibility should be well documented as the main goal of this exercise is to get more detailed insight in benefits and limitations of different methods. During the second work meeting in Trondheim, participants representing 5 different countries presented their first results, comparing amongst others "Forced power flexibility", "Available storage capacity" and "Storage efficiency." Although the results were still in a preliminary state, the analysis clearly highlighted on the one hand clear overlaps between some of the indicators existing in literature and emphasized on the other hand that the energy flexibility of a building varies in time.

Site visit – Living Lab in Trondheim

Francesco Goia

The Living Lab at the Norwegian University of Science and Technology (NTNU) in Trondheim is a multipurpose experimental facility, designed to carry out experimental investigations at different levels, ranging from envelope to building equipment components, from ventilation strategies to action research on lifestyles and technologies, from technologies for solar energy conversion to building-grid interaction. The primary aim of the Living Laboratory is thus to realize a building that is representative, as a typology, of the most common Norwegian dwelling – the single family house – and to demonstrate how CO_2-neutral construction can be realized in the Norwegian climate. It has a gross volume of approximately 500 m^3 and a heated surface (floor area) of approximately 100 m^2. It is realized with state-of-the-art technologies for energy conservation measurements and renewable energy source exploitation. The Living Lab is designed to minimize energy demand for its operation and to harvest solar energy to such an extent that converted solar energy (both through passive measures and active technologies) is larger, on a yearly basis, than the building energy demand. Moreover, since the building was design to achieve the Zero Emission target for materials and operations, particular care was paid in order to select materials and systems that minimizes embodied emissions.

Thermal energy necessary to cover heating, ventilation and domestic hot water demands is primarily planned to be obtained by a ground source heat pump connected to a surface collector field located in the back-yard of the Living Laboratory.

The plant-side of the heat pump is connected to an integrated tank that combines a buffer vessel for the heating circuit (160 l) and a domestic hot water vessel of 240 l. The two tanks are equipped with one auxiliary electric coil each and can be connected to the solar thermal panel system installed on the façade.

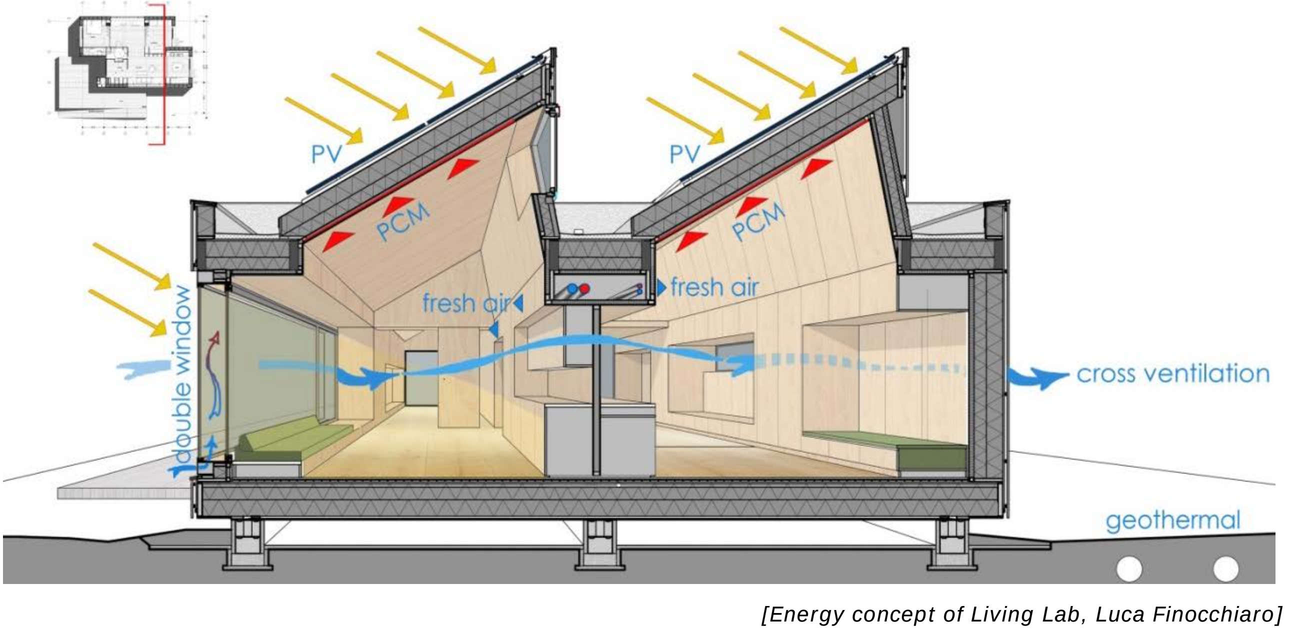
Two different terminal units have been installed for the heating system, so that it two different modes and efficiencies can be tested: floor heating and one high-temperature (55 °C) radiator. Ventilative heating can be also exploited to cover heating demand in combination with fresh air supply need. This function is enabled by balance mechanical ventilation unit (with rotatory heat recovery system) coupled with electric and hydronic coils.

Two façade-integrated solar thermal panels are installed on the south-facing façade of the building. A total of 48 PV polycrystalline silicone cells modules are installed on the two roof slopes of the building, with total installed power (DC) of thus approximately 12.5 kW_P. At the present, there is not an electric battery installed in the building, but plans are under development to complement the building with such a technology.

In total, more than 200 signals are continuously acquired to fully monitor energy and environmental performance of the building.

Simultaneously, more than 70 signals are sent out from the building level controller (integrated with the data acquisition system) to manage the wide range of building features that can be controlled in the facility. A particular feature of the Living Laboratory is that its management system is fully developed in LabView environment. This means that it does not rely on any proprietary software/solution from a specific HVAC supplier, but it can be freely modified according to any desired specification, such as test of different strategies for thermal management of building, thermal energy storage and predictive control algorithms. Moreover, it is interesting to mention that the facility can be fully operated without any person living in it, thanks to a series of functions that can replicate occupancy of the building and connected loads (e.g. as internal loads, domestic hot water loads, use of appliances, artificial lighting, opening of windows).

The Living Laboratory can represent an interesting test rig for experiments carried out in the framework of the IEA EBC Annex 67. The contribution to the Annex from the use of this facility can primarily be related to three activities: 1) acquisition and post-processing of data to define real users' occupancy schedules and associated loads; 2) assessment of (solar) renewable energy potential, and analysis of time and quantity match between solar energy availability and building energy use, in a Nordic climate context; 3) test of different strategies to increase energy flexibility in buildings through management of thermal/electric loads through energy storage solutions and/or other control strategies for HVAC components or building components.



[Energy concept of Living Lab, Luca Finocchiaro]

National Projects

German Joint Research Project "Grid-supportive Buildings"

The focus of the energy transition in Germany is on decreasing CO2 emissions (i.e. fossil fuels) via increasing efficiency and the use of renewable energy systems (i.e. RE systems). The large-scale introduction of non-adjustable and fluctuating energy from solar and wind presents special challenges to the energy system. Local differences between electricity production and demand may lead to problems in voltage stability or resource utilization. Therefore, the time-dependent profile of energy consumption will play an important role, in addition to the absolute electricity consumption. By shifting the electricity consumption for heating and cooling power to more favourable times and storing the energy as heat, buildings can make a major contribution to relieving the stress on the electricity systems and transmission grids. Using electric heat pumps, co-generation and compression chillers in combination with thermal storage units, it is possible to convert and store a large amount of surplus electricity with high efficiency. The achieved flattening of the residual load profile has a positive influence on the remaining part of the system infrastructure. The objective of the joint research project "Grid-supportive buildings" is a holistic view of buildings as part of the energy system. Here, it will be investigated how buildings behave in a future electricity grid and how they can contribute to the stability of the grid.

Partners: Fraunhofer Institute for Solar Energy Systems, Fraunhofer Institute for Building Physics, RWTH Aachen

More information:

http://www.netzreaktivegebaeude.de/english.php

Next IEA Annex 67 meetings

- IEA Annex 67 3rd experts meeting - October 17-19, 2016 Bolzano, Italy
- IEA Annex 67 4th experts meeting – March 15-17, 2017 Freiburg, Germany

Energy flexibility related events

I. 12th REHVA World Congress CLIMA2016 – Date: 22-25 May 2016, Aalborg, Denmark
More information: http://www.clima2016.org

IEA EBC Annex 67 session (TS 5) includes 10 presentations of various topics related to energy flexible buildings

Date: Tuesday May 24 from 13:30 to 15:00

Programme for TS 5 session:

1. IEA EBC Annex 67 Energy Flexible Buildings. S.Ø. Jensen, A. Marszal-Pomianowska
2. Application of high-resolution domestic electricity load profiles in network modelling. A case study of low voltage grid in Denmark. A. Marszal-Pomianowska, I.D. de Cerio Mendaza, P. Heiselberg, B. Bak-Jensen.
3. Identifying a comfortable excitation signal for generating building models for model predictive control: a simulation study. R.E. Hedegaard, T. Pedersen, M.D. Knudsen, S. Petersen
4. Handling Stochastic Occupancy in an Economical Model Predictive Control Framework for Heating System Operation in Dwellings. T.H. Pedersen, M.D. Knudsen, R.E. Hedegaard, S.Petersen.
5. Quantifying active demand response potential: impact of dynamic boundary conditions. G. Reynders, J. Diriken, D. Saelens
6. Demand-side management of the heating need of residential buildings. J. Le Dréau
7. Operational load shaping of office buildings connected to thermal energy storage using dynamic programming. C. Finck
8. Numerical study on load shifting strategies for the heating and cooling of an office building under consideration of variable grid conditions in Germany. K. Klein, D. Kalz, S. Herkel.
9. Developing an Energy Management System for optimizing the interaction of a residential building with the electrical and thermal grids. R. Ruusu, S. Cao, A. Hasan, J. Kortelainen, T. Karhela
10. Model predictive control of space heating and the impact of taxes on demand response: A simulation study. M. Knudsen, R. Hedegaard, T. Pedersen, S. Petersen

II. Workshop Grid-Supportive Buildings: Opportunities and Challenges (As part of CLIMA 2016)

Organized by: IEA EBC Annex 67 and German project "Netzreaktive Gebäude"

Date: Tuesday May 24 from 15:30 to 17:30

More information:

http://www.clima2016.org/UserFiles/IEA%20topical%20sessions%20and%20workshops/WS_26-%282%29.pdf

III. Conference on Local Energy Communities Hype or hope for stimulating sustainability?

Date: 26 May 2016, Delft, Netherlands

More information:

https://www.aanmelder.nl/87238

IEA EBC ANNEX 67
Energy Flexible Buildings

Operative Agent: Søren Østergaard Jensen
sdj@teknologisk.dk
Coming website: Annex67.org

Participants:

Austria, Belgium, Canada, China, Denmark, Finland, France, Germany, Italy, Netherlands, Norway, Portugal, Spain, Switzerland, UK