IEA-ECES Annex 31

Energy storage with Net Zero Energy Buildings and Districts: Optimization and Automation

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1: Background and Justification

Evidence from a variety of research suggests that the built environment contributes substantially to global energy consumption and to the production of gases that impact climate change: buildings use about 40% of the world-wide total energy. This fact highlights the importance of targeting building energy use as a key to decreasing the energy consumption. Hence, net-zero energy buildings (NZEBs) and district cogeneration systems have been suggested as approaches to achieving this goal. NZEBs, are buildings that produce as much energy as they use over the course of a year. District cogeneration systems are local energy generators that provide any of heating, cooling, or electricity services to nearby clusters of buildings. There are a number of challenges in the design, construction and operation of NZEBs and districts.

Presently, designers use guidelines developed for passive solar buildings to design NZEBs where the focus is on the design of a well-insulated- and airtight building envelope. Then, the building is connected with an on-site source of energy. The main drawback of *renewable* energy sources is the variability and intermittence in their availability; significant mismatches between energy demand time and energy production time can occur. Thus to make the NZEB a viable solution it may need to be integrated with several sources of renewable energy, such as solar, wind, ground heat pumps, and bio-mass, as well as energy storage.

Energy storage technologies are a central element of designing, operating an intelligent NZEBs and they are needed for efficient use of renewable energy resources and dealing with the intermittency of energy supply and demand. This problem affects not only individual NZEBs but also district-scale projects. In regards to electrical storage technologies, the current lack of technical knowledge, of both design tools and the cost associated with integrating energy storage technologies in buildings, have led grid connection to be the current norm. In such applications, buildings are connected to the utility grid, allowing for any surplus energy to be exported. The building buys back the electricity from the electric grid when renewable energy generation cannot meet its energy requirement. In this way, the electrical grid is treated as a “virtual” energy store to overcome the temporal mismatch between energy supply and demand. Whilst this is currently feasible for individual buildings, this will not be sustainable from the grid point-of-view. Thus, *local* energy storage may be needed in the long-term to balance local energy generation.

For NZEBs or districts to reach their full potential, the issue of integrating energy storage and optimizing its operation must be properly addressed. It is worth stating that, the essential goals for achieving NZEBs is to reach the appropriate combination, integration and optimization of different distributed energy systems with energy storage. It is *not* the objective to maximize energy exported to the grids – dispersing it to be used at other places. Thus, to effectively meet the concept of NZEBs, whether or not this is achieved using district energy resources, energy storage has a vital role to play due to the intermittency in energy demand against the transient cost or availability of energy resources. In other words, all types of energy storage technologies must be taken into consideration to find the optimum use of flexible energy supply systems.

Further research is needed to develop efficient and reliable design approaches and operating strategies for thermal and electrical energy produced on-site by NZEBs and/or districts. Previous annexes have dealt with some issues in this area. ECES Annex 7 evaluated various strategies for energy storage control and operation for industrial and building applications, but focused only on cold storage. ECES Annex 19 dealt with the optimization and improvement of industrial process heat and power generation with thermal energy storage techniques, but focused only on high temperature applications (i.e., TES technologies for applications beyond 120 °C). ECES Annex 23 deals with the application of energy storage to various types of energy efficient buildings, but focused mainly on the development of simulation tools and not on the integration, and development of control strategies. ECES Annex 24 mainly focused on the development of advanced materials and systems for the compact storage of thermal energy.

Solar heating and cooling (SHC) Task 40 and energy conservation in buildings and community systems (ECBCS), Annex 52 - (IEA/ECBCS) dealt with buildings that integrated heating/cooling systems with local power generation and used the electricity grid as buffer storage: This was one approach towards achieving net zero energy solar buildings.

2: Identified research gaps

Research in the area of design and analysis of NZEBs and districts is very complex and is inherently interdisciplinary. The current research approach to energy efficiency, though multidisciplinary in principle, is hindered by the lack of effective tools and methodologies that address interdisciplinary aspects of the integrating NZEBs with districts. Over the last decade, extensive research has been carried out on the improvement of energy efficiency in buildings. However, this research has focused on the optimization and improvement of individual system components, such as building envelopes, rather than optimizing the whole system including economic cost/benefits. Current industry practices also rarely consider the detailed interactions between a building's mechanical ventilation system, energy storage system, renewable energy system, and the local grid: Thus, optimization of ***whole system*** efficiency is rarely achieved.

The concept of energy use and storage integration with other renewable energy technologies for NZEBs and districts requires not only integration and optimization but ***accurate forecasting and controls to predict and react to future energy demand***. For example, weather forecasts can be integrated into system controls to improve prediction of renewable nergy generation and expected heating and cooling demand.

3: Scope, Objectives and Limitations

3.1 Annex Scope

The Annex is developed within the scope of: Efficient integration of energy storage with NZEBs and districts; optimisation and operation.

3.2 Objectives

The general objective of this Annex is to address the integration, control and automation of energy storage with NZEBs, districts, and/or local utilities. The focus will be on the development of design methods, optimization and control tools related to predicting, operating, and evaluating the performance of NZEBs and districts when energy storage is available.

This objective can be subdivided into eight specific objectives:

A. To assess the technical and economic impact of energy storage systems on the total performance of NZEBs and districts,
B. To develop methods for optimizing the total performance of NZEBs and districts that include energy storage,
C. To develop design-stage tools for assessing the financial and environmental impacts of energy storage systems integrated with NZEBs and districts,
D. To develop efficient and advanced control algorithms and/or strategies for the operation of NZEBs and districts with energy storage systems, for different climatic conditions and energy markets,
E. To develop and provide design guidelines for integrated energy storage with NZEBs and districts,
F. To disseminate the knowledge and experience acquired in this Annex.

4: Demarcation

The Annex will focus on analysis and development of design and control tools for optimization and control of integrated NZEBs and districts with energy storage.

The annex will address both individual buildings and districts. The Annex will not address, devise or deliver new numerical modelling techniques, new thermal storage materials, or new measurement techniques.

5: Means

5.1 Methodology

To address the specific Annex objectives, the research and development work in the Annex will be divided in a number of subtasks provided below;

5.2 Subtasks

TASK A: ***Methodologies and tools for the evaluation of combined various energy storage and saving techniques; and optimisation of the whole building***

A.1: Comprehensive literature review will be conducted. Existing storage and energy saving techniques available for NZEB and used in the previous studies will be identified. A literature review on existing district energy systems will also be carried out, with a specific goal to categorize chosen technologies (and successes/failures) based on climate zones, building types, and macroeconomic conditions.

A.2: A holistic framework will be set up to identify the best combinations of techniques with the goal of integrating energy storage into NZEBs or districts.

A.3: Define critical factors or variables that effect the predicted cost/benefit of integrated energy systems utilising storage. It would also be important to define what factors determine the technology choice.

TASK B: ***To develop effective control strategies for the operation of the energy system[s], including energy storage***

B.1: Review existing control strategies for the operation of NZEB with/without the integration of energy storage.

B.2: Develop effective control strategies for optimizing the operation of individual building systems

B.3: Develop effective control strategies for optimizing the operation of district level systems. One key question is whether and how it is possible to aggregate individual building information into clusters.

B.4: Develop methodologies of quantifying economic/environmental benefits of integrated systems with energy storage to the utility systems for different climatic conditions. This includes cost/benefit analyses for the developer and consumers and the potential to compare optimum ‘districts’ to optimum NZEBs without district connection.

TASK C: To develop design guidelines for integrating energy storage with NZEBs and districts

C.1: Carry out state-of-the-art review of related design guidelines for NZEBs

C.2: Produce design and testing guidelines for integrated energy storage with NZEBs based on simulations and available field measurements.

C.3: Create a forum for researchers, scientists and industries to disseminate knowledge, skills and experience acquired in the integration, optimisation and automation of NZEBs with energy storage and harmonised guidelines

TASK D: Life cycle economic and environmental evaluation of the effective integration of energy storage for NZEB

D.1: State-of-the-art review of LCA/LCC (life cycle costing) of the integration of energy storage for NZEB.

D.2: Development of methodologies for removing barriers for successful application of this technology

D.3 Develop methodologies for jointly evaluating economic and environmental impact of the integration of energy storage for NZEB

D.4: Development of approaches to optimizing district networks using thermal storage. This includes cost/benefit analyses for the developer and consumers. This also includes the potential to compare optimum ‘districts’ to optimum NZEBs without district connection.