Energy flexible buildings towards resilient low carbon energy systems – knowledge gained through Annex 67 and research questions for Annex 82

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Common understanding that we need to replace fossil fuels with renewable energy
Example: Green transition in Denmark

Goals
50 % green power by 2020 - Reached
100 % green power by 2030
70 % GHG reduction by 2030
100 % climate neutral by 2050

Who consume more or store energy
Who will deliver or consume less
IEA EBC Annex 67 Energy Flexible Buildings

Working and reporting: 2015-2019

OA: Søren Østergaard Jensen, Danish Technology Institute (former)

16 participating countries: Austria, Belgium, Canada, China, Denmark, Finland, France, Germany, Ireland, Italy, Norway, Portugal, Spain, Switzerland, The Netherlands, UK

https://www.annex67.org/
Energy Flexibility in buildings – Terminologies and Definitions

Energy Flexibility represents the capacity of a building to react to one or more penalty signals, without compromising the occupant comfort conditions and taking into account the technical constraints of the building and its HVAC system.
Energy Flexibility in buildings – Terminologies and Definitions

08 INFRASTRUCTURE
KEY GRIDS:
Power network; District heating; District cooling

07 STAKEHOLDERS
KEY ACTORS:
Energy suppliers; Private, commercial and industrial customers; Building managers; Technology providers; The National Regulatory Authority; Aggregators

06 TECHNOLOGY
KEY ELEMENTS:
Energy storage: thermal and electrical; Smart appliances

05 CONTROL
KEY ELEMENTS:
Controller type; Control approach: direct and indirect control; Control objective: Penalty signal; Requirements of the surroundings grids

01 DRIVING FORCES
KEY FORCES:
Mitigation of carbon emissions; Intermittent renewable energy sources in energy system; Mitigation of operational bottlenecks in energy system

02 DEFINITION
KEY CHARACTERISTICS:
Ability to manage its demand and generation according to local climate conditions, user needs and requirements of the surrounding grids

03 METHODS
KEY CHARACTERISTICS:
Period of activation [minutes/hours], Energy saved and/or used [Wh], Peak Load increase/reduction [W].

04 ENERGY DEMAND
KEY ELEMENTS:
Space heating; Space cooling; Domestic hot water; Ventilation; Electricity use for plug loads (in some cases appliances include also electric vehicle)
Building energy systems

[Diagram showing various components of a building energy system, including district heating, power grid, battery, fuel switch, buffer storage, and user, with arrows indicating energy flow between these components.]

- Generation
- Net power load
- Net power demand
- Heat-cold generation
- Heat-cold delivery
- Behavior
Type of flexibility in buildings

- Shiftable load
- Deferrable load
# Building energy systems studied in Annex 67

<table>
<thead>
<tr>
<th>Building Typology</th>
<th>Energy Conversion</th>
<th>Load Shifting Strategy</th>
<th>Control Strategy</th>
<th>Analysis based on</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residential SFH</td>
<td>Heat pump</td>
<td>Building mass</td>
<td>Rule based</td>
<td>Simulation</td>
</tr>
<tr>
<td>Residential MFH</td>
<td>District heating</td>
<td>Water storage</td>
<td>Model predictive</td>
<td>Data driven</td>
</tr>
<tr>
<td>Non-residential</td>
<td>Other</td>
<td>Batteries</td>
<td>Fuel switch</td>
<td>Monitoring</td>
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<tr>
<td>Residential SFH</td>
<td>17</td>
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<tr>
<td>Residential MFH</td>
<td>4</td>
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<tr>
<td>Non-residential</td>
<td>11</td>
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<tr>
<td>District / cluster</td>
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<td>Heat pump</td>
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<tr>
<td>District heating</td>
<td>5</td>
</tr>
<tr>
<td>Other</td>
<td>13</td>
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# Building energy systems studied in Annex 67

<table>
<thead>
<tr>
<th>Load shifting strategy</th>
<th>Building thermal mass</th>
<th>18</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Water storage</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>Batteries</td>
<td>10</td>
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<tr>
<td></td>
<td>Fuel switch</td>
<td>2</td>
</tr>
<tr>
<td>Control strategy</td>
<td>Rule based</td>
<td>19</td>
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<tr>
<td></td>
<td>Model predictive</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>Data driven</td>
<td>1</td>
</tr>
<tr>
<td>Analysis based on</td>
<td>Simulation</td>
<td>25</td>
</tr>
<tr>
<td></td>
<td>Monitoring</td>
<td>9</td>
</tr>
</tbody>
</table>
A smart building is an energy-flexible building, which is equipped with penalty-aware controllers responding to external penalty or control signals.
Characterizing flexibility of penalty-aware buildings

- control signal,
- penalty signal,
- reward signal,
- disturbance signal

Flexibility Function
Characterizing flexibility of penalty-aware buildings

Flexibility Index: the reaction of a building or cluster of buildings to penalty signals, e.g., CO₂ intensity

![Graph showing demand change over time for three buildings: Building 1, Building 2, Building 3](image)

Flexibility Function for three different building types

![Graph showing penalty signals for wind, solar, and ramp problems over time](image)

Penalty signals representing wind, solar and ramp problems

<table>
<thead>
<tr>
<th>Building</th>
<th>Wind (%)</th>
<th>Solar (%)</th>
<th>Ramp (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Building 1</td>
<td>35.1</td>
<td>7.2</td>
<td>18.9</td>
</tr>
<tr>
<td>Building 2</td>
<td>10.3</td>
<td>24.0</td>
<td>37.5</td>
</tr>
<tr>
<td>Building 3</td>
<td>4.9</td>
<td>11.1</td>
<td>71.0</td>
</tr>
</tbody>
</table>

For building 3, 71% of the ramp based penalty cost can be saved due to the flexibility of the building.

Output from Annex 67

- **Principles of Energy Flexible Buildings** summarizes the main findings of Annex 67 and targets all interested in what Energy Flexibility in buildings is, how it can be controlled, and which services it may provide.

- **Characterization of Energy Flexibility in Buildings** presents the terminology around Energy Flexibility, the existing indicators used to evaluate the flexibility potential and how to characterize and label Energy Flexibility.

- **Stakeholder perspectives on Energy Flexible buildings** displays the viewpoint of different types of stakeholders towards Energy Flexible Buildings.

- **Control strategies and algorithms for obtaining Energy Flexibility in buildings** reviews and evaluates control strategies for Energy Flexibility in buildings.

- **Experimental facilities and methods for assessing Energy Flexibility in buildings** describes several test facilities including experiments related to Energy Flexibility and draws recommendations for future testing activities.

- **Examples of Energy Flexibility in buildings** summarizes different examples on how to obtain Energy Flexible Buildings.

- **Project Summary Report** brief summary of the outcome of Annex 67.
IEA EBC Annex 82: Energy Flexible Buildings towards resilient low carbon energy systems

Further work identified by Annex 67, to ensure that energy flexibility from buildings will actually be an asset for the future energy networks:

1) scaling from single buildings to clusters of buildings (aggregation);

2) energy flexibility and resilience in multi-carrier energy systems (electricity, district heating/cooling and gas);

3) acceptance/engagement of the stakeholders; and

4) business models.
### Subtasks and Objectives

<table>
<thead>
<tr>
<th>Stk A: Scaling from single buildings to clusters of buildings</th>
<th>Stk B: Flexibility and resilience in multi-carrier energy systems</th>
<th>Stk C: Stakeholders acceptance and engagement</th>
<th>Stk D: Development of appropriate implementation (business) models</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methods for aggregation of energy flexibility from building clusters</td>
<td>Investigation energy flexibility services from buildings connected to multi-carrier energy systems</td>
<td>Mapping barriers/motivations/acceptance of stakeholders associated with energy flexibility measures</td>
<td>Investigation of business models for energy flexible services to the energy networks</td>
</tr>
<tr>
<td>Demonstration of energy flexibility through simulations/experiments/field studies</td>
<td>How extreme events affect the resilience of energy systems, what role energy flexible buildings play</td>
<td>How to include the view of the stakeholders in development of technical solutions</td>
<td>Recommendations to policy makers and government entities</td>
</tr>
</tbody>
</table>
IEA EBC Annex 82: Energy Flexible Buildings towards resilient low carbon energy systems

Workplan

Stk A: Scaling from single buildings to clusters of buildings

A.1 Methodology for characterisation of energy flexibility from clusters of buildings
A.2 Forecasting energy flexibility from clusters of buildings Activity
A.3 Controlling energy flexibility from clusters of buildings

Stk B: Flexibility and resilience in multi-carrier energy systems

B.1 Characterization methodology for flexibility and resilience in multi-carrier systems
B.2 Control of existing multi-carrier energy systems to improve flexibility
B.3 Design of future multicarrier energy systems for increased flexibility and resilience

Stk C: Stakeholders acceptance and engagement

C.1 Analysis of stakeholder’s behaviour, acceptance and engagement
C.2 Development of strategies to engage stakeholders
C.3 Recommendations to policy makers

Stk D: Development of appropriate implementation (business) models

D.1 Business cases from the perspective of the consumer and the solution provider side
D.2 Value Preposition and benefits of Flexible Systems
D.3 Least Cost Approach for Flexible Systems
D.4 Recommendations to policy makers

30 November 2021
22 participating counties: Australia, Austria, Brazil, Belgium, Canada, China, Denmark, Czechia, Finland, France, Germany, Ireland, Italy, The Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, UK, USA
Thank you!

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