ANNEX 74

EBC
Energy in Building and Communities Programme

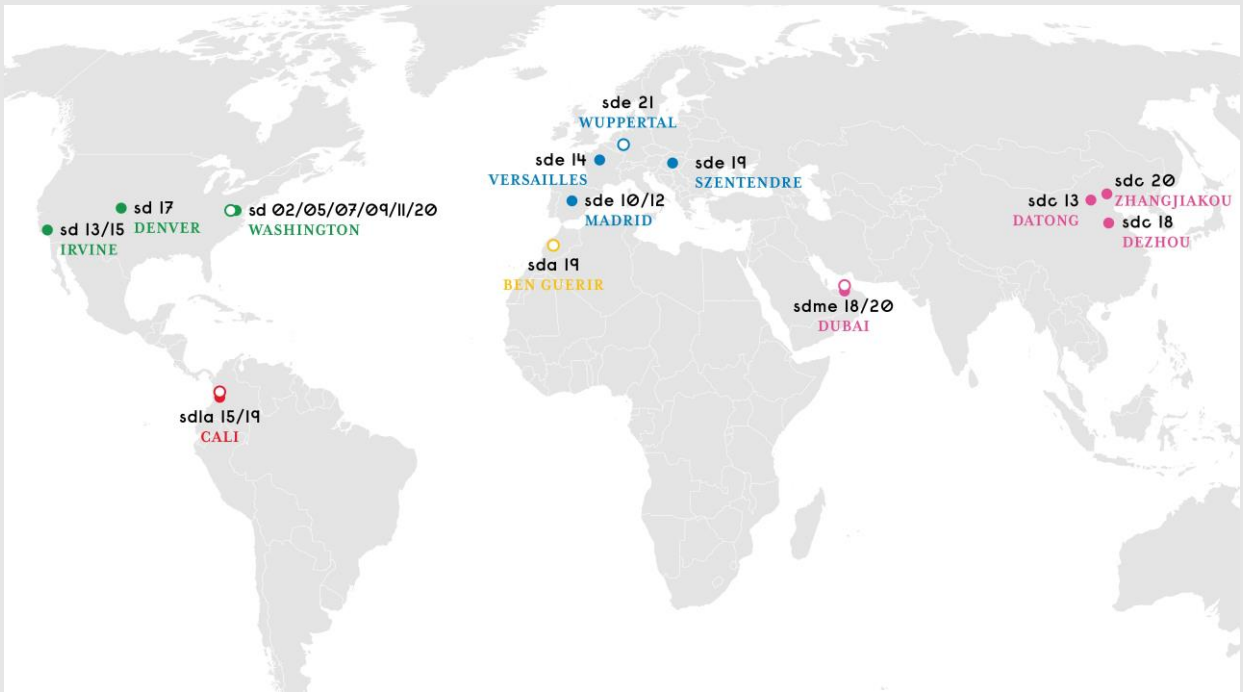
International Energy Agency

Competition and Living Lab Platform (Annex 74)

Project Summary Report

Energy in Buildings and Communities Technology Collaboration Programme

November 2022



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Project Summary Report

Energy in Buildings and Communities Programme

November 2022

Editors

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Published by University Wuppertal, Faculty Architecture and Civil Engineering, Department Building Physics and Technical Services, Pauluskirchstr. 7, D - 42285 Wuppertal, Germany, 2021.

Participating countries in EBC:
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Summary

The Annex 74 „Competition and Living Lab Platform“ ran between January 2018 und June 2021 within the Energy in Buildings and Communities Technology Collaboration Programme (EBC) of the International Energy Agency[1]. The Annex starting point was the success story of the Solar Decathlon. The Solar Decathlon is an international student competition based on an initiative of the U.S. Department of Energy started in 2000. In this competition, universities from all over the world design, build and operate solar powered houses. It is the only student competition worldwide addressing the realization and performance assessment of buildings and not the design only. During the competition’s final phase, each interdisciplinary team assembles its house in a common Solar Village. The final phase includes a public exhibition, monitoring and 10 contests, the reason why the competition is named a "Decathlon".

Annex 74 was intended as a platform mapping and linking the building competition and living lab experiences worldwide and working towards further improving existing as well as developing new formats. Annex 74 should stimulate the technological knowledge, the scientific level and the architectural quality within future competitions and living labs based on the development of a systematic knowledge platform as well as on the link to expertise from previous and current IEA activities[2]. A total of eleven experts from nine countries participated in this small Annex with varying degrees of intensity.

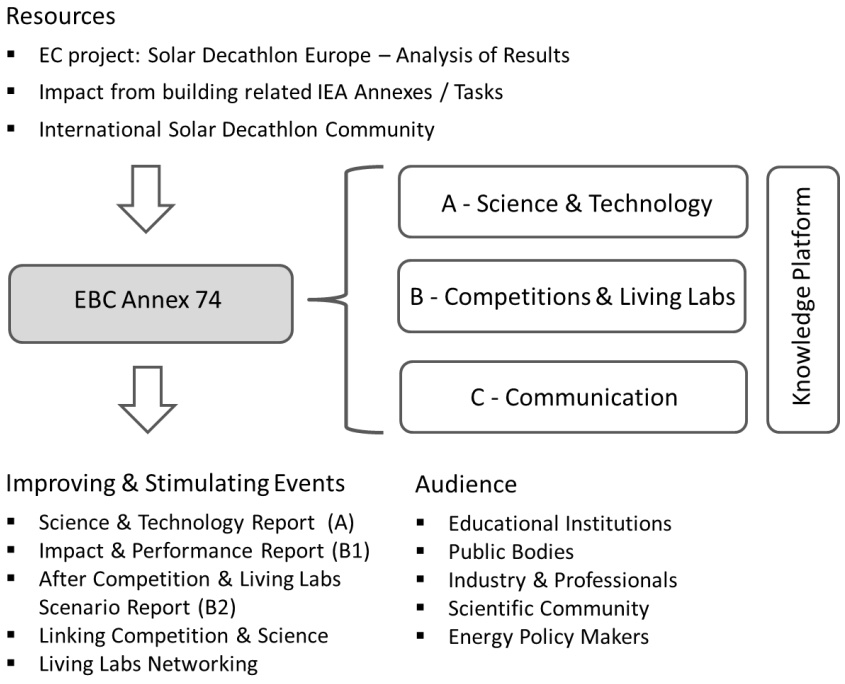

Figure 1: Structure of the Annex and its general workflow. The report presented here is the outcome of the subtask A on Science and Technology

The work was structured in three tasks and a knowledge platform as a cross cutting issue:

Subtask A - Science & Technology: The subtask circles around the analysis of past competitions with regard to topics and technologies as well practical and scientific relevant results.

Subtask B - Competitions & Living Labs: This subtask analysis the different competitions and related event activities with regard to the success factors.

[1] https://annex74.iea-ebc.org/

[2] www.building-competition.org

Subtask C – Communication: The activity focuses on a web based information portal on past and future competitions.

Four documents were produced as a result of subtask A. Its main report includes a review of the European editions of the Solar Decathlon between 2010 and 2019. 65 solar-powered competition buildings with numerous innovations were analysed regarding the building design and construction as well as the energy engineering. The presentation provides the background knowledge for the future development of the competition format. At the same time, it already shows which impulses have been introduced for the next edition in 2022 in Germany as a result of the analyses carried out. The main report supplemented by three so-called focus reports:

- The focus report "Monitoring Data Visualization" contains for an overview of the graphical processing of the measurement data collected within past Solar Decathlon competitions.
- The report under the title "Topical Papers" contains a set of thematic in-depth papers that link typical topics of the Solar Decathlon with research and practice issues, pointing out connections to IEA research networks.
- The documentation "Project Facts Template" presents a newly developed data collection structure for the quantitative data of buildings in a competition.

The main report of subtask B “Solar Decathlon Competitions - Impacts and Performance” focuses around a systematic worldwide survey to measure the impact and performance of the various competition editions. Dozens of semi-structured interviews were conducted to complement the raw data of the surveys and to enrich the analysis. More than 70 interviews were conducted with students, professors and researchers, professionals, companies, and the various organizing teams and key people involved in the development of the competition since its origins. These interviews helped to understand the relationship between objectives - strategies - achieved performance, key drivers, lessons learned, and suggestions for future improvement. The intense experience accumulated in all editions is rich and varied. A systematic analyses has been carried out throughout this project to allow us to make a critical balance, to recognize the great potential of the competition, and to draw many lessons learned not only regarding the competition itself, but also on how to give continuity by taking advantage of previous experience, maximizing the outreach performance.

The purpose of the focus report “After Competition & Living Lab Scenarios” is to make knowledge available about the after-competition use of Solar Decathlon projects as living labs to those who are intending to participate in a living lab competition and those who are on the way to set up their own living lab. The report allows a compact overview for future organizers and teams about successfully implemented living labs..

Main parts of the Annex have been linked to an EC project running parallel to document the results and lessons learned especially from the European Solar Decathlon edition and communicate these within the Smart City Information System. The project was finished by the end of 2020 under the service contract ENER/C2/2016-502/SER/SI2.763962. The final report is made available by the project coordinator: https://www.egen.green/news/solar-decathlon-europe/

Project duration:	2018 – 2021
Operating Agents:	Karsten Voss, Germany, Sergio Vega, Spain (vice)
Participating countries:	Belgium, China (since 2019), Germany, The Netherlands, Spain, Switzerland, United States
Observers:	Hungary, United Arab Emirates, Colombia and Morocco (since 2019)
Further information:	www.annex74.iea-ebc.org www.building-competition.org

1. Project Outcomes

1.1 Subtask A – Science and Technology

The outcome of this subtask is documented with the deliverables. The 150 pages main report includes two extensive chapters with a review of the European editions of the Solar Decathlon between 2010 and 2019. 65 solar-powered competition buildings with numerous innovations were created in the four competitions. While chapter 2 focuses on building design and construction, chapter 3 focuses on energy engineering. Both chapters contain extensive cross-sectional analyses, tables and comparative graphs. Based on chapter 3, a comprehensive journal paper was published in the Energy and Buildings journal titled “Solar Decathlon Europe – A Review on the Energy Engineering of Experimental Solar Powered Houses”. The presentation provides the background knowledge for the future development of the competition format. At the same time, it already shows which impulses have been introduced for the next edition in 2022 in Germany as a result of the analyses carried out. These include, among other things, the introduction of significantly improved documentation of the competition entries in terms of their characteristics and performance indicators. It has become apparent that the previous type of documentation was only suitable for cross-sectional analyses to a very limited extent. The focus report "Project Facts Template" documents the newly developed procedure in detail. Together with the focus report "Monitoring Data Visualization", chapter 4 presents the different approaches for monitoring in the previous international competitions. This covers a selection of competitions worldwide. This selection helps to better prepare and systematize future tasks. Chapter 5 contains the introduction and a compact presentation of the contents of the focus report "Topical Papers". This focus report comprises a total of 100 pages of information for the deepening of 11 individual topics.

A major concern within subtask A was the discussion of the question of the scientific benefit of building energy competitions such as the Solar Decathlon. Scientific work was and is partly done by the participating teams during or after the competition within their own university environment. The competition as a whole only allows this to a limited extent due to its boundary conditions. The rules practiced so far only allow for robust cross-sectional studies in exceptional cases. With analyses and discussions within the Annex, sub-areas could be identified in which a linkage with scientific work seems possible. For this purpose, proposals were developed in chapter 6, which have already been incorporated into the rules for the Solar Decathlon 2022. This concerns, for example, the PV system analysis (performance ratio), the building-power grid interaction (energy flexibility) and the comparison of simulation and reality of the thermal building behaviour (co-heating test). Chapter 7 presents recent activities on how research work can be continued at a central location on the respective competition sites within so-called "Living Labs" in the follow-up to competitions.

In total subtask A within Annex 74 gave the floor for a critical engineering focused review of past activities within the Solar Decathlon. A special focus lay on the European editions. Keeping competitions like this attractive in future must ensure to profit from lessons learned and from knowledge transfer. Together with the integration of new developments in architecture, construction and energy engineering attractive profiling of future events can take place. The experiments with the European event in 2022 will show how the additional scientific task can be matched successfully with a competition profile.

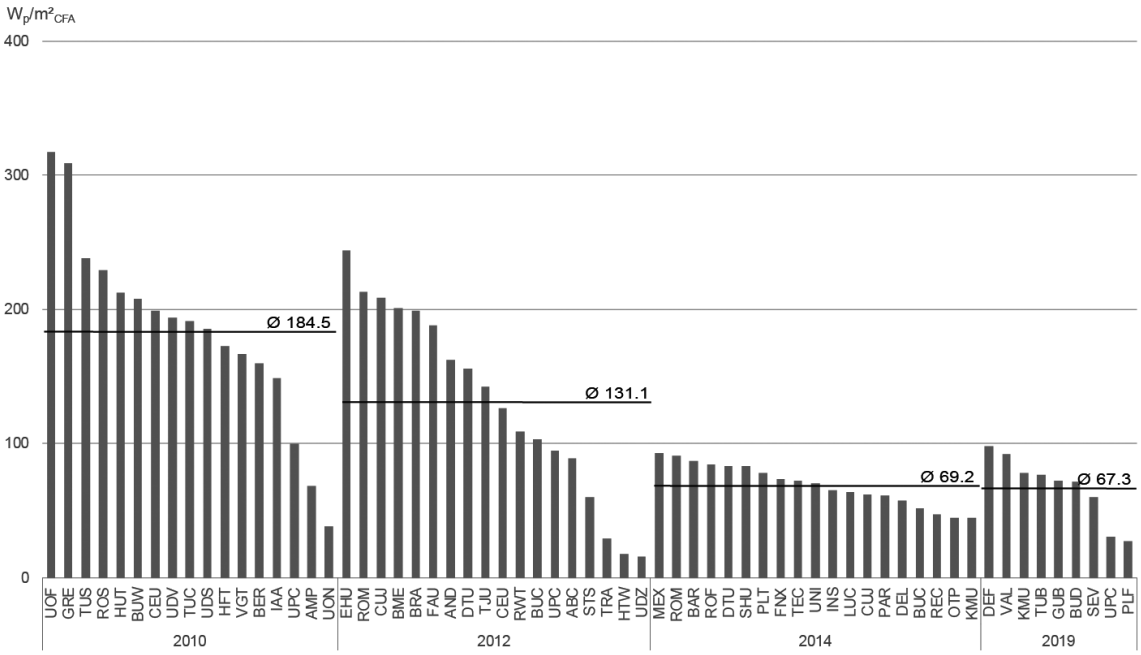

Figure 2: Example for the past competition documentation & analysis - Correlation between the installed peak power of the PV systems and the conditioned net floor area of the houses in the European competitions.

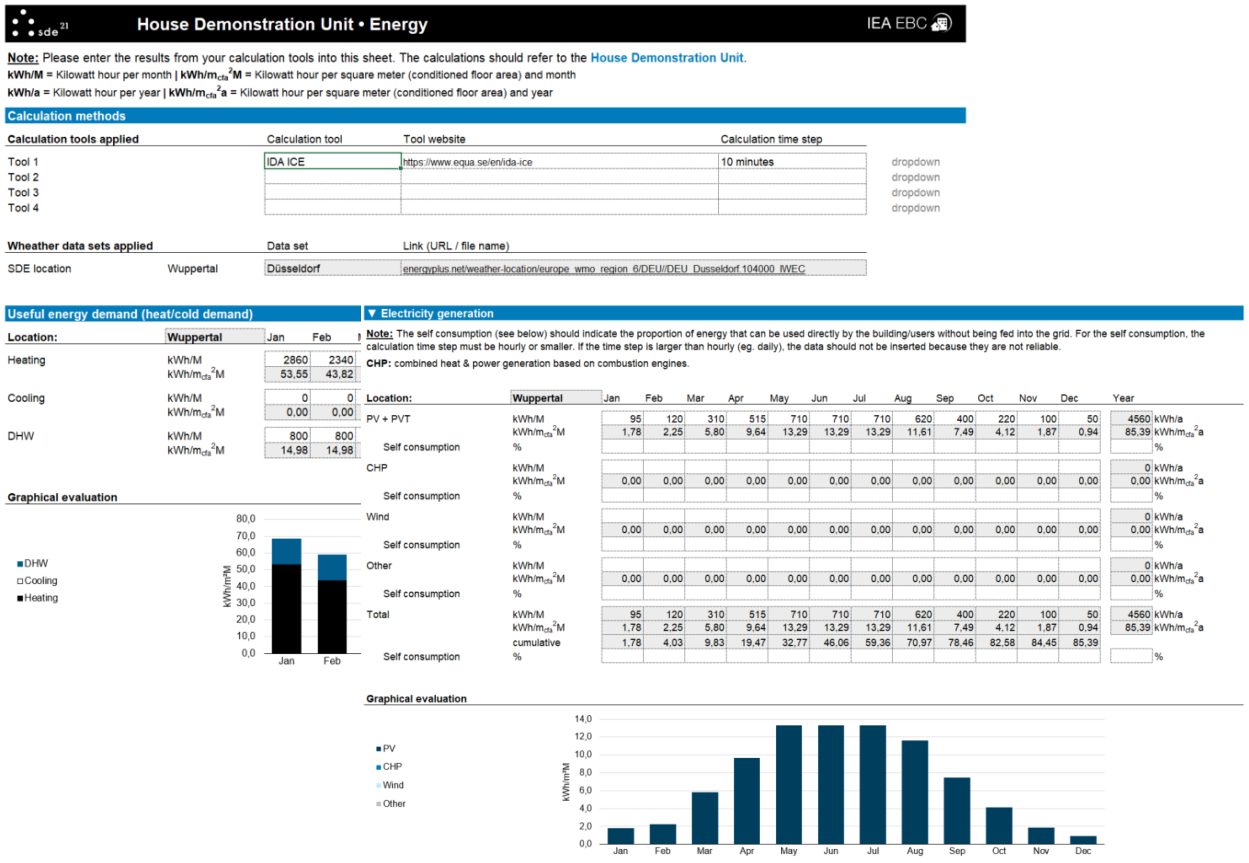

Figure 3: Example page of the new documentation system for competition buildings, based on a comprhensive MS-Excel table structure. Sorce: Universiy Wuppertal

1.2 Subtask B – Competition & Living Labs

To be added by Sergio

1.3 Subtask C – Communication

Beside the Annex web page the most significant output of the communication activities is the online "Building Energy Competition & Living Lab Knowledge Platform" (https://building-competition.org/). This knowledge platform is a major activity to secure the information, experiences and data from building energy competitions such as the Solar Decathlon and living labs worldwide. It adds to the Solar Decathlon US information system (http://solardecathlon.gov) and the individual websites of the events or living labs.

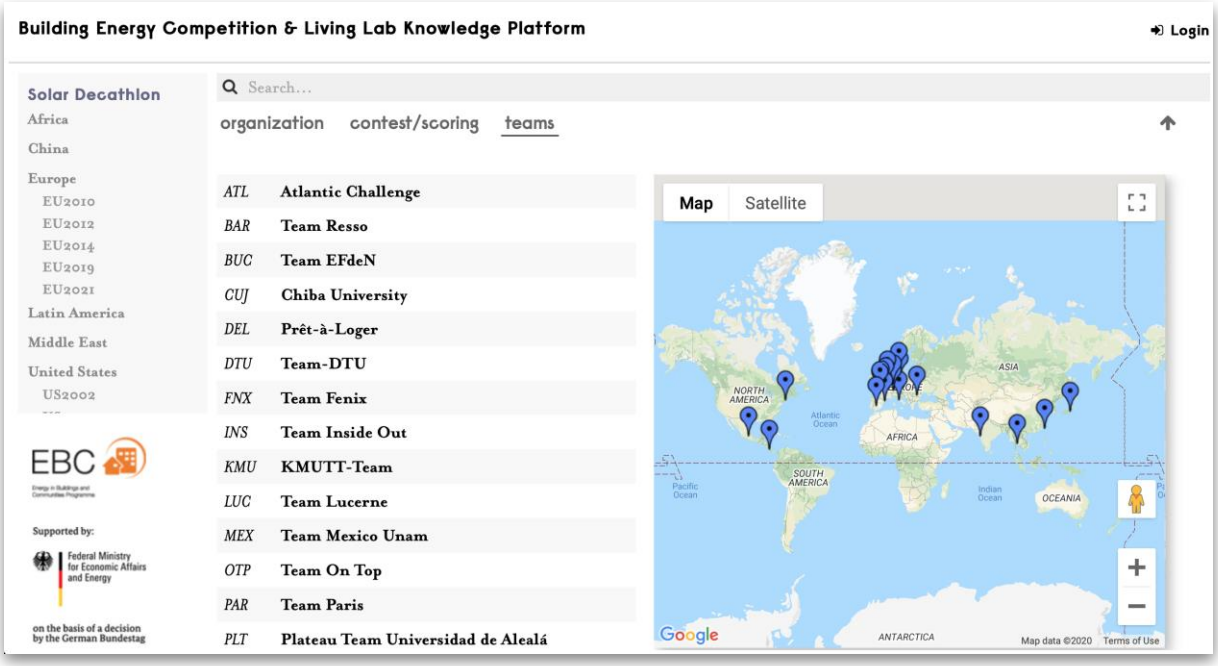

Figure 4: The web portal "Building Energy Competition & Living Lab Knowledge Platform", continuously online and improved since 2019: https://building-competition.org/

Figure 5: The Solar Decathlon Europe in June 2022 was first edition of the competition profiting from the findings of Annex 74 output. The picture shows the demonstration units from the teams of Karlsruhe (DE) and Eindhoven (NL), © SDE 21/22

2. Outlook

This Annex collects valuable information on past competitions, with a focus on the Solar Decathlon and namely its European editions. With the online building competition knowledge platform, the information is made publicly available for a wide audience. It specially addresses future organizers of building energy competitions for students.

The SDE 21/22 in Germany was the first Solar Decathlon being able to benefit from the Annex 74 output, namely subtask A. Its main profiling was done by adding a design challenge to the demonstration unit task. The design challenge defined as a typical urban densification task creates a real context for all of the demonstration units. In SDE 21/22, context is a main issue to better position the competition in the architectural debate, and it allows the consideration of adjacent urban layer aspects such as mobility. The common urban context, including the focus on further construction and use of the existing building stock, reflects main key European requests.

All-electric homes as demonstrated in all SD Competitions to date are just one of the options to reduce climate emissions of buildings. It is a precondition that the power used is mainly based on renewables. Urban options for the transformation of the building stock to climate neutrality might be different and based on a mix of energy systems and sources such as green district heat/cold, biogas, green hydrogen etc. Future organisers will need to align a competition to local and regional conditions.

One issue that urbanisation brings is the affordability of living space. The focus should not lie just on technical prowess or design aesthetics, but should also demonstrate affordable solutions for the general public to fully cover the social dimension of an urban transformation to climate neutrality.

Working with performance simulation tools for energy, indoor climate, lighting, life cycle assessment, circularity, etc. in the early design phase, stimulates the buildings' design proposals, and avoids extra costs for adjustments in the later phases of planning and construction. Workshops, working documents, and common tools may be considered to raise the overall level in this field of work. The focus report with its set of topical papers also may work as thematic inspiration and link to IEA research activities. Building information modelling (BIM) also serves as the state-of-the-art format for intensive documentation and linking of information over the entire life-cycle of a building. Future competitions are a very suitable testing ground for BIM application and the teaching of BIM best-practices. Student competitions are a very valuable instrument for education of future engineers and architects and should consider an up-to-date level in the use of simulation and design tools as well as information exchange platforms.

To date, the analyses of the SD energy systems have been mainly limited to the houses' energy consumption and the energy yield of the solar power systems. The considerable time and expense that goes into developing and constructing the buildings raises the question of an advanced monitoring concept. The post processing of the SDE 21/22 results will show, how successful research and competition are compatible. The established living labs with buildings remaining on former competition sites give the floor open the dialogue for future research and more the continued benefits from the large efforts teams' who have been dedicated their energies spent onto the design and construction of innovative demonstration houses.

To be added by Sergio

3. Meetings

Within the working phase, there were nine working meetings, five of which were held as online events due to the pandemic.

- Solar Decathlon Europe (open event)
  June 10-26, 2022 - Mirker Bahnhof, Wuppertal, Germany
- IEA EBC Webinar: Innovation and Energy Policy for Buildings - International Collaboration to Accelerate Change
  June 7, 2022, 11:00am-2:00pm UTC / GMT - TBD, Germany
- 7th Annex meeting
  May 11, 2021 - TBD, Germany
- 6th Annex Meeting
  October 5-6, 2020 - University Wuppertal, Wuppertal, Germany
- 5th Annex meeting
  March 23-24, 2020 - UPM Madrid, Madrid, Spain
- 4th Annex Meeting
  July 29-30, 2019 - EMI, Szentendre, Hungary
- 3rd Annex Meeting
  April 1-2, 2019 - Gent University, Gent, Belgium
- 2nd Annex Meeting
  November 16-17, 2018 - TBD, Dubai, United Arab Emirates
- 1st Open Thematic Workshop "Competition & Living Lab Platform" - Solar Decathlon Building Simulation and Monitoring – Status and Perspectives
  November 16, 2018, 9:00am-5:00pm - Conference Tent of the SDME Solar Hai, Dubai, United Arab Emirates
- 1st Annex Meeting
  May 22-23, 2018 - TBD, Szentendre, Hungary

4. Deliverables

Subtask A

Title	Editors	Link	Year
Competition and Living Lab Platform (Annex 74) Science & Technology (Subtask A) - *Main Report*	Voss, Vega	https://annex74.iea-ebc.org/publications https://doi.org/10.25926/jvxm-9k35	2021
Competition and Living Lab Platform (Annex 74) Science & Technology (Subtask A) - *Monitoring Data Visualization*	Voss, Vega	https://annex74.iea-ebc.org/publications https://doi.org/10.25926/8ab3-kd54	2021
Competition and Living Lab Platform (Annex 74) Science & Technology (Subtask A) - *Topical Papers*	Voss, Vega	https://annex74.iea-ebc.org/publications https://doi.org/10.25926/3f99-xy74	2021
Competition and Living Lab Platform (Annex 74) Science & Technology (Subtask A) - *Project Facts Template*	Voss, Vega	https://annex74.iea-ebc.org/publications https://doi.org/10.25926/zaqc-9b57	2021

Subtask B

Title	Editors	Link	Year
Competition and Living Lab Platform (Annex 74) Competitions & Living Labs (Subtask B) *Solar Decathlon Competitions – Impacts and Performance.*	Voss, Vega	https://annex74.iea-ebc.org/publications	2022
Competition and Living Lab Platform (Annex 74) Competitions & Living Labs (Subtask B) *After Competition & Living Lab Scenarios*	Voss, Vega	https://annex74.iea-ebc.org/publications	2022

Subtask C

Title	Editors	Link	Year
Annex web Portal	Voss, Vega	https://annex74.iea-ebc.org/	2018
Knowledge Platform	Hendel, Voss	https://building-competition.org/	2019

5. Publications

Voss, K., Russel, P., Hendel, S.: “Solar Decathlon Europe and the Energy Endeavour Initiative,” proceedings of the Eurosun, pp. 1–9, 2016

Hendel, S.: The Solar Decathlon Knowledge Platform – Concept and Initial Application, proceedings of the Eurosun, 2018

Voss, K., Hendel, S., Stark, M.: Solar Decathlon Europe – A Review on the Energy Engineering of Experimental Solar Powered Houses, Energy and Buildings, volume 251, November 2021, https://doi.org/10.1016/j.enbuild.2021.111336

Arranz, B, Vega, S. Amaral, R.: Participatory Research for the Evaluation of Satisfaction with Solar Decathlon Competitions: A Survey Analysis, mpi, November 2021, https://www.researchgate.net/publication/356508201_Participatory_Research_for_the_Evaluation_of_Satisfaction_with_Solar_Decathlon_Competitions_A_Survey_Analysis

6. List of Participants

Country	Organisation	Name	Function
Germany	University of Wuppertal	Prof. Dr.-Ing. Karsten Voss Dr.-Ing. Katharina Simon M.Sc. Susanne Hendel	Operating Agent
Spain	Technical University Madrid Universitat Politècnica de Catalunya	Prof. Dr. Sergio Vega Prof. Torsten Masseck	Operating Agent, Vice Lead Subtask C
The Netherlands	Energy Endeavour Foundation	Louise Holloway	
Belgium	Ghent University	Prof. Nathan Van Den Bossche	Lead Subtask C (until 2020)
Switzerland	Haute école d’ingénierie et d’architecture de Fribourg	Prof. Dr. Jean-Philippe Bacher	
USA	U.S. Department of Energy	Linda Silverman John Mayernik	
China	China Overseas Development Association	Yuan Tian	

7. EBC & the IEA

The International Energy Agency

The International Energy Agency (IEA) was established in 1974 within the framework of the Organisation for Economic Co-operation and Development (OECD) to implement an international energy programme. A basic aim of the IEA is to foster international co-operation among the 30 IEA participating countries and to increase energy security through energy research, development and demonstration in the fields of technologies for energy efficiency and renewable energy sources.

The IEA Energy in Buildings and Communities Programme

The IEA co-ordinates international energy research and development (R&D) activities through a comprehensive portfolio of Technology Collaboration Programmes. The mission of the IEA Energy in Buildings and Communities (IEA EBC) Technology Collaboration Programme is to develop and facilitate the integration of technologies and processes for energy efficiency and conservation into healthy, low emission, and sustainable buildings and communities, through innovation and research. (Until March 2013, the IEA EBC Programme was known as the IEA Energy Conservation in Buildings and Community Systems Programme, ECBCS.)

The R&D strategies of the IEA EBC Programme are derived from research drivers, national programmes within IEA countries, and the IEA Future Buildings Forum Think Tank Workshops. These R&D strategies aim to exploit technological opportunities to save energy in the buildings sector, and to remove technical obstacles to market penetration of new energy efficient technologies. The R&D strategies apply to residential, commercial, office buildings and community systems, and will impact the building industry in five areas of focus for R&D activities:

- Integrated planning and building design
- Building energy systems
- Building envelope
- Community scale methods
- Real building energy use

The Executive Committee

Overall control of the IEA EBC Programme is maintained by an Executive Committee, which not only monitors existing projects, but also identifies new strategic areas in which collaborative efforts may be beneficial. As the Programme is based on a contract with the IEA, the projects are legally established as Annexes to the IEA EBC Implementing Agreement. At the present time, the following projects have been initiated by the IEA EBC Executive Committee, with completed projects identified by (*) and joint projects with the IEA Solar Heating and Cooling Technology Collaboration Programme by (☼):

Annex 1:	Load Energy Determination of Buildings (*)
Annex 2:	Ekistics and Advanced Community Energy Systems (*)
Annex 3:	Energy Conservation in Residential Buildings (*)
Annex 4:	Glasgow Commercial Building Monitoring (*)
Annex 5:	Air Infiltration and Ventilation Centre
Annex 6:	Energy Systems and Design of Communities (*)
Annex 7:	Local Government Energy Planning (*)
Annex 8:	Inhabitants Behaviour with Regard to Ventilation (*)
Annex 9:	Minimum Ventilation Rates (*)
Annex 10:	Building HVAC System Simulation (*)
Annex 11:	Energy Auditing (*)
Annex 12:	Windows and Fenestration (*)

Annex 13:	Energy Management in Hospitals (*)
Annex 14:	Condensation and Energy (*)
Annex 15:	Energy Efficiency in Schools (*)
Annex 16:	BEMS 1- User Interfaces and System Integration (*)
Annex 17:	BEMS 2- Evaluation and Emulation Techniques (*)
Annex 18:	Demand Controlled Ventilation Systems (*)
Annex 19:	Low Slope Roof Systems (*)
Annex 20:	Air Flow Patterns within Buildings (*)
Annex 21:	Thermal Modelling (*)
Annex 22:	Energy Efficient Communities (*)
Annex 23:	Multi Zone Air Flow Modelling (COMIS) (*)
Annex 24:	Heat, Air and Moisture Transfer in Envelopes (*)
Annex 25:	Real time HVAC Simulation (*)
Annex 26:	Energy Efficient Ventilation of Large Enclosures (*)
Annex 27:	Evaluation and Demonstration of Domestic Ventilation Systems (*)
Annex 28:	Low Energy Cooling Systems (*)
Annex 29:	Daylight in Buildings (*)
Annex 30:	Bringing Simulation to Application (*)
Annex 31:	Energy-Related Environmental Impact of Buildings (*)
Annex 32:	Integral Building Envelope Performance Assessment (*)
Annex 33:	Advanced Local Energy Planning (*)
Annex 34:	Computer-Aided Evaluation of HVAC System Performance (*)
Annex 35:	Design of Energy Efficient Hybrid Ventilation (HYBVENT) (*)
Annex 36:	Retrofitting of Educational Buildings (*)
Annex 37:	Low Exergy Systems for Heating and Cooling of Buildings (LowEx) (*)
Annex 38:	Solar Sustainable Housing (*)
Annex 39:	High Performance Insulation Systems (*)
Annex 40:	Building Commissioning to Improve Energy Performance (*)
Annex 41:	Whole Building Heat, Air and Moisture Response (MOIST-ENG) (*)
Annex 42:	The Simulation of Building-Integrated Fuel Cell and Other Cogeneration Systems (FC+COGEN-SIM) (*)
Annex 43:	Testing and Validation of Building Energy Simulation Tools (*)
Annex 44:	Integrating Environmentally Responsive Elements in Buildings (*)
Annex 45:	Energy Efficient Electric Lighting for Buildings (*)
Annex 46:	Holistic Assessment Tool-kit on Energy Efficient Retrofit Measures for Government Buildings (EnERGo) (*)
Annex 47:	Cost-Effective Commissioning for Existing and Low Energy Buildings (*)
Annex 48:	Heat Pumping and Reversible Air Conditioning (*)
Annex 49:	Low Exergy Systems for High Performance Buildings and Communities (*)
Annex 50:	Prefabricated Systems for Low Energy Renovation of Residential Buildings (*)
Annex 51:	Energy Efficient Communities (*)
Annex 52:	Towards Net Zero Energy Solar Buildings (*)
Annex 53:	Total Energy Use in Buildings: Analysis and Evaluation Methods (*)
Annex 54:	Integration of Micro-Generation and Related Energy Technologies in Buildings (*)
Annex 55:	Reliability of Energy Efficient Building Retrofitting - Probability Assessment of Performance and Cost (RAP-RETRO) (*)
Annex 56:	Cost Effective Energy and CO2 Emissions Optimization in Building Renovation (*)
Annex 57:	Evaluation of Embodied Energy and CO2 Equivalent Emissions for Building Construction (*)
Annex 58:	Reliable Building Energy Performance Characterisation Based on Full Scale Dynamic Measurements (*)
Annex 59:	High Temperature Cooling and Low Temperature Heating in Buildings (*)
Annex 60:	New Generation Computational Tools for Building and Community Energy Systems (*)
Annex 61:	Business and Technical Concepts for Deep Energy Retrofit of Public Buildings (*)
Annex 62:	Ventilative Cooling (*)
Annex 63:	Implementation of Energy Strategies in Communities (*)
Annex 64:	LowEx Communities - Optimised Performance of Energy Supply Systems with Exergy Principles (*)
Annex 65:	Long-Term Performance of Super-Insulating Materials in Building Components and Systems

Annex 66:	Definition and Simulation of Occupant Behavior in Buildings (*)
Annex 67:	Energy Flexible Buildings (*)
Annex 68:	Indoor Air Quality Design and Control in Low Energy Residential Buildings (*)
Annex 69:	Strategy and Practice of Adaptive Thermal Comfort in Low Energy Buildings
Annex 70:	Energy Epidemiology: Analysis of Real Building Energy Use at Scale
Annex 71:	Building Energy Performance Assessment Based on In-situ Measurements
Annex 72:	Assessing Life Cycle Related Environmental Impacts Caused by Buildings
Annex 73:	Towards Net Zero Energy Resilient Public Communities
Annex 74:	Competition and Living Lab Platform
Annex 75:	Cost-effective Building Renovation at District Level Combining Energy Efficiency and Renewables
Annex 76:	Deep Renovation of Historic Buildings towards Lowest Possible Energy Demand and CO2 Emissions
Annex 77:	Integrated Solutions for Daylight and Electric Lighting
Annex 78:	Supplementing Ventilation with Gas-phase Air Cleaning, Implementation and Energy Implications
Annex 79:	Occupant Behaviour-Centric Building Design and Operation
Annex 80:	Resilient Cooling of Buildings
Annex 81:	Data-Driven Smart Buildings
Annex 82:	Energy Flexible Buildings towards Resilient Low Carbon Energy Systems
Annex 83:	Positive Energy Districts
Annex 84:	Demand Management of Buildings in Thermal Networks
Annex 85:	Indirect Evaporative Cooling
Annex 86:	Energy Efficient Indoor Air Quality Management in Residential Buildings

Working Group - Energy Efficiency in Educational Buildings (*)
Working Group - Indicators of Energy Efficiency in Cold Climate Buildings (*)
Working Group - Annex 36 Extension: The Energy Concept Adviser (*)
Working Group - HVAC Energy Calculation Methodologies for Non-residential Buildings (*)
Working Group - Cities and Communities (*)
Working Group - Building Energy Codes