ANNEX 72

EBC
Energy in Building and Communities Programme

International Energy Agency

Assessing Life Cycle Related Environmental Impacts Caused by Buildings

Project Summary Report

Technology Collaboration Programme
by iea

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Project Summary Report

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Picture on front page: Construction site in Montréal, Quebec, Canada; Rolf Frischknecht, © 2019

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Project Summary for Policy and Decision Makers

Buildings and infrastructures serve basic needs and are the basis for social and economic development. The production, construction, maintenance and operation of construction works are associated with considerable energy and material flows as well as undesirable effects on the global and local environment.
One focus is on the methodological basis for quantifying and assessing greenhouse gas (GHG) emissions in the life cycle of buildings. These have an impact on global warming and, with a share of about 40 % of global GHG emissions (IEA & UN Environment 2018)[1], contribute to the fast deployment of the remaining GHG emission budget which corresponds to the 1.5°C target. There is an urgent need for action.
In order to be able to quantify, evaluate and specifically reduce these impacts, suitable assessment methods and design tools are needed. Such methods and tools enable decision-makers not only to recognise but also to influence the impacts on the environment as early as the design stage as well as throughout the project. The further development of such assessment methods and design aids for buildings was one of the tasks of the IEA EBC Annex 72. The basic principles and recommendations for action developed by more than 60 scientists from 25 countries in Europe, the Americas and Asia are now available on the IEA EBC Annex 72 website[2].

Context and policy implications

1. The embodied GHG emissions of buildings, and of construction product manufacture in particular (about 10% of global GHG emissions), need to get into focus and be reduced drastically.
2. In more and more countries, life cycle assessment (LCA) methods and data, design tools and environmental benchmarks are becoming ready for application in building related legislation.
3. There is a need to introduce legally binding requirements to limit life cycle related GHG emissions of new constructions and of refurbishments by 2025 latest. A roadmap to net zero life cycle related GHG emissions by 2035 is also much needed to guide activities in the right direction.
4. The GHG emissions associated with the construction and use of buildings are underestimated in sectoral analyses concentrating on operation. To obtain the full overview of GHG emissions caused by buildings and other environmental impacts, a cross-sectoral analysis of the entire field of action "construction, maintenance, use and deconstruction of buildings" is necessary.

Life cycle related modelling and assessment

5. When assessing environmental performance of buildings, the complete building in its entire life cycle must be considered, including all upstream and downstream processes. For the design and assessment, suitable building and life cycle models with a high degree of transparency are needed to make uncertainties clear and able to reduce.
6. The main indicator for quantifying potential impacts on the climate are the GHG emissions, measured in kg CO_2 equivalents. GHG emissions should be determined using LCA and preferably divided into a fossil and a biogenic share. The resulting carbon footprint of a building should be supplemented by

[1] IEA and UN Environment (2018) 2018 Global Status Report: towards a zero-emission, efficient and resilient buildings and construction sector. Global Alliance for Buildings and Construction, Paris.
[2] https://annex72.iea-ebc.org/publications, access on 15 May 2023.

information on the biogenic carbon content as well as other indicators to record the environmental performance.

7. Some life cycle modelling is methodologically demanding, and clear rules are necessary here. Examples are the handling of biomass, plants for the generation of renewable energy and permissible approaches to offset for GHG emissions in the balance. Annex 72 provides recommendations for these modelling rules.

Life cycle related environmental data and databases

8. Countries lacking a LCA database for the construction sector on a national level are encouraged to get started as soon as possible.
9. The LCA database should cover construction materials (both generic and company/product specific), technical systems (such as HVAC and photovoltaic systems), energy and water supply, transport as well as waste management and waste water treatment services. It should address life cycle related GHG emissions as well as other main environmental challenges such as fine particles emissions, radioactive waste, resource depletion and biodiversity losses.
10. Extensive documentation, independent review and full data transparency are considered main features, which help ensure appropriate data quality.

Life cycle related environmental benchmarks

11. Suitable assessment standards in the form of benchmarks and target values are required for the assessment of the environmental performance of buildings, and in particular the GHG emissions in the life cycle of buildings. These benchmarks and target values form an inseparable unit with the respective method and data basis.
12. Currently, benchmarks based on technical and/or economic feasibility are increasingly complemented by target values derived from planetary boundaries, taking into account the GHG emissions budget still available to meet defined global warming limits.
13. The benchmarks and target values relating to the complete life cycle can be sub-divided, for example into embodied and operational parts, for orientation and communication purposes.
14. With “(net) zero GHG emission”, the first universal benchmark exists that is suitable for all types of buildings and uses in all climate zones.

Design tools and building information modelling (BIM)

15. The environmental impacts of the building should be followed and reduced throughout the design process. A set of guidelines was developed to provide outlook and recommendations related to the integration of the LCA into design process and design tools to support the stakeholders involved in the building design process and transfer to them science based findings.
16. The set of guidelines systematically answers questions such as when and for what purpose will the LCA be conducted, how to prepare the information about the building to be integrated in the tools or workflow, which work-flows and tools should be used, which visualization and communication of the results in LCA should be used, for whom and for what is the LCA needed for each step of the design process.

17. To improve the understanding and to enable a practical use of the contents of this document to all the stakeholders involved, a summary of these guidelines and recommendations to reduce environmental impacts along the design process have been included in a special practice-oriented document: the **Design Decision Table**.

Extended Project Technical Summary

Background

In response to concerns about climate change, energy security and social equity, countries around the world are either planning to substantially reduce energy demand and greenhouse gas (GHG) emissions or in the case of emerging economies to develop in less energy intensive ways. The construction as well as heating and cooling of buildings is one major cause of primary energy demand (PED), GHG emissions and environmental impacts of developed and emerging economies. Buildings have a long service life of between some decades to more than 100 years. Thus, investment decisions on buildings today determine by and large the environmental impacts during several future decades. Furthermore, the upfront GHG emissions caused by the construction of buildings immediately reduce the remaining emission budget to keep global temperature rise below 1.5°C. Furthermore, such decisions involve a trade-off between additional investments today and potential savings during use and end of life (both in terms of economic costs and PED, natural resources like primary mineral materials, GHG emissions and further environmental impacts). Solutions are needed that minimise and/or balance both the operational and the embodied part of life cycle related environmental impacts of buildings.

Today, natural resources such as clean air, clean water, biodiversity or primary resources are free and their use is hardly charged. The current price system does not (systematically) account for such external environmental effects (market failure) which leads to an inefficient (over)use of environmental resources. That is why, environmental life cycle assessments of human activities are necessary to highlight the inefficient use of natural resources and to take measures and action to increase the resource efficiency of buildings and construction. Environmental life cycle assessments provide a basis for integrating external effects in the form of external costs into economic considerations.

Objectives

In support of the principal aim of reducing the PED, GHG emissions and other environmental impacts along the life cycle of buildings (construction, use/operation and end of life), the work of Annex 72 was organised towards achieving the following objectives:

1. establish a common methodology guideline to assess the life cycle based PED, GHG emissions and environmental impacts caused by buildings
2. establish methods for the development of specific environmental benchmarks for different types of buildings to help designing buildings with a minimum life cycle based PED, GHG emissions and environmental impacts
3. derive regionally differentiated guidelines and tools (building design and planning tools such as BIM and others) for architects and planners
4. establish a number of case studies, focused to allow for answering some of the research issues, including optimisation strategies and how related design processes and decisions happen in practice, and for deriving empirical benchmarks

5. develop national/regional databases with regionally differentiated LCA data tailored to the construction sector, covering material production, building technology manufacture, energy and water supply, transport services as well as waste management and waste water treatment services; share experiences with the setup and update of such databases

The scope of the Annex is intended to support design processes and decision making related to new buildings and retrofit/redevelopment/repurposing of existing buildings. It covers dwellings (single and multiple family housings), office buildings, school buildings, hospitals and others. The life cycle covers the stages production (production of construction materials including resource extraction), construction process (erection of the building), use (operational energy and water use, maintenance, repair and replanned placement of building components), as well as end of life (de-construction, waste processing and disposal). The indicators addressed comprise PED (non-renewable and renewable), GHG emissions as well as environmental impacts such as fine particles emissions, radioactive waste, resource depletion and biodiversity losses caused by buildings.

Findings

The main findings are grouped according to methodology, data and databases, environmental benchmarks and design process and tools and can be summarised as follows:

Methodology

When assessing environmental performance of buildings, the complete building in its entire life cycle must be considered, including all upstream and downstream processes. For the planning and assessment, suitable building and life cycle models with a high degree of transparency are needed to make uncertainties visible and able to reduce.

The main indicator for quantifying potential effects on the climate are the GHG emissions, measured in kg CO_2 equivalents. GHG emissions should be determined using LCA and preferably divided into a fossil and a biogenic share. The resulting carbon footprint of a building should be supplemented by information on the biogenic carbon content as well as other indicators to record the environmental performance.

Some life cycle modelling is methodologically demanding, and clear rules are necessary here. Examples are the handling of biomass (modelling carbon uptake and release), plants for the generation of renewable energy and permissible approaches to offset for GHG emissions in the balance. A72 provides recommendations for these modelling rules.

Data and databases

Countries lacking a LCA database for the construction sector are encouraged to get started as soon as possible.

The LCA database should cover construction materials (both generic and company specific), building technologies (such as ventilation and photovoltaic systems), energy and water supply, transport as well as waste management and waste water treatment services. It should address life cycle related GHG emissions as well as other main environmental challenges such as fine particles, radioactive waste, resource depletion and biodiversity losses.

Extensive documentation, independent review and full data transparency are considered main features, which help ensure appropriate data quality.

Environmental benchmarks

Suitable assessment standards in the form of benchmarks and target values are required for the assessment of the environmental performance of buildings, and in particular the GHG emissions in the life cycle of

buildings. These benchmarks and target values form an inseparable unit with the respective method and data basis.
Currently, benchmarks based on technical and/or economic feasibility are increasingly complemented by target values derived from planetary boundaries, taking into account the GHG emissions budget still available to meet defined global warming limits.
The benchmarks and target values relating to the complete life cycle can be sub-divided, for example into embodied and operational parts, for orientation and communication purposes.
With "(net) zero GHG emission", the first universal benchmark exists that is suitable for all types of buildings and uses in all climate zones.

Design process and tools

The environmental impacts of the building should be followed and reduced throughout the design process. A set of guidelines is developed to provide outlook and recommendations related to the integration of the LCA into design process and design tools to support the stakeholders involved in the building design process and transfer to them science-based findings.
The set of guidelines is systematically answering questions such as when and for what purpose will the LCA be conducted, how to prepare the information about the building to be integrated in the tools or work-flow, which work-flows and tools should be used, which visualization and communication of the results in LCA should be used, for whom and for what is the LCA needed for each step of the design process.
To improve the understanding and enable a practical use of the contents of this document to all the stakeholders involved, a summary of these guidelines and recommendations to reduce environmental impacts along the design process have been included in a special practice-oriented document: the **Design Decision Table**.

Recommendations

The IEA EBC Annex 72 experts agreed on the following recommendations[3], grouped according to various stakeholders related to buildings and construction.

Government and administration

1. Introduce legally binding maximum target values for GHG-emissions of new constructions and of refurbishments by 2025 latest with a roadmap to net zero GHG emissions in the life cycle by 2035.
2. Consider introducing a legally binding minimum benchmark for biogenic carbon stored in buildings (biogenic carbon content) taking local availability, building tradition and suitability into consideration. Define the benchmark in a way that it helps to maintain, preferably increase the amount of biogenic carbon stored in the national building stock and in the built environment in general.
3. Facilitate the development, introduction and operation of a national and regional LCA database for the construction sector, covering construction materials, building technology, energy supply, transport and waste management services.
4. Specify the contents of international and national standards to ensure consistency among the life cycle assessments of construction materials, building technologies and buildings in your country.
5. Facilitate the development of bill of materials, material passports, digital logbooks, digital twins and digital permits to document the material and environmental characteristics and to enable the future use of material resources embodied in buildings.
6. Consider launching research programs on sustainable construction and on construction materials and building technology (e.g. HVAC) with low environmental, resource and GHG footprints.

[3] The recommendations were previously published in the Monte Verità Declaration on a built environment within planetary boundaries.

7. Launch a research program on negative emission technologies, either in a joint effort involving several countries or co-ordinated with other countries' research activities.
8. Enhance the education in environmental sustainability and feasible solutions to address environmental challenges in the general population.

Investors, banks and financial institutions

9. Consider sufficiency ("build less") and to refurbish existing buildings and urban areas as a relevant alternative to new construction following deconstruction.
10. Reconsider the construction and real estate sectors including upgrade and adaptation strategies as an economically attractive sector for financial investments.
11. Demand the quantification of GHG emissions, environmental impacts and resource consumption as a basis for risk assessment and economic valuation which is a precondition to invest in building projects.
12. Invest in building projects with low GHG emissions, environmental impacts and resource consumption and promote and support measures to reduce GHG emissions, environmental impacts and resource consumption of building projects.
13. Demand the integration of an assessment of GHG emissions, environmental impacts and resource consumption in the building design stages as relevant decision criteria and demand their improvements and reduction, respectively.
14. Keep yourself informed about existing and new targets, regulations and target values for buildings with regard to GHG emissions, environmental impacts and resource consumption, including the EU taxonomy for sustainable activities.

Research organisations (universities, research institutes)

15. Establish a knowledge/information centre on sustainable construction.
16. Foster research on the assessment and reduction of life cycle based environmental impacts of buildings and of construction materials manufacture, on budget based environmental benchmarks for buildings and on negative emission technologies by establishing chairs on sustainable construction, sustainable manufacturing and climate mitigation.
17. Offer mandatory/obligatory courses on environmental LCA and its application in the construction sector and its suppliers within the curricula of designers and architects and of civil and process engineers, business administration and facility management. The courses should also address the awareness and the environmental concern of employees in the building and construction sector.
18. Train engineers and architect to design with low carbon building materials and to design buildings with low GHG emissions, environmental impacts and resource consumption.
19. Offer courses on negative emission technologies in process engineering and forest management.
20. Embed courses on environmental sustainability in all curricula of the university.

Designers, Architects and Engineers

21. Discuss the overall design targets and actively address the sufficiency question: Challenge the clients brief in view of size and level of comfort of the building project and support the client in target setting.
22. Identify options to reduce the environmental impacts of the building project by changing the design, the static and/or materialisation of the building.
23. Consider the refurbishment of an existing building as a relevant alternative of demolition following new construction.
24. Assess the different design options with environmental LCA and discuss the results with the client.
25. Identify and realise solutions to increase the adaptability and the longevity of the building.
26. Apply circularity principles using locally sourced materials, recycled materials and materials with low environmental impacts, and design building elements for easy disassembly and easy reuse. Use LCA to ensure lower life cycle based environmental impacts of such solutions.

27. Strive for lowering operational energy demand and cover the remaining demand with energy from renewable sources.
28. Introduce GHG emissions, environmental impacts and resource consumption of construction materials, building technology and energy supply during use as an important decision criterion when selecting (construction material and building technology) suppliers and energy systems.
29. Use advanced and reliable tools to quantify the GHG emissions, environmental impacts and resource consumption of the building project from early design stage to hand over and ensure continuity along the design process.
30. In the early design stage, consider to apply safety factors on the environmental impacts of building elements to cope with the uncertainties and to avoid unwelcome surprises later-on.
31. Structure the LCA model of the building and its life cycle according to well accepted schemes.
32. Consider to systematically document the characteristics and materialisation of your buildings and to use digital options such as bill of materials, material passports, digital logbooks/building passports, and digital permits to document the material and environmental characteristics and facilitate the future use of material resources of buildings.
33. Periodically attend further education courses on sustainable construction.

Operators of Environmental Product Declaration (EPD) programs, sector specific LCA database, certification schemes and labels

34. Follow international standards on environmental LCA to the extent possible.
35. Close the room for manoeuvre offered by international and national standards to ensure consistency among the life cycle assessments of construction materials and building technologies in your country.
36. Ensure to include product, use and end of life stages and consider to also include transport to construction site and construction.
37. Assign and require one single life cycle inventory database to be used to establish the LCA of all products and systems embedded in a construction work and of buildings. Allow to use life cycle inventory data from other databases in exceptional cases.
38. Be cautious in dealing with environmental credits attributed to the building, in particular if borrowed from future generations and other third parties. Check for and eliminate any possible double counting of these environmental credits.
39. Apply the core list of environmental and resource indicators requested by international standards and complement those by indicators that are used or required in your national context to quantify the life cycle based environmental impacts and resource consumption of buildings.
40. Consider method, data, tools and environmental benchmarks and targets as interdependent elements needed for a consistent, reliable and relevant assessment and evaluation of environmental impacts and resource consumption of buildings.
41. Consider keeping benchmarks and target values for environmental impacts of the building and for potential benefits beyond the building's perimeter separate.
42. Introduce a binding and demanding target value for life cycle based GHG emissions of buildings (carbon footprint) including a road map to net zero by 2035. Introduce a second, other than GHG-related footprint target value for life cycle based environmental impacts and resource consumption of buildings to avoid burden shifting.
43. Prefer absolute target values to relative ones (defined against a virtual reference building)
44. Consider introducing a minimum benchmark for biogenic carbon stored in buildings (biogenic carbon content) taking local availability, building tradition and suitability into consideration. It may help to maintain or even increase the amount of biogenic carbon stored in the built environment.

Construction product and building technology manufacturers

45. Establish a roadmap to net zero GHG emissions of construction material and building technology manufacture and their end of life treatment to be reached by 2035.

46. Establish and publish environmental life cycle assessments of your products and your organisation. Use Environmental Product Declarations (EPD) or other suitable and established ways to document and supply the information and data.
47. Optimise your manufacturing process incl. your supply chains by introducing take back systems, increase the share of recycled raw materials, increase the material and energy efficiency, and generally foster circularity, and further reduce the environmental, resource and GHG footprints of your organisation and your products.
48. Purchase electricity products based on renewable energy, for which production and quality (guarantee of origin, GO or renewable energy certificate, RECS) of the electricity stem from the same power plants or ask the electricity provider for such an electricity product.
49. Invest in negative emission technologies rather than purchasing CO_2 emission certificates to neutralise remaining fossil CO_2 emissions.
50. Engage with suppliers and ask them to reduce their GHG emissions to net zero or change to suppliers with lower GHG emissions and more ambitious reduction targets. Give preference to suppliers, which additionally cause low environmental impacts and low resource consumption.
51. Adhere to international standards, use an acknowledged and transparent LCA database when performing the LCA and report according to a “true and fair view”.

Construction companies

52. Reduce GHG emissions, environmental impacts and resource consumption caused by construction processes for construction and deconstruction.
53. Choose or recommend suppliers of construction materials with low GHG emissions, low environmental impacts and low resource consumption.
54. Rely on supply transport logistics with low GHG emissions, low environmental Impacts and low resource consumption.
55. Reduce the amount of waste, and sort and recycle material wasted during construction, replacement, refurbishment and deconstruction.

Real estate agents

56. Encourage the owners of buildings for sale to inform about the buildings’ life cycle based GHG emissions, environmental impacts and resource consumption.
57. Encourage potential buyers and tenants to ask for life cycle based GHG emissions, environmental impacts and resource consumption caused by the buildings under examination.
58. Report on life cycle based GHG emissions, environmental impacts and resource consumption caused by the buildings you are offering.

Users and tenants

59. Question your demand for a rental object in terms of size, level of comfort and equipment.
60. Use life cycle based GHG emissions, environmental impacts and resource consumption as key criteria when selecting your rental object.
61. Use energy and water economically and use the rental object and its equipment mindfully by e.g. following cleaning and maintenance instructions.
62. Choose energy carriers and products with low GHG emissions, low environmental impacts and low resource consumption.

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Official project deliverables

B Report on Context-specific methods guidelines on the environmental LCA of buildings, including biogenic carbon assessment
C Report on guidelines for planners on how to optimise the life cycle performance of buildings using planning tools such as BIM
D Report on national LCA databases used in the construction sector
E Report on building case studies
F Report on environmental benchmarks of buildings, including zero emission buildings
G Report on how to establish an LCA database targeted to the construction sector
I Optimisation case studies
J Understanding the impact of individual, industry & political decisions on transitions towards environmental sustainability

Key publications

- Buildings LCA and digitalization: Designers' toolbox based on a survey
  Di Bari R., Horn R., Bruhn S., Alaux N., Ruschi Mendes Saade M., Soust-Verdaguer B., Potrč Obrecht T., Hollberg A., Birgisdottír H., Passer A. and Frischknecht R. (2022) Buildings LCA and digitalization: Designers' toolbox based on a survey. In: IOP Conference Series: Earth and Environmental Science, 1078(1), pp. 012092, 10.1088/1755-1315/1078/1/012092, retrieved from: https://dx.doi.org/10.1088/1755-1315/1078/1/012092.
- Attitude Towards LCA in Hungary and Czechia – Results of a Survey among Building Design Professionals
  Szalay, Z., Lupisek A. (2022) Attitude Towards LCA in Hungary and Czechia – Results of a Survey among Building Design Professionals. Central Europe towards Sustainable Building International Scientific Conference, Prague
- Demands, default options and definitions: How artefacts mediate sustainability in public housing projects in Sweden and Cyprus

Francart, N., Polycarpou, K., Malmqvist, T., & Moncaster, A. (2021). Demands, default options and definitions: How artefacts mediate sustainability in public housing projects in Sweden and Cyprus. Energy Research & Social Science, 92: 102765 https://doi.org/10.1016/j.erss.2022.102765

- Environmental and Economic Optimisation of Buildings in Portugal and Hungary
  Kiss, B., Silvestre, J. D., Andrade Santos, R., Szalay, Z. (2021) Environmental and Economic Optimisation of Buildings in Portugal and Hungary, SUSTAINABILITY 13 : 24 Paper: 13531, https://doi.org/10.3390/su132413531
- Environmental modelling of building stocks – An integrated review of life cycle-based assessment models to support EU policy making
  Röck M., Baldereschi E., Verellen E., Passer A., Sala S., Allacker K. (2021) Environmental modelling of building stocks – An integrated review of life cycle-based assessment models to support EU policy making. In: Renew Sustain Energy Rev, 2021;151, https://doi.org/10.1016/j.rser.2021.111550.
- Multicriteria-Oriented Optimization of Building Energy Performances: The Annex 72 IEA-EBC Experience
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EBC and 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 (TCPs). The mission of the IEA Energy in Buildings and Communities (IEA EBC) TCP is to support the acceleration of the transformation of the built environment towards more energy efficient and sustainable buildings and communities, by the development and dissemination of knowledge, technologies and processes and other solutions through international collaborative research and open innovation. (Until 2013, the IEA EBC Programme was known as the IEA Energy Conservation in Buildings and Community Systems Programme, ECBCS.)

The high priority research themes in the EBC Strategic Plan 2019-2024 are based on research drivers, national programmes within the EBC participating countries, the Future Buildings Forum (FBF) Think Tank Workshop held in Singapore in October 2017 and a Strategy Planning Workshop held at the EBC Executive Committee Meeting in November 2017. The research themes represent a collective input of the Executive Committee members and Operating Agents to exploit technological and other opportunities to save energy in the buildings sector, and to remove technical obstacles to market penetration of new energy technologies, systems and processes. Future EBC collaborative research and innovation work should have its focus on these themes.

At the Strategy Planning Workshop in 2017, some 40 research themes were developed. From those 40 themes, 10 themes of special high priority have been extracted, taking into consideration a score that was given to each theme at the workshop. The 10 high priority themes can be separated in two types namely 'Objectives' and 'Means'. These two groups are distinguished for a better understanding of the different themes.

Objectives - The strategic objectives of the EBC TCP are as follows:

- reinforcing the technical and economic basis for refurbishment of existing buildings, including financing, engagement of stakeholders and promotion of co-benefits;
- improvement of planning, construction and management processes to reduce the performance gap between design stage assessments and real-world operation;
- the creation of 'low tech', robust and affordable technologies;
- the further development of energy efficient cooling in hot and humid, or dry climates, avoiding mechanical cooling if possible;
- the creation of holistic solution sets for district level systems taking into account energy grids, overall performance, business models, engagement of stakeholders, and transport energy system implications.

– Means - The strategic objectives of the EBC TCP will be achieved by the means listed below:
– the creation of tools for supporting design and construction through to operations and maintenance, including building energy standards and life cycle assessment (LCA);
– benefitting from 'living labs' to provide experience of and overcome barriers to adoption of energy efficiency measures;
– improving smart control of building services technical installations, including occupant and operator interfaces;
– addressing data issues in buildings, including non-intrusive and secure data collection;
– the development of building information modelling (BIM) as a game changer, from design and construction through to operations and maintenance.

The themes in both groups can be the subject for new Annexes, but what distinguishes them is that the 'objectives' themes are final goals or solutions (or part of) for an energy efficient built environment, while the 'means' themes are instruments or enablers to reach such a goal. These themes are explained in more detail in the EBC Strategic Plan 2019-2024.

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 CO_2 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-Centric Building Design and Operation
Annex 80: Resilient Cooling
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

ANNEX 72

EBC

Energy in Building and Communities Programme