EBC

Energy in Buildings and Communities Programme

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IEA EBC Annex on Resilient Cooling for Residential and Small Commercial Buildings

Draft Annex Text

An inexorable increase in energy consumption for the cooling of buildings, and the increase in overheating of buildings is caused by urbanisation and densification, climate change, elevated comfort expectations together with economic growth and affordability of AC, and inappropriate architectural design practices.

Meeting this challenge requires further development and application of low energy and low carbon cooling solutions on a large scale. In order to expedite the transition of our new-build and existing building stock to nearly zero energy building (nZEB) and nearly zero carbon building (nZCB) status we have to take immediate action.

A wide range of appropriate solutions are already available, such as cool materials, solar shading, ventilative cooling, solar and adiabatic cooling, hydronic thermal mass activation, phase change materials (PCMs), ground source heat exchangers and other natural heat sinks, heat recovery systems, etc. However, many suffer from practical and economic obstacles that keep them from mass application (e.g. lack of guaranteed Key Performance Indicators (KPI), lack of design guidelines, lack of knowledge on system integration, lack of recognition of the value of particular technologies in standards and compliance tools, regional fragmentation of suppliers/supply-chain, etc). These solutions need concerted support from the international scientific communities, knowledge transfer and quantification of the economic potential.

Other technologies are emerging, but need further technological research to reach appropriate technology readiness levels. These include: advanced glazing technologies, micro-cooling and personal comfort control, electrostatic air cleaning, combinations of comfort ventilation and ventilative cooling, high performance vapour-compression and absorption chillers.

The IEA Resilient Cooling Annex will address this multi-disciplinary challenge and boost the development and implementation of robust low-energy and low-carbon cooling solutions on a large scale by transferring knowledge, coordinating international research endeavours and promoting a variety of systems and solutions.

Content

1. Background and Motivation

Urbanisation and densification, climate change, elevated comfort expectations together with inappropriate architectural design practice are exacerbating issues of building overheating and leading to ever-increasing cooling intensities in our built environment. This situation is sometimes complicated by issues of unintended consequences resulting from application of energy efficiency measures. For example, modern construction systems to deliver buildings with high air-tightness and high levels of insulation can increase the risk of buildings overheating. Consequently, the worldwide energy consumption used for cooling is rising significantly.

The current market for air conditioning technologies for residential and small offices is dominated by cheap but low efficiency A/C-devices. For example, instead of addressing solutions of enhanced overheating protection or passive cooling, split units are installed more and more frequently in existing buildings, which in most cases have been operated without active cooling before.

There is significant need for efficient and robust cooling technologies: peak shaving, load shifting, hybrid operation, coupling with PV-gains and other variable renewable energy sources.

In many residential interiors and small offices, hybrid cooling is a sufficient and favourable solution, which raises numerous research issues as to optimisation of system layout and system integration, user interfaces and control algorithms, and direct or indirect coupling with PV systems and other unsteady renewable energy sources.

Some resilient cooling solutions may already be regarded as mature, but still need support. Others are still emerging. Resilient cooling solutions often lack implementation in standardization, guidance on design, operational guarantees and poor consideration in compliance tools.

Furthermore, knowledge about overheating protection, robust passive and active cooling is traditionally regionally based. Since overheating problems in dense urban surroundings become an international phenomenon, there is a great need to improve the exchange of knowledge and experience between cultures and climate zones.

A number of other IEA Annexes have previously dealt with some aspects of low energy and low carbon cooling before, and are listed below. They focus on specific technologies. The new Annex Resilient Cooling will build upon the outcomes of these Annexes but will extend the research focus to impact assessment and integrated systems.

Annex 28	Low energy cooling systems
Annex 35	Hybrid Ventilation
Annex 37	Low Exergy Systems for Heating and Cooling
Annex 48	Heat Pumping and Reversible Air Conditioning
Annex 49	Low Exergy Systems for High Performance Buildings and Communities
Annex 59	High Temperature Cooling and Low Temperature Heating in Buildings
Annex 62	Ventilative Cooling
Annex 67	Energy Flexible Buildings (ongoing)
Annex 69	Strategy and Practice of Adaptive Thermal Comfort in Low Energy Buildings (ongoing)

2. Scope

2.1 Definition of Resilient Cooling

In the context of this Annex, Resilient Cooling is used to denote low energy and low carbon cooling solutions that strengthen the ability of individuals and our community as a whole to withstand, and also prevent, the thermal and other impacts of changes in global and local climates; particularly with respect to increasing ambient temperatures and the increasing frequency and severity of heat waves.

According to this definition, resilient cooling includes technologies and solutions that:

a) Reduce externally induced heat gains to indoor environments;
b) Offer personal comfort apart from space cooling;
c) Remove heat from indoor environments; and
d) Control the humidity of indoor environments.

The level of resilience will be evaluated using KPIs, which will be developed within STA, such as:

i. Affordability and life cycle cost effectiveness
ii. Energy efficiency
iii. Carbon intensity
iv. Capacity to be integrated with other energy systems (e.g. direct connection to on-site renewable energy sources).
v. Social aspects, vulnerability, and others

2.2 Focus

The focus of the Annex will be resilient cooling applications for residential and for small non-residential buildings, both existing and new constructions.

The Annex will encompass both active and passive cooling technologies and systems. All systems of concern will be evaluated regarding technical and social aspects, including energy efficiency, peak load performance and control range, impact on climate and ecosystems, affordability, resilience against blackouts and others.

The Annex will investigate resilient cooling applications against the variety of external parameters such as climate, building typologies, internal load and occupancy profiles, various levels of Building Management System (BMS) capability and automation, new buildings and retrofitting of existing buildings.

The scope of the Annex will be restricted to measures within the building itself. It will therefore exclude the field of urban microclimate engineering, but will take into account the variety of possible outdoor climatic conditions (temperature, humidity, air quality, noise, etc).

The Annex will furthermore exclude research on indoor comfort. However, indoor comfort levels will be treated as important boundary conditions. International comfort models will be used as the basis for performance assessment. In case of active cooling, the Fanger model of general comfort and local discomfort will be applied. As in case of passive cooling and free running mode buildings with adaptive options the adaptive comfort model will be applied. Knowledge exchange with Annex 69 (Strategy and Practice of Adaptive Thermal Comfort in Low Energy Buildings) will be actively facilitated.

2.3 Technologies and Solutions

The Annex faces and consciously addresses the complexity arising from the wide range of candidate 'Resilient Cooling' technologies and solutions. The research methods and subtasks are set-up specifically to deal with this complexity.

Based on discussions and inputs during the Annex definition and preparation phase, we anticipate that the Resilient Cooling Annex will include systematic research in the following fields. The development of a list of candidate technologies will be one of the key tasks in the early phase of the Annex. Its results will depend to an extent on the research priorities of the participating institutions.

Reducing external heat gains to indoor environments

- Advanced solar shading
- Cool materials
- Advanced glazing technologies
- Ventilated facades

Increasing personal comfort apart from space cooling

- Ventilative Cooling by comfort ventilation and elevated air movement
- Micro-cooling and personal comfort control

Removing heat from indoor environments (production, emission and combined)

- Ventilative Cooling by night flush ventilation
- Thermal mass utilization, including PCM and off-peak ice storage
- Adiabatic/evaporative cooling
- High performance compression refrigeration machines, including single split, multiple split, VRV units and chillers.
- High performance absorption chillers, including desiccant cooling
- Natural heat sinks, such as ground water, borehole heat exchangers, ground labyrinths, earth tubes, sky radiative cooling, roof ponds, green roofs, green façades and others.

Removing humidity from indoor environments

- High performance dehumidification including desiccant humidification.

3. Objectives

Our overall aim is to support a rapid transition to an environment where resilient low energy and low carbon cooling systems are the mainstream and preferred solutions for cooling and overheating issues in buildings. The Annex will focus on the following specific objectives.

- To quantify the potential benefits of resilient cooling for a wide range of building typologies, climate zones, functional specification and other boundary conditions. (Subtask A)
- To systematically assess benefits, limitations and performance indicators of resilient cooling. To identify barriers as well as conducive conditions to implementation (Subtask A)
- To provide guidelines for the integration of resilient cooling systems in energy performance calculation methods and regulations. This includes specification and verification of key performance indicators. (Subtask A)
  To extend the boundaries of existing low energy and low carbon cooling solutions by specific national R&D programmes, including methodological approaches such as numeric modelling and measurements on lab scale and prototype scale.
- To develop new solutions, combinations and applications of resilient cooling technologies. (Subtask B)
  To investigate the real performance of resilient cooling solutions through field studies.
  To analyse performance gaps and develop solutions to overcome them. (Subtask C)
  To analyse, exchange and encourage policy actions, including Minimum Energy Performance Standards, building codes, financial incentive and product labelling programmes, educational initiatives, as well as others. (Subtask D)
- To establish a link to international programmes such as KIGALI – Cooling Efficiency Programme, Mission Innovation Challenge #7 and correlated IEA Technology Collaborating Programmes. (Subtask D)

4. Subtasks

To address the specific Annex objectives research and development will be divided into four concurrent subtasks, wherein appropriate research methodologies will be adopted. The four Subtasks are as follows:

Subtask A: Impact Assessment
Subtask B: Solutions
Subtask C: Field studies
Subtask D: Policy Actions

4.1 Subtask A: Impact Assessment

This subtask will systematically assess the benefits, limitations and performance indicators of resilient cooling and will identify barriers as well as conductive conditions to implementation.

The subtask will provide guidelines for the integration of resilient cooling systems in existing and new energy performance calculation methods, and indoor comfort prediction methods.

Appropriate KPIs will be developed during the first phases of the Annex to evaluate resilience of cooling systems using a holistic approach that includes technical criteria (e.g. life cycle cost effectiveness, energy efficiency) social aspects (e.g. affordability, usability, availability) and ecological impacts (e.g. carbon intensity, climate warming potential).

Subtask A will be organized as a number of tightly focussed activities. A key aspect of this work will be the assembly and synthesis of current knowledge and evidence bases, and will involve intensive collaboration and exchange of information between the participating institutions and countries.

The subtask will be divided into the following research activities.

Activity A.1. This will include systematic assessment of potential benefits and other impacts, limitations and performance indicators of resilient cooling systems under a wide range of application scenarios and other boundary conditions. We will generate Resilient Cooling 'Technology Profiles' to clearly summarise and promote the operational characteristics and benefits of each technology/system. Recommendations for good implementation, commissioning and operation will also be developed. Barriers to application and further research opportunities will be identified, which will inform research activities of Subtask B.

Activity A.2. This activity will focus on the development of multi-criteria technology characterisation methodologies that will lead to consistent and measurable key performance indicators (KPIs) covering technical performance, range of situations where particular systems are applicable, ecological and social aspects, ecological impacts, and user-technology interaction analyses. This work will be tailored to residential buildings and smaller commercial buildings with relatively simple building management systems (BMS). The KPIs derived from this research activity will then also be implemented in the Technology Profiles of research activity A.1.

Activity A.3. This activity will include identification and further development of methods and tools for prediction of the capacity and performance of the full range of viable resilient cooling system types to reduce cooling needs and overheating risks. Again, the findings on suitable methods and tools from this research activity will be integrated into the multi-criteria Technology Profiles generated in research Activity A.1.

4.2 Subtask B: Solutions

This subtask will carry out specific research towards improvements and new developments of resilient cooling and overheating protection solutions. Il will extend the boundaries of existing low energy and low carbon cooling solutions and develop new solutions, combinations of technologies and applications.

Subtask B will be organized within specific national R&D projects, including methodological approaches such as numeric modelling and measurements on lab scale and prototype scale.

Given that many countries have specific climatic and other contextual interests Subtask B will cover research topics that are both internationally relevant and nationally specific. It will cover a broad variety of research topics and research methodologies, leveraging the specific research priorities and capabilities of the participants in the Annex.

The subtask will be divided into the following research activities.

Activity B.1. This activity will carry out specific research towards the extension of the range of situations where existing resilient cooling technologies and systems may be applied (e.g. with regard to building type, climate zones, occupancy characteristics, etc).

Activity B.2. will examine user interaction issues and system control issues, including the impact of user behaviour on system performance.

4.3 Subtask C: Field Studies

This subtask will showcase the opportunities and benefits of resilient cooling through analysis and evaluation of well-documented applications of different low energy and low carbon technologies. The field studies will synthesise examples of specific technologies and solutions rather than focussing on specific buildings. It will examine the performance gap of existing cooling applications, with special concern at socio-technological interaction as well as control strategies.

The outcomes of Subtask C will illustrate and support the Technology Profiles developed in Subtask A.

The subtask will be structured into the following research activities:

Activity C.1. Development of a clear framework for presentation of field studies.

Activity C.2. Performance analysis and evaluation of performance gaps of resilient cooling solutions, design methods and tools with special concern at socio-technological interaction as well as control strategies using criteria and methods defined in Activity C.1.

Activity C.3. Lessons learned and development of recommendations for design and operation of resilient cooling solutions as well as identification of barriers for application and functioning.

4.4 Subtask D: Policy Actions

Subtask D will deal with policy related endeavours promoting energy efficiency and resilience in cooling. This subtask seeks to advance product labelling programmes, AC minimum energy performance standards (MEPs) as well as the implementation of sustainable building codes in national, European and international standards.

This subtask will analyse product labelling programmes, building regulations, standards and compliance requirements, to identify international best practice examples as well as potential barriers. One of the objectives of subtask D is to set frameworks for Demand Side Management (DSM) including social programmes and others.

The goal is to develop recommendations for future regulatory policies to support the implementation and mainstreaming of resilient cooling systems on a national, European and international level.

In that sense Subtask D will strive to represent a toehold for international programmes such as KIGALI – Cooling Efficiency Programme, Mission Innovation Challenge #7 and correlated IEA Technology Collaborating Programmes.

Activity D.1. The analysis and international cross comparison of national and international product labelling programmes, AC minimum energy performance standards (MEPs), sustainability aspects building regulations and standards relating to resilient cooling are subject of this activity.

Activity D.2. Subtask D is expected to act as toehold for collaboration with international programmes such as KIGALI – Cooling Efficiency Programme, Mission Innovation Challenge #7 and correlated IEA Technology Collaborating Programmes.

5. Results and Deliverables

Through the systematic assessment of resilient cooling systems across the participating countries the annex will generate Resilient Cooling ‘Technology Profiles’ which will extract and promote operational characteristics and benefits of each technology/system resulting in international knowledge transfer.

The annex will yield instructions for the improvement of existing systems and their control strategies as well as for the implementation of new resilient cooling solutions for residential buildings and small commercial buildings.

The annex will generate guidelines for resilient cooling solutions allowing for the reduction of overheating risks as well as the cost-effective, energy-efficient and low-carbon coverage of cooling demands.

In-depth documentation of field studies will allow for broader and deeper understanding of key parameters and boundary conditions essential for the performance of resilient cooling solutions.

The annex will produce recommendations for the integration of resilient cooling in product labelling programmes, legislation, standards on national, European and international levels as well as in design briefs and in energy performance calculation and verification methods.

5.1 Official deliverables

The deliverables are listed below:

	Official deliverables	*Target group*	*Related subtask*
D1	Overview and state-of-the art of Resilient Cooling	Research community and associates. Policy makers	STA, STB, STC
D2	Midterm Report	Research community and associates + EBC Programme	STA, STB, STC, STD
D3	Resilient Cooling Source Book	Building component developers and manufacturers. Architects and design companies, engineering offices and consultants	STA, STB
D4	Resilient Cooling Field Studies	Architects, consulting engineers	STC
D5	Resilient Cooling Design and Operation Guidelines	Architects and design companies, engineering offices and consultants, real estate developers	STA, STB, STC
D6	Recommendations for legislation and standards (national, European, international)	Policy makers and experts involved in building energy performance standards and regulation	STD
D7	Project Summary Report	Research community and associates + EBC Programme	STA, STB, STC, STD

All reports will be published electronically.

5.2 Annex beneficiaries and outreach activities

The Annex beneficiaries will be:

- The building research community and associated specialists
- Architects and design companies, engineering offices and consultants in building physics, energy, HVAC and sustainable construction
- Building component and HVAC-system developers and manufacturers with an interest in high performance systems
- Real estate developers
- Policy makers and experts involved in building energy performance standards and regulation
- Educational institutions

	Outreach activities	***Target group***
01	Internet site and Annex newsletter	Research community and associates, EBC Programme
02	Social Media (Build-up, Linked-in, ...)	Building Sector, often specific target groups
03	Active internet seminars (webinars)	Building Sector, but most events will have specific target groups
04	Conferences and seminars	Building Sector, but most events will have specific target groups
05	Proceedings of international events	Building Sector, but most events will have specific target groups

6. Management of the Annex

The Annex is managed by the Operating Agent assisted by Subtask Leaders and Subtask Co-Leaders.

6.1 Operating agent

The Operating Agent is responsible for the overall performance and the time schedule of the Annex, for reporting, and for information dissemination activities. The Operating Agent is Peter Holzer, Institute of Building Research & Innovation, Austria.

6.2 Subtask leaders

The Subtask Leaders shall be participants who bring a high level of expertise to the subtask they manage and who undertake substantial research and development in the field of the subtask. They are elected by the Annex participants. Duties of the subtask leaders are:

- Coordinate the work performed under the subtask
- Assist the Operating Agent in preparing the detailed work plans and editing the final reports of the Annex
- Direct the technical workshops of the subtask and provide the Operating Agent with the workshop results
- Coordinate the technical reports resulting from the Subtask

Subtask leaders will be determined within the Annex preparation phase.

Subtask A will be led by Wendy Miller from Australia, Queensland University of Technology. Subtask co-leader will be Attia Shady from University of Liège.

Subtask B will be led and co-led by a consortium from Denmark, Chen Zhang from Aalborg University and Ongun Berk Kazanci from Technical University of Denmark.

For the lead of Subtask C there is interest from Guoqiang Zhang from Hunan University, China as well as from Dahai Qi from the University of Sherbrooke, Canada.

For Subtask D there are no candidates yet, cooperation with KCEP is intended.

7. Time schedule

The duration of the Annex in the working phase will be three years, planned to start in July 2019, the preparation phase had been started in July 2018. Two meetings will be held every year. The Operating Agent will organize semi-annual plenary Annex meetings at varying locations, each time hosted by one of the participating countries. In connection with the plenary Annex meetings, a semi-annual Subtask Leaders meeting will be organized. If needed, the participants and Subtask Leaders of each subtask may decide to organize separate meetings. In such cases, they must inform the Operating Agent of the meeting and its results. A fourth year will be used for reporting.

8. Funding and commitment

The work is divided into four subtasks. Each participant shall work in at least one of the subtasks. All participants are also required to deliver information and written material to the final reports. Each participant shall individually bear their own costs incurred in the Annex activities. Funding is expected to cover labour costs, consumables and investments (including eventual overhead costs) associated with the execution of activities defined in paragraph 3 and 4, and to cover traveling costs for participating in at least two expert meetings per year during the four-year working phase of the Annex. The working meetings shall be hosted by one of the participants. The costs of organizing the meeting shall be borne by the host participant.

All participating countries will have access to the workshops and results of all subtasks. Each participating country must designate at least one individual (an active researcher, scientist or engineer, here called the expert) for each subtask in which they decide to participate. It is expected that the same expert attends all meetings and acts as technical contact regarding the national subtask contribution. A minimum commitment of four person-months of labour for each year of the Annex term will be required for participation. For the subtask coordinators funding shall allow for four person-months and an extra two person-months per year for Annex activities. For the Operating Agent, funding shall allow for four person-months and an extra four person-months per year for Annex activities including the attendance at the two ExCo meetings per year.

Contributions from the following countries are expected:

Country	Institution	Name		STA	STB	STC	STD	Probability
Austria	Institute of Building Research & Innovation	Peter	Holzer	X	X	X	X	participating
	Institute of Building Research & Innovation	Philipp	Stern	X	X	X	X	participating
	e7 Energie Markt Analyse GmbH	Gerhard	Hofer	X		X		participating
Australia	University of Wollongong	Paul	Cooper	X	X	X		participating
	Queensland University of Technology	Wendy	Miller	X	X			participating
Belgium	BBRI	Peter	Wouters				X	interested
	K Leuven	Hilde	Breesch		X	X		participating
	University of Liège	Shady	Attia	X	X	X		participating
Canada	Concordia U, Montreal	Liangzhu (Leon)	Wang	X	X	X		participating
	Université de Sherbrooke	Dahai	Qi	X	X	X		participating
China	Hunan University	Guoqiang	Zhang	X	X	X	X	participating
	Hunan University	Yin	Wei	X	X	X	X	participating
	Hunan University	Zhengtao	Ai					participating
Denmark	Aalborg University	Per	Heiselberg	X	X			participating
	Aalborg University	Chen	Zhang	X	X			participating
	Technical University of Denmark	Bjarne	Olesen	X	X		X	participating
	Technical University of Denmark	Ongun	Kazanci	X	X		X	participating
France	Univérsité de la Rochelle	Emmanuel	Bozonnet	X	X	X		participating
	Univérsité de la Rochelle	Anais	Machard	X	X	X		participating
	ESIROI	Francois	Gardé					interested
Italy	Politecnico Torino	Giacomo	Chiesa	X	X		X	participating
	EURAC	Annamaria	Belleri		X	X		interested
Ireland	CIT, Cork	Paul	O'Sullivan					interested
Japan	LIXIL	Toshihiro	Nonaka					interested
	Tokyo City University	Hom Bahadur	Rijal					interested

Sweden	University of Gävle	Abolfazl	Hayati					interested
UK	Brunel University	Maria	Kolokotroni	X	X	X		participating
	The Bartlett School of Environment, Energy and Resources (BSEER)	Anna	Mavrogianni	X	X	X		interested
	Oxford Brookes University	Rajat	Gupta		X	X		interested
	School of Architecture and the Built Environment Lincoln	Behzad	Sodagar	X	X			participating

9. Intellectual Property

The Operating Agent will hold all intellectual property rights arising from the Annex on behalf of the participants in accordance with the EBC Implementing Agreement.