EBC

Energy in Buildings and
Communities Programme

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IEA EBC Annex 80 on Resilient Cooling for Residential and Small Non-Residential Buildings

Annex Text

The world is facing a rapid increase of air conditioning of buildings. This is driven by multiple factors, such as urbanisation and densification, climate change and elevated comfort expectations together with economic growth in hot and densely populated climate regions of the world. The trend towards cooling seems inexorable therefore it is mandatory to guide this development towards sustainable solutions.

Against this background, it is the motivation of Annex 80 to develop, assess and communicate solutions of resilient cooling and overheating protection. 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, thermal and other impacts of changes in global and local climates. It encompasses the assessment and Research & Development of both active and passive cooling technologies of the following four groups:

a) *Reduce externally induced heat gains to indoor environments;*
b) *Enhance personal comfort apart from cooling whole spaces;*
c) *Remove sensible heat from indoor environments;*
d) *Control latent heat (humidity) of indoor environments.*

The Annex 80's main objective 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.

Content

1. Background and Motivation

The world is facing a rapid increase of air conditioning of buildings, both in numbers of units and in energy demand. This is driven by multiple factors, such as urbanisation and densification, climate change and elevated comfort expectations together with economic growth in hot and densely populated climate regions of the world. The trend towards cooling seems to be inexorable, so it is mandatory to guide this development towards sustainable solutions.

Beyond this, number, strength and duration of heat waves worldwide are rising significantly driven by climate change. In a growing number of densely populated regions of the world, ambient temperatures during heat waves already pass the 50 degree Celsius mark. Availability and affordability of cooling becomes not only a question of comfort but of survival.

Against this background, it is the motivation of the newly proposed Annex to develop, assess and communicate solutions of resilient cooling and overheating protection.

The term of "Resilient Cooling" was deliberately chosen as name for the newly proposed Annex:
It centres the development of cooling solutions, which are not only efficient, affordable and climate-protective, but also robust and supportive in cases of extreme occurrences.

A wide range of cooling technologies and solutions is already available. Nevertheless, significant joint efforts are still needed to really guide the mainstream development of cooling into the direction of sustainability and resilience. The new Annex is motivated to contribute to this challenge and effectively support not only the development but the broad application of resilient cooling:

- Systematical assessment of existing cooling technologies, their potentials, limitations and qualities of resilience.
- Development and improvement of cooling technologies: robust, efficient, carbon-neutral, affordable.
- Assessment of real performance of cooling solutions, to identify performance gaps and develop solutions to systematically overcome them.
- Identification and communication of policy actions which may support the broad application of sustainable and resilient cooling applications.

A number of IEA Annexes have previously dealt with aspects of low energy and low carbon cooling before. They focus on specific technologies. The new Annex Resilient Cooling will build upon the outcomes of these Annexes and will integrate them into its wider approach.

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

The term of “Resilient Cooling” was deliberately chosen as name of the newly proposed Annex:
It centres the development of cooling solutions, which are not only efficient, affordable and climate-protective, but also robust and supportive in cases of extreme occurrences.

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, 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.

2.2 Focus

The Annex includes assessment and R&D in four groups of cooling technologies:

e) Reduce externally induced heat gains to indoor environments;
f) Enhance personal comfort apart from cooling whole spaces;
g) Remove sensible heat from indoor environments;
h) Control latent heat (humidity) of indoor environments.

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

The Annex encompasses both, active and passive cooling technologies and systems. All systems of concern are 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 investigates resilient cooling applications with regard to 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 is restricted to measures within the building itself. It therefore excludes the field of urban microclimate engineering, but takes into account the variety of possible outdoor climatic conditions (temperature, humidity, air quality, noise, etc.).

The Annex furthermore excludes research on indoor comfort. However, indoor comfort levels are treated as important boundary conditions. International comfort models are used as the basis for performance assessment. In case of active cooling, the Fanger model of general comfort and local discomfort is applied. As in case of buildings with adaptive options using passive cooling technologies and operating in free running mode, 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

Resilient Cooling covers a wide range of technologies and solutions. The Annex faces the challenge to deal with this broad range and with the complexity arising from this.

Within the Annex's focus, already given in the previous chapter, the Annex covers the range of technologies listed below. The research methods and subtasks, described in chapter 4, are set up specifically to deal with this broad range and complexity.

Reducing external heat gains to indoor environments

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

Increasing personal comfort apart from space cooling

- Comfort ventilation and elevated air movement
- Micro-cooling and personal comfort control

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

- Ventilative cooling
- Thermal mass utilization, including hydronic activation, PCM and off-peak storage
- Evaporative cooling
- Night-time sky radiative 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, roof ponds, green roofs, green façades and others
- Solar cooling
- Heat recovery systems

Removing humidity from indoor environments

- High performance dehumidification including desiccant humidification.

3. Objectives

The general objective of the Annex 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.

This shall be achieved by a well-coordinated approach of (A) systematic technology assessment, (B) specific R&D-projects, (C) real performance evaluations and (D) support of policy actions.

Within this four-step approach, the Annex focuses on the following objectives.

- Quantification of the potential benefits of resilient cooling for a wide range of building typologies, climate zones, functional specifications and other boundary conditions. (Subtask A)
- Systematical assessment of benefits, limitations and performance indicators of resilient cooling. Identification of barriers as well as conductive conditions to implementation. (Subtask A)
- Provision of guidelines for the integration of resilient cooling systems in energy performance calculation methods and regulations. (Subtask A)

- Extension of boundaries and improvement of performance of existing low energy and low carbon cooling solutions. (Subtask B)
- Development of new solutions, combinations and applications of resilient cooling technologies. (Subtask B)

- Investigation of real performance of resilient cooling applications by the means of field studies. (Subtask C)
- Analysis of performance gaps and development of solutions to overcome them. (Subtask C)

- Analysis, exchange and encouragement of policy actions, including minimum energy performance standards, building codes, financial incentive and product labelling programmes, educational initiatives, as well as others. (Subtask D)
- Establishment of 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 are divided into four concurrent subtasks, wherein appropriate research methodologies are adopted. The four Subtasks are:

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

4.1 Subtask A: Impact Assessment

Subtask A systematically assesses the benefits, limitations and performance indicators of resilient cooling solutions. It identifies barriers as well as conductive conditions to implementation. The subtask provides guidelines for the integration of resilient cooling systems in existing and new energy performance calculation methods, and indoor comfort prediction methods.

Appropriate KPIs are developed within Subtask A, to evaluate resilience of cooling systems using a holistic approach that includes economical and technical criteria (e.g. life cycle cost effectiveness, technical life span, energy efficiency), environmental impacts (e.g. effects on urban heat islands, local air pollution), cultural and social aspects (e.g. affordability, usability, availability) and ecological impacts (e.g. carbon intensity, climate warming potential).

Subtask A is organized as a number of tightly focussed activities. A key aspect of this work assembles and synthesises current knowledge and evidence bases, and involves intensive collaboration and exchange of information between the participating institutions and countries.

The subtask is divided into the following research activities.

Activity A.1 This includes systematic assessment of potential benefits, limitations and performance indicators of resilient cooling systems under a wide range of application scenarios and other boundary conditions. We 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 are being developed. Barriers to application and further research opportunities are being identified, which will inform research activities of Subtask B.

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

Activity A.3 This activity includes 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 Activity A.1.

4.2 Subtask B: Solutions

Subtask B carries out specific R&D towards new developments and improvements of resilient cooling and overheating protection solutions. It extends the boundaries of existing low energy and low carbon cooling solutions and develops new solutions, combinations of technologies and applications.

Subtask B is 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 covers research topics that are both internationally relevant and nationally specific. It covers a broad variety of research topics and research methodologies, leveraging the specific research priorities and capabilities of the participants in the Annex.

The subtask is structured into the following research activities.

Activity B.1 This activity carries out specific R&D projects towards development of new solutions and combinations of technologies and applications. Furthermore it comprises R&D projects 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 This activity examines user interaction issues and system control issues, including the impact of user behaviour on system performance.

4.3 Subtask C: Field Studies

Subtask C showcases the opportunities and benefits of Resilient Cooling through analysis and evaluation of well-documented applications of low energy and low carbon (resilient) cooling technologies.

The field studies analyse and monitor examples of specific technologies and solutions rather than specific buildings. It examines the performance gap of existing cooling applications as well as their real performance in situ, 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 is structured into the following research activities:

Activity C.1 This activity develops a systematic framework for the conduction of the field studies and the investigation of the gathered datasets.

Activity C.2 This activity consists of 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 This activity compiles lessons learned and develops recommendations for design and operation of resilient cooling solutions as well as identification of barriers for applications and functioning in the form of a publishable Field Study Reports.

4.4 Subtask D: Policy Actions

Subtask D deals with policy related endeavours, promoting energy efficiency and resilience in cooling.

This subtask analyses product labelling programmes, AC minimum energy performance standards (MEPs), 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 strives to represent a toehold for international programmes, such as

- KIGALI – Cooling Efficiency Programme
- Mission Innovation Challenge #7
- IEA Technology Collaborating Programmes

Activity D.1 This activity analyses and internationally performs cross comparison of national and international product labelling programmes, AC minimum energy performance standards (MEPs), sustainability aspects in building regulations and standards related to resilient cooling.

Activity D.2 This activity encompasses collaboration with international programmes such as KIGALI – Cooling Efficiency Programme, Mission Innovation Challenge #7 and correlated IEA Technology Collaborating Programmes to support mainstreaming of resilient cooling solutions.

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 non-residential 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 energy performance calculation and verification methods.

5.1 Official deliverables

The official deliverables are listed below:

	Official deliverables	***Target group***	***Related Subtask***
D1	State-of-the-Art-Report	▪ Research community and associates ▪ Real Estate developers ▪ Policy makers	STA, STB, STC
D2	Midterm Report	▪ Research community and associates ▪ IEA and EBC Programme	STA, STB, STC, STD
D3	Source Book	▪ Building component developers and manufacturers ▪ Architects and design agencies ▪ Engineering offices and consultants	STA, STB
D4	Field Studies	▪ Building component developers and manufacturers ▪ Architects and design agencies ▪ Engineering offices and consultants ▪ Real Estate developers	STC
D5	Design and Operation Guidelines	▪ Architects and design agencies ▪ Engineering offices and consultants ▪ Real Estate developers	STA, STB, STC
D6	Recommendations for policy actions, legislation and standards	▪ Policy makers ▪ Legal interest groups ▪ Experts involved in building energy performance standards and regulation	STD

D7	Project Summary Report	▪ Research community and associates ▪ IEA and EBC Programme ▪ Real Estate developers ▪ Policy makers	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 agencies, 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, most events will have specific target groups
04	Conferences and seminars	Building Sector, most events will have specific target groups
05	Proceedings of international events	Building Sector, 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 and dissemination activities. The Operating Agent is Peter Holzer, Institute of Building Research & Innovation, Austria.

6.2 Subtask leaders

The Subtask Leaders are 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. Duties of the subtask leaders are:

- Coordination of work performed in the subtask
- Assistance to the Operating Agent in preparation of detailed work plans and editing of final reports of the Annex
- Management of technical workshops of the subtask and provision of workshop results to the Operating Agent
- Coordination of technical reports resulting from the Subtask

Subtask leaders have been determined during the Annex preparation phase.

Subtask A leader is Wendy Miller from Australia, Queensland University of Technology.
Subtask A co-leader is Attia Shady from University of Liège.

Subtask B leader is Chen Zhang from Aalborg University. Ongun Berk Kazanci from Technical University of Denmark is co-leader.

Subtask C leader is Dahai Qi from the University of Sherbrooke, Canada
Subtask C co-leader is Gerhard Hofer from e7 Energie Markt Analyse GmbH, Austria.

Subtask D leader is Peter Graham from Global Building Performance Network, Australia.

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 has been started in July 2018.
Two Expert 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. Ahead of these meetings there will be regular web meetings (every other month) for more frequent exchange and coordination of work groups.

Subtask Leaders of each subtask may decide to organize separate meetings and shall keep the Operating Agent informed of the meetings and results. The fourth year of the Annex will be used for reporting.

The following dates of Expert Meetings have been agreed upon:

The first expert will take place on 21st-22nd of October 2019 in Vienna, Austria.
The second meeting will take place on 15th-16th of April 2020 in Windsor, United Kingdom.
The third Expert Meeting is scheduled to take place in Brisbane, Australia in October 2020.

In these dates, web meetings will be held every other month.
A preparative web meeting will be held one week in advance of each Expert Meeting.

8. Funding and commitment

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 and reporting phase of the Annex. The work meetings shall be hosted by one of the participants. The costs of organizing the meeting shall be borne by the host participant. The collection of contributions towards costs is possible though.

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 confirmed:

Country	Institution	Prename	Surname	LoN	NRI	Subtask			
						A	B	C	D
Austria	Institute of Building Research & Innovation	Peter	Holzer	X	X	X	X	X	X
	Institute of Building Research & Innovation	Philipp	Stern	X	X	X	X	X	X
	e7 Energie Markt Analyse GmbH	Gerhard	Hofer	X	X	X		X	
	Vasko und Partner	Christian	Steininger		X			X	
Australia	Queensland University of Technology	Wendy	Miller	X		X	X		
	University of Wollongong	Paul	Cooper	X		X	X	X	

	Global Buildings Performance Network	Peter	Graham	X					X
Belgium	Belgian Building Research Institute	Peter	Wouters						X
	University of Liège	Shady	Attia	X		X	X	X	
	KU Leuven	Hilde	Breesch	X	X		X	X	
Canada	Concordia University, Montreal	Liangzhu	Wang	X	X		X	X	
	Concordia University, Montreal	Hua	Ge	X	X		X	X	
	Université de Sherbrooke	Dahai	Qi	X			X	X	
China	Hunan University	Guoqiang	Zhang	X	X	X	X	X	X
	Hunan University of Science and Technology	Yin	Wei	X	X	X	X	X	X
	Hunan University	Zhengtao	Ai	X	X	X	X	X	
Denmark	Aalborg University	Per	Heiselberg	X	X	X	X		
	Aalborg University	Chen	Zhang	X	X	X	X		
	Technical University of Denmark	Bjarne	Olesen	X	X	X	X		X
	Technical University of Denmark	Ongun	Kazanci	X	X	X	X		X
France	Univérsité de la Rochelle	Emmanuel	Bozonnet	X	X	X			x
	Univérsité de la Rochelle	Anais	Machard	X	X	X			x
Italy	Politecnico Torino	Giacomo	Chiesa	X	X	X	X		X
	Politecnico Milano	Silvia	Erba			X			
	Politecnico Milano	Andrea	Sangalli			X			
	EURAC – Europäische Akademie Bozen	Annamaria	Belleri	X	X		X	X	
UK	Brunel University	Maria	Kolokotroni	X		X	X	X	
	The Bartlett School of Environment, Energy and Resources (BSEER)	Anna	Mavrogianni		X	X	X	X	
	UCL Institute for Environmental Design and Engineering	Marcella	Ucci						
	Oxford Brookes University	Rajat	Gupta				X	X	
	School of Architecture and the Built Environment Lincoln	Behzad	Sodagar	X	X	X	X		X

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.