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, 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.
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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)
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 the following KPI’s:

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).

2.2 Focus

The focus of the Annex will be resilient cooling applications for existing residential buildings, typically with no central BMS being available. Another focal point of the Annex will be resilient cooling applications for Nearly-Zero-Energy-Buildings (nZEBs).

The Annex will encompass both active and passive cooling technologies and systems. All technologies of concern will be evaluated regarding minimisation of energy consumption, greenhouse emissions and other critical environmental impacts.

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 of course take outdoor climatic conditions into account (temperature, humidity, air quality, noise, etc).

The Annex will exclude research focussed specifically increasing our knowledge of indoor comfort, however, indoor comfort levels will be treated as important boundary conditions. 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

A wide range of candidate technologies and solutions will be considered for investigation in the Annex, and the development of a definitive list of candidates will be one of the key tasks in the early phase of the Annex. This will also depend to an extent on the research priorities of the participating institutions. Based on discussions and inputs during the Annex definition phase, we anticipate that the Resilient Cooling Annex will include systematic research in the following fields.

**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 as a means of maintaining thermal comfort
- Micro-cooling and personal comfort control

**Removing heat from indoor environments (production, emission and combined)**
- Ventilative Cooling (e.g. night flush ventilation)
- Thermal mass utilization, including PCM and off-peak ice storage
- Adiabatic/evaporative cooling
- High performance compression chillers, including split, multiple split and VRV units
- 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**
- Desiccant dehumidification and cooling.
3. Objectives

Our overall aim is to rapidly 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.
- To systematically assess benefits, limitations and performance indicators of resilient cooling. To identify barriers to implementation and conduct research to overcoming such barriers and facilitating implementation on a large scale. (Subtask A)
- To provide guidelines on 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 and their control strategies and to develop recommendations for flexible and reliable resilient cooling solutions that can create comfortable conditions under a wide range of climatic conditions (Subtask B).
- To demonstrate the performance of resilient cooling solutions through analysis and evaluation of well-documented case studies. (Subtask C)
- To analyse regulations, standards and compliance requirements and to develop recommendations for further development in regulatory context supporting the implementation of resilient cooling systems. (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 main subtasks are as follows:

Subtask A: Impact Assessment
Subtask B: Solutions
Subtask C: Case studies
Subtask D: Regulatory Initiatives

4.1.1 Subtask A: Impact Assessment

This subtask will systematically assess the potential benefits, costs and other impacts of resilient cooling technologies and systems for a wide range of situations and applications.

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 and agreed during the first phases of the Annex to evaluate resilience of cooling systems using a holistic approach that includes affordability, life cycle cost effectiveness, energy efficiency, carbon intensity.

Subtask A will be organized as a number of tightly focussed activities. A key aspect of this work will be the assembly and synthesis our 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 design, commissioning and operation will also be developed. Barriers to implementation and further research opportunities will be identified, which will feed into the 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 socio-economic impacts, and user-technology interaction analyses. This work will be tailored to residential buildings and
smaller commercial buildings with relatively simple BMSs. The KPIs derived from this research activity will also be used in the Technology of research activity A.1.

Activity A.3. This activity will include identification and further development 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 directly feed into the multi-criteria Technology Profiles to be generated in Research Activity A.1.

4.1.2 Subtask B: Solutions

This subtask will carry out specific research towards improvements and new developments of resilient cooling and overheating protection solutions. Complementary to technological research it will furthermore develop recommendations for the way in which these systems should be integrated with other building design features and sub-systems.

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. Specific research towards the extension of the range of situations where existing resilient cooling technologies and systems may be applied (e.g. with to building type, climate zones, occupancy characteristics, etc).

Activity B.2. Examination of the important issue of user interactions with and control of these systems, and the impact of user behaviour on system performance.

Activity B.2. Development of recommendations to practitioners for the integration of new and existing resilient cooling solutions and control strategies into buildings of different typologies.

4.1.3 Subtask C: Case studies

This subtask will showcase the opportunities and benefits of resilient cooling through analysis and evaluation of well-documented case studies. The case-studies will synthesise examples of specific technologies and solutions rather than focusing on specific buildings. The outcomes of Subtask C will illustrate and support the Technology Profiles developed in Subtask A.

The subtask will be divided into the following research activities:


Activity C.2. Performance analysis and evaluation of resilient cooling solutions, design methods and tools using similar criteria and methods.
**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.

### 4.1.4 Subtask D: Regulatory Initiatives

Subtask D will deal with the development of roadmaps and strategies for implementation of resilient cooling regulatory initiatives, in national, European and international standards.

This subtask will analyse regulations, standards and compliance requirements, to identify international best practice examples as well as potential barriers. The goal is to develop recommendations for future regulatory initiatives to support the implementation and mainstreaming of resilient cooling systems on a national, European and international level.

**Activity D.1.** Analysis and international cross comparison of national regulations and standards relating to resilient cooling.

**Activity D.2.** This activity will develop recommendations for integration of resilient cooling solutions in legislation, standards, design briefs as well as on energy performance calculation and verification methods.

### 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 case 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 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:

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<tr>
<th>Official deliverables</th>
<th>Target group</th>
<th>Related subtask</th>
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<tbody>
<tr>
<td>D1 Overview and state-of-the art of Resilient Cooling</td>
<td>Research community and associates. Policy makers</td>
<td>STA, STB, STC</td>
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<tr>
<td>D2 Resilient Cooling Source Book</td>
<td>Building component developers and manufacturers. Architects and design companies, engineering offices and consultants</td>
<td>STA, STB</td>
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<td>D3 Resilient Cooling case studies</td>
<td>Architects, consulting engineers</td>
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<tr>
<td>D4 Resilient Cooling Design and Operation Guidelines</td>
<td>Architects and design companies, engineering offices and consultants</td>
<td>STA, STB, STC</td>
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<td>D5 Recommendations for legislation and standards (national, European, international)</td>
<td>Policy makers and experts involved in building energy performance standards and regulation</td>
<td>STD</td>
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<tr>
<td>D6 Project Summary Report</td>
<td>Research community and associates + EBC Programme</td>
<td>STA, STB, STC, STD</td>
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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
<table>
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<th>Outreach activities</th>
<th>Target group</th>
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<tr>
<td>Internet site and Annex newsletter</td>
<td>Research community and associates, EBC Programme</td>
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<td>Social Media (Build-up, Linked-in, ...)</td>
<td>Building Sector, often specific target groups</td>
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<td>Conferences and seminars</td>
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<td>Proceedings of international events</td>
<td>Building Sector, but most events will have specific target groups</td>
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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.

For Subtask A there’s interest from Australia, Queensland University of Technology
7. Time schedule

The duration of the Annex in the working phase will be three years, planned to start in summer 2019, with the preparation phase beginning in summer 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:

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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.