ANNEX 80

EBC
Energy in Building and Communities Programme

International Energy Agency

Resilient Cooling of Buildings Policy Recommendations (Annex 80)

Energy in Buildings and Communities Technology Collaboration Programme

May 2024

Technology Collaboration Programme
by iea

ANNEX **80**

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Preface

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 considering 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 analysis (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 (*)
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 (*)
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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

Foreword

The world is facing a rapid increase of cooling of buildings. This is driven by multiple factors, such as urbanization and densification, climate change, power shortage, and elevated comfort expectations as well as economic growth, especially in hot and densely populated regions of the world. The trend towards cooling seems inexorable. It is mandatory to guide this development towards sustainable solutions.

Against this background, it is the motivation of EBC Annex 80 “Resilient Cooling of Buildings” 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 communities to withstand, and prevent, adverse thermal and other impacts due to changes in global and local climates.

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. This can be done by the development of resiliency indicators, categorization of cooling technologies (both passive and active) and reviewing of potential and market availability and future prospects of various technologies.

This report is a main deliverable of Annex 80 and addresses policy-related endeavors that promote energy efficiency and resilience in cooling. It analyzes product-labelling programs; air conditioning (AC) minimum energy performance standards (MEPS) and voluntary measures; and building regulations, standards, and compliance requirements, to identify international best practice examples as well as potential barriers. It seeks to develop recommendations for future national and international regulatory policies to support the implementation and mainstreaming of resilient cooling systems, engaging with international programs.

Other outcomes of EBC Annex 80 Resilient Cooling of Buildings are the Resilient Cooling Guidebook, the Technology Profile Sheets, the Field Studies Report, and articles produced by the contributors of field studies. These are available at https://annex80.iea-ebc.org/

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Abstract

International Energy Agency Energy in Buildings and Communities (IEA EBC) Annex 80: Resilient Cooling of Buildings promotes a rapid transition to the mainstream and preferred use of resilient low-energy and low-carbon cooling systems in buildings. Annex 80 Subtask D (Policy Actions) advances policy-related endeavors that support energy efficiency and resilience in cooling. The Subtask team analyzed product-labelling programs; air conditioning minimum energy performance standards (MEPS) and voluntary measures; and building regulations, standards, and compliance requirements, identifying policy gaps and opportunities. It then generated a set of 37 policy recommendations that boost resilience to heat waves and/or power grid failure by reducing heat gain, removing sensible heat, enhancing thermal comfort without mechanical cooling, or removing latent heat. Strategies addressed include advanced solar shading/advanced glazing, cool envelope materials, evaporative envelope surfaces, ventilated envelope surfaces, heat storage and release, ventilative cooling, adiabatic/evaporative cooling, compression refrigeration, high-temperature cooling systems using low-grade thermal energy, comfort ventilation, micro-cooling and personal comfort control, and whole-building solutions. Each recommendation identifies the mechanism(s) through which the policy would be applied and the disruption(s) mitigated; details the what, why, how, who, where, timeline, cost, and potential undesirable side effects of implementation; and suggests a policy model to follow.

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1 Introduction

International Energy Agency Energy in Buildings and Communities (IEA EBC) Annex 80: Resilient Cooling of Buildings seeks 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". Annex 80 Subtask D (Policy Actions) addresses policy-related endeavors that promote energy efficiency and resilience in cooling. It analyzes product-labelling programs; air conditioning (AC) minimum energy performance standards (MEPS) and voluntary measures; and building regulations, standards, and compliance requirements, to identify international best practice examples as well as potential barriers. It seeks to develop recommendations for future national and international regulatory policies to support the implementation and mainstreaming of resilient cooling systems, engaging with international programs such as KIGALI Cooling Efficiency Program, Mission Innovation Challenge #7, and correlated IEA Technology Collaborating Programs [1].

The Subtask D working group established methods for the collection and assessment of existing policies, detailed and analyzed policies within this framework, and identified policy gaps and opportunities [2]. It then generated the following set of 37 policy recommendations to advance the resilient cooling of buildings.

2 Scope

These recommendations promote passive or low-energy cooling strategies for buildings that boost resilience to heat waves and/or power grid failure by reducing heat gain, removing sensible heat, enhancing thermal comfort without mechanical cooling, or removing latent heat. They do not address power-grid resilience, ways to supplement grid power, or other means of responding to extreme heat, such as relocating building occupants or mitigating the urban heat island.

Each recommendation serves as a starting point for the development of a comprehensive solution. That is, it represents the beginning rather than the end of the process of creating and implementing a policy.

Most of our policy-cost assessments are qualitative because measure costs were excluded from the scope of the Annex.

3 Policy recommendations

This section details each of the 37 recommendations, providing the following fields for each.

- **Policy number.** A serial number (1-37) identifying the policy.
- **Category.** Either the cooling technology addressed by the policy recommendation, or "whole building" if the recommendation applies to design, construction, or operation of the entire building. Table 1 presents a taxonomy of resilient cooling technologies.
- **Author(s).** The working group member(s) who wrote the policy recommendation.
- **Summary.** A summary of the policy recommendation.
- **Policy mechanism(s).** The mechanism(s)—regulation, information, incentives, R&D, or standards—through which the policy recommendation could be applied. Note that a standard establishes definitions, methods, and requirements, while a regulation enforces a standard.
- **Technology target.** Whether the policy recommendation targets a specific technology, or is agnostic (technology independent).
- **Disruption(s) mitigated.** The type of disruption(s)—heatwave and/or power outage—against which the policy recommendation would boost resilience. The power outage box is ticked if the recommendation would mitigate overheating coincident with a *grid* power failure. Policies that promote passive or low-energy cooling qualify, while those that seek to improve the efficiency of technologies that require grid power, such as compressive cooling, do not.
- **What.** What the policy recommendation is to accomplish.
- **Why.** Why the policy recommendation should be developed and applied.
- **How.** How the policy recommendation is to be developed and applied.
- **Who.** Who will create, implement, and/or execute the policy recommendation.
- **Where.** Where the policy recommendation could apply.
- **Implementation timeline.** Whether the time to implement the policy recommendation would be short (typically less than 1 year), medium (1 to 5 years), or long (greater than 5 years).
- **Cost**. Costs to create, implement, and/or execute the policy recommendation.
- **Potential significant undesirable side effects of executing the policy.** What could go wrong.
- **Policy model to follow.** An existing policy that could inform the creation, implementation, and execution of the policy recommendation.

Table 1. Taxonomy of resilient cooling strategies explored by IEA Annex 80. Source: Ref. [3].

A. Reducing heat gains to the indoor environment and people
    1. Advanced solar shading/advanced glazing
    2. Cool envelope materials
    3. Green roofs, roof ponds, green façades, ventilated roofs, and ventilated façades
        a. Evaporative envelope surfaces, including green roofs, roof ponds, and green façades
        b. Ventilated envelope surfaces, including ventilated roofs and ventilated façades
    4. Heat storage and release, including thermal mass, phase-change materials, and off-peak ice storage
B. Removing sensible heat from the indoor environment
    1. Ventilative cooling
    2. Adiabatic/evaporative cooling
    3. Compression refrigeration
    4. Absorption refrigeration, including desiccant cooling
    5. Natural heat sinks, such as ground water, borehole heat exchangers, ground labyrinths, earth tubes, and sky radiative cooling
    6. High-temperature cooling systems using low-grade thermal energy, such as radiant cooling and chilled beams
C. Enhancing personal comfort by means other than space cooling
    1. Comfort ventilation (elevated air movement)
    2. Micro-cooling and personal comfort control
D. Removing latent heat from the indoor environment
    1. High-performance dehumidification including desiccant humidification

There is a matrix (online workbook here) that can be used to filter the recommendations by category, author, policy mechanism, technology target, and/or disruption(s) mitigated. It can also serve as a quick reference guide for the policy recommendations presented here.

Technologies referenced in this document are defined in Section 4 of Ref. [3].

3.1 Encourage the adoption of advanced windows through technical guidelines or policies

Policy number: 1

Category: A1 (Advanced solar shading/advanced glazing)

Author(s): Amanda Krelling

Summary: Encourage the use of advanced (high performance) windows through technical guidelines, or by including rigorous prescriptive or performance paths to policies.

POLICY MECHANISM(S)

Regulation	Information	Incentives	R&D	Standards
	✓			✓

TECHNOLOGY TARGET

Specific	Agnostic
✓	

DISRUPTION(S) MITIGATED

Heatwave	Power Outage
✓	✓

What: The appropriate adoption of advanced window technologies can be encouraged through the dissemination of technical guidelines to design teams and contractors about the benefits, disadvantages, and best practices of the technology. Rigorous prescriptive or performance paths can also be included in standards to speed up the uptake process.

Why: Transparent building envelope surfaces may admit significant amounts of solar heat indoors and have therefore significant impact on occupant thermal comfort and energy use of buildings. However, current policies often address them with regard to energy efficiency, but not to thermal resilience during disruptive events. Furthermore, there is a lack of guidance on implementing advanced window technologies.

How: Develop and provide technical guidelines to design teams and contractors about the use of advanced window technologies. Additionally, prescriptive and performance paths can be included in standards, describing minimum or maximum values of thermal and optical performance properties, which should account for the prevailing local climate and building construction practices.

Who: Researchers and industry experts would develop the technical guidelines and prescriptive or performance criteria in standards. Design teams and contractors would find technical support through the guidelines and follow the prescriptive or performance criteria in standards.

Where: Applicable worldwide, but guidelines and prescriptive/performance criteria must be developed by accounting for the local climate characteristics and building construction practices.

Implementation timeline: Short for guidelines (less than 1 year) and medium (1-5 years) to long (greater than 5 years) for standards.

Cost: Low cost to implement the policy. Medium-high cost to execute the policy, depending on the transparent area and the chosen technology.

Potential significant undesirable side effects of executing the policy: (1) Increase the cost of construction. (2) Increase the overheating risk, particularly in free-running (not air-conditioned) buildings in warm/hot climates by preventing heat loss in insulated glazing (e.g., double- and triple-paned windows). (3) Reduce daylight admitted into the building.

Policy model to follow: Advanced window technologies have become a standard practice in many places around the world to increase energy efficiency of buildings. The window industry and fenestration organizations (e.g., in the U.S., the National Fenestration Rating Council and the Fenestration and Glazing Industry Alliance) have established product performance rating and certification processes to ensure and communicate the energy performance of window products. Such initiatives are also present at a national level in multiple countries such as Argentina and Brazil, where model codes were developed to label windows according to their energy efficiency (IRAM 11507-6 and ABNT NBR 10821-4, respectively).

For HVAC design purposes, ASHRAE Standard 55 has adopted both prescriptive and performance approaches to determining the heating effect of solar radiation on occupants within buildings. The underlying performance approach requires the solar radiation transmitted through fenestration to be independently determined. Once the radiation is indoors, the approach quantifies its direct impact on occupants, which can be very significant in both comfort and air conditioning energy usage. This information is useful in encouraging effective shading devices and higher performance glazing products. The prescriptive approaches are contained in Section 5.3.2 of the current addendum to Standard 55, and the Performance approach is in Normative Appendix C. It is embodied in the ASHRAE/CBE Thermal Comfort Tool. The ASHRAE Journal gives an overview of both approaches here.

3.2 Provide in-depth guidance to support the uptake of solar shading technologies

Policy number: 2

Category: A1 (Advanced solar shading/advanced glazing)

Author(s): Amanda Krelling

Summary: Provide in-depth guidance to support the uptake of solar shading technologies, highlighting good practices that have been found to provide effective management of solar heat loads.

POLICY MECHANISM(S)

Regulation	Information	Incentives	R&D	Standards
	✓			

TECHNOLOGY TARGET

Specific	Agnostic
✓	

DISRUPTION(S) MITIGATED

Heatwave	Power Outage
✓	✓

What: The appropriate design of solar shading technologies can be encouraged through the dissemination of technical reports that guide design teams and contractors about the benefits and best practices of managing solar heat loads. While trees, landscaping and adjacent buildings can provide some shading, the focus here is on static and dynamic glazing and shading building elements designed to manage solar gain as desired on an hourly and seasonal basis.

Why: Solar shading is an effective strategy to manage solar heat gains. However, solar shading technologies are superficially addressed in many policies, often not providing any guidance to support their usage, particularly in cold or temperate climates. Available solutions are diverse and require proper instruction to choose between materials, functionalities, and operation modes.

How: Develop and provide technical guidelines for design teams about the use of solar shading technologies. Their adoption requires in-depth analyses of the sunlight during the design stage, as well as trade-offs regarding architectural design, installation cost, and required maintenance.

Who: Researchers and industry experts would develop the technical guidelines. Design teams and contractors would use the guidelines.

Where: Relevant for warm/hot climates, but applicable worldwide if designed according to local climate characteristics and needs (present and future).

Implementation timeline: Short (less than 1 year).

Cost: Low cost to implement the policy. Execution of the policy highly depends on the chosen technology (e.g., static or dynamic solutions).

Potential significant undesirable side effects of executing the policy: Could reduce passive solar heating in cold winters, especially if static solutions are adopted, such as solar control window films.

Policy model to follow: The Sustainable Construction Standards for Chilean Housing (ECSV) provides guidance by including sun path illustrations, solar inclination angles for capital cities, and additional recommendations to design solar shadings.

3.3 Offer incentives and rebates to install advanced solar shading / glazing

Policy number: 3

Category: A1 (Advanced solar shading/advanced glazing)

Author(s): Mamak P.Tootkaboni & Vincenzo Corrado

Summary: Incentives and rebates offered by utilities and other public or private entities can encourage achieving glazing and shading performance levels that exceed code minimums.

POLICY MECHANISM(S)

Regulation	Information	Incentives	R&D	Standards
		✓		

TECHNOLOGY TARGET

Specific	Agnostic
✓	

DISRUPTION(S) MITIGATED

Heatwave	Power Outage
✓	✓

What: The adoption of advanced solar shading/ glazing technologies with performance levels that exceed new code minimum requirements can be promoted with incentive and rebate programs, specifically designed for both new and retrofit construction, and for all building types and climates.

Why: Current policies frequently deal with glazing and solar shading through prescriptive requirements, such as limiting values of thermal transmittance and total solar energy transmittance (a.k.a. solar heat gain coefficient). They do not provide directions for the proper application and control of advanced technologies.

How: Offer incentives and rebates, such as tax deductions, based on technical documentation and components/materials certification that demonstrate the performance of the adopted technologies.

Who: National and local governments and private entities should create and execute the incentives and rebates properly.

Where: The effectiveness of advanced solar shading / glazing technologies depends on the values of solar radiation during the cooling period. That gives greater potential to these technologies in climate zones with high solar radiation and on façades receiving higher solar radiation in the cooling period.

Implementation timeline: Medium (1-5 years).

Cost: Low to implement; Medium to execute.

Potential significant undesirable side effects of executing the policy: (1) Increase the cost of construction. (2) Increase the overheating risk, particularly in warm/hot climates, especially in free-running (not air-conditioned) buildings. (3) Reduction of daylight admitted into the building. (4) Reduction of passive solar heating during winter (especially if static solutions are adopted, such as solar control window films).

Policy model to follow: Eco bonus in Italy, that consists of tax deductions spread over several years, transferable to other financial subjects (e.g., banks).

3.4 Add code requirements for external movable solar shading to reduce solar heat gains through glazed areas

Policy number: 4

Category: A1 (Advanced solar shading/advanced glazing)

Author(s): Pierre Jaboyedoff

Summary: Develop and enforce stringent norms of the maximal allowed solar heat gain coefficient (SHGC) value for window systems. Building codes should specify the use of external movable shading systems for solar radiation exposed façades.

POLICY MECHANISM(S)

Regulation	Information	Incentives	R&D	Standards
	✓			✓

TECHNOLOGY TARGET

Specific	Agnostic
✓	

DISRUPTION(S) MITIGATED

Heatwave	Power Outage
✓	✓

What: The mandatory use of external movable shading systems can reduce the sensible cooling load in residential buildings by 20-50%. It has been successfully enforced in Switzerland since 2014.

Why: Heat gains through the building envelope are generally caused in large part by solar heat gains (40-80%) through windows. This has not yet been recognized in many countries explicitly. Generally external movable shading is not explicitly included in the envelope building codes, yet it is one of the most effective methods to significantly reduce solar heat gains.

How: Add to the existing mandatory envelope building code a section specifically dedicated to the limitation of the Solar Heat Gain Coefficient (SHGC) value as a function of the window-to-wall ratio (WWR). For example, in Switzerland, for south (equator-facing) façades, the value of the SHGC must be ≤ 0.15 up to 45% WWR, and then decreases gradually down to 0.08 for 100% WWR.

Who: The national government agency in charge of energy building codes should issue a mandatory clause specifying the maximal allowable SHGC values as a function of the window-to-wall ratio on different façade orientation. The information and teaching about this technology should be generated by architect and engineer associations with contributions of external shading manufacturers.

Where: With the improvement of building envelope insulation and larger glazed area, overheating due to high solar gains across glazed areas does occur even in temperate climates.

Implementation timeline: Medium (1-5 years).

Cost: Generally, within 1-3% of the total building cost.

Potential significant undesirable side effects of executing the policy: No negative effect known.

Policy model to follow: A nationally mandatory building envelope code about solar shading, the Swiss Norm SIA 180:2014, has been successfully enforced in Switzerland since 2014.

3.5 Add cool-surface prescriptions for indoor thermal quality to green building standards

Policy number: 5

Category: A2 (Cool envelope materials)

Author(s): Ronnen Levinson

Summary: Add indoor thermal quality (occupant thermal comfort) sections to green building standards and green building certification programs (like the Passive Survivability pilot credit in LEED), then provide a prescriptive compliance path that includes cool roofs and walls.

POLICY MECHANISM(S)

Regulation	Information	Incentives	R&D	Standards
				✓

TECHNOLOGY TARGET

Specific	Agnostic
✓	

DISRUPTION(S) MITIGATED

Heatwave	Power Outage
✓	✓

What: Provide a path in green buildings to credit the use of solar reflective and thermal radiative (sky cooling) roofs and walls to cool the interior of buildings, just as they are recognized in some green building standards (e.g., Sections A4.106.5 of 2019 CALGreen).

Why: The direct cooling benefit of solar reflective and thermal radiative roofs and walls (ability to cool occupants by reducing the solar heat gain and thermal heat loss of the modified building) will typically exceed the indirect benefit of these surfaces (ability to cool building occupants by lowering the outside air temperature), but this direct environmental benefit is not yet recognized in green building standards.

How: Propose language recognizing the indoor cooling benefits of solar reflective and thermal radiative roofs & walls for Sections A4.507 "Environmental comfort" (residential) and

A5.507.1.1.2 "Thermal comfort" (nonresidential) of 2019 CALGreen. Could do something similar in the International Green Construction Code (IgCC) and other green building standards.

Who: Researchers and the cool surface industry would develop updates to green building standards through the public input process (CALGreen) and/or consensus body work (IgCC). Architects and builders seeking green building credits would incorporate cool surfaces in constructions (and possible retrofits, if the green building standards address retrofits).

Where: Might be limited to hot-summer climates, but these days nearly everywhere qualifies.

Implementation timeline: Medium, since building standards typically operate on three-year cycles.

Cost: Low to execute; low to implement for most types of cool roofs and walls.

Potential significant undesirable side effects of executing the policy: May reduce passive solar heating in cold/temperate climates. Might not benefit the building occupants if applied in a cool-summer climate.

Policy model to follow: Analogous to crediting cool surfaces for urban heat island mitigation in green building standards.

3.6 Add cool-roof and cool-wall provisions to building standards and programs worldwide

Policy number: 6

Category: A2 (Cool envelope materials)

Author(s): Ronnen Levinson

Summary: Ensure that cool-roof and cool-wall provisions are included in building energy standards, green building standards, green building certification programs in all climates with hot summers.

POLICY MECHANISM(S)

Regulation	Information	Incentives	R&D	Standards
				✓

TECHNOLOGY TARGET

Specific	Agnostic
✓	

DISRUPTION(S) MITIGATED

Heatwave	Power Outage
✓	✓

What: Some major building energy standards (e.g., International Energy Efficiency Code [IECC], California Title 24 Part 6) prescribe or credit the use of cool roofs or walls for energy efficiency, while some major green building standards (e.g., International Green Construction Code [IgCC], CALGreen) and green building certification programs (e.g., LEED, Green Globes) credit the use of cool roofs or walls for urban heat island reduction. Similar prescriptions or credit should be incorporated in such standards and programs worldwide for all hot-summer climates.

Why: The energy-savings and heat-island reduction benefits of cool surfaces in hot-summer climates have been well documented, and prescription of or credits for use of these surfaces has been approved by the government agencies or consensus bodies responsible for these California- or USA-centric standards and programs. They should logically be extended to the standards and programs used in other countries.

How: China and India have adopted cool-surface provisions in their building energy efficiency standards with technical assistance from U.S. researchers. Other countries may wish to simply borrow language from IECC, IgCC, California Title 24 Part 6, or CALGreen.

Who: Extension of cool surfaces to additional standards and programs may be bottom-up (driven by proposals from academics and industry) for consensus standards/programs or top-down (led by government agencies) for government-run standards/programs. This could be an International Energy Agency-organized effort.

Where: None so long as cool roofs are promoted only in suitable climates (e.g., ASHRAE zones 1-5).

Implementation timeline: Medium, since building standards typically operate on three-year cycles.

Cost: Low to execute; low to implement for most types of cool roofs and walls.

Potential significant undesirable side effects of executing the policy: Could increase annual energy use if applied to cool-summer climates.

Policy model to follow: Review processes followed by China and India.

3.7 Introduce or improve cool-surface rebate programs

Policy number: 7

Category: A2 (Cool envelope materials)

Author(s): Ronnen Levinson

Summary: Develop rebates for manufacturers or homeowners to offset initial cool surface product premiums.

POLICY MECHANISM(S)

Regulation	Information	Incentives	R&D	Standards
		✓		

TECHNOLOGY TARGET

Specific	Agnostic
✓	

DISRUPTION(S) MITIGATED

Heatwave	Power Outage
✓	✓

What: Power utilities and government agencies in some U.S. states offer (or previously offered) rebates to building owners who buy cool roof products. This policy would create new upstream (manufacturer) and downstream (consumer) rebate programs designed to offset the initial cost premium (if any) for selecting a cool version of a roof or wall product.

Why: While many cool roof/wall products are priced the same as otherwise comparable warm products, some cool products that require specialized components or manufacturing processes may cost more to produce and sell for a higher price, especially when the cool-surface market is new and limited. Rebates that offset these cost premiums can drive both demand and supply for cool surfaces.

How: Power utilities would use ratepayer funds and government agencies would use tax revenues to provide upstream and/or downstream incentives. While not yet tested, upstream incentives that subsidize the production of cool-surface materials so that they retail for the same price as otherwise-similar warm-surface materials might be cheaper to provide (no distributor/contractor markup) and easier to administer (there are far fewer manufacturers than consumers).

Who: The rebate programs would be developed by regulated power utilities that have mandates to promote energy efficiency, and could be copied by government agencies. Multiple utilities and government agencies may wish to support a single funding agent to avoid the need to create duplicative programs.

Where: Anywhere cool surfaces are beneficial—typically hot-summer climates.

Implementation timeline: Short (about 1 year) to launch; medium (1-5 years) to engage many manufacturers / consumers.

Cost: Low to create; medium to implement, but would draw from ratepayer or tax funds already designated for energy efficiency or building resilience.

Undesirable side effects of executing the policy: Potential for fraud if the program is administered carelessly.

Policy model to follow: Find one or more successful downstream rebate programs here. Still seeking an upstream rebate program to emulate.

3.8 Provide cool-surface training to building contractors

Policy number: 8

Category: A2 (Cool envelope materials)

Author(s): Ronnen Levinson

Summary: Create a training and certification program for roof/wall contractors to (a) understand cool surface benefits and (b) locate and apply/install products.

POLICY MECHANISM(S)

Regulation	Information	Incentives	R&D	Standards
	✓			

TECHNOLOGY TARGET

Specific	Agnostic
✓	

DISRUPTION(S) MITIGATED

Heatwave	Power Outage
✓	✓

What: Create a training and certification program to teach roof/wall contractors about the many benefits of cool roofs and walls, how to communicate these benefits to their customers, and how to apply/install cool surface products if special practices are required.

Why: Building owners often take envelope product advice from building professionals, such roof/wall contractors, who may not know enough about the benefits of cool surfaces to recommend them to customers, and in some cases (e.g., cool exterior wall paints) may be unfamiliar with application details. This may lead contractors to recommend and consumers to select warm surface materials in hot climates.

How: With technical support from non-commercial entities such as academic researchers, government agencies, and non-governmental organizations, cool roof/wall industry associations would develop training programs to certify contractors and other vendors for sale of their products. These could leverage existing training or re-certification programs such as those offered by community colleges in the United States. Consumers could then look for cool-surface certified suppliers.

Who: The training program would be created and executed by cool roof/wall industry associations with assistance from cool-surface benefit experts.

Where: Anyone could be trained and certified, though such programs may be country-specific.

Implementation timeline: Short (about 1 year) to launch; medium (1-5 years) to train a substantial number of certified cool-surface vendors.

Cost: Low to create and implement.

Undesirable side effects of executing the policy: None.

Policy model to follow: The InstallationMasters® Training and Certification Program offered by the Fenestration and Glazing Industry Alliance trains and certifies contractors to install windows and patio doors.

3.9 Expand cool-roof policies to include cool walls

Policy number: 9

Category: A2 (Cool envelope materials)

Author(s): Ronnen Levinson

Summary: Expand cool-roof policies to include cool walls, accounting for roof-wall differences in materials and physics.

POLICY MECHANISM(S)

Regulation	Information	Incentives	R&D	Standards
✓		✓		✓

TECHNOLOGY TARGET

Specific	Agnostic
✓	

DISRUPTION(S) MITIGATED

Heatwave	Power Outage
✓	✓

What: Expand every building energy standard, green building program, product rating program, and product certification program that already incorporates cool roofs to also include cool walls.

Why: Even regions of the United States and other nations that have well-established cool roof policies and programs may lack analogous policies and programs promoting the use of cool walls.

How: Review national and local policies and programs that promote cool roofs, then draft additional language to promote cool walls where climate appropriate.

Who: Annex 80 subtask D participants may identify some opportunities based on their policy reviews, but additional researchers would be required to review cool roofs policies and programs worldwide. These workers can suggest cool-wall additions to policy and program operators such as code bodies, government agencies, and power utilities.

Where: Anywhere cool roofs are already recognized in policies and programs. Appendix B of Ref. [4] provides detailed application guidelines for cool walls.

Implementation timeline: Short to launch since Annex 80 subtask D members have already reviewed cool roof/wall policies; medium to implement policy changes.

Cost: Low to launch (academics); medium to implement (requires efforts by many stakeholders and ongoing technical guidance from researchers).

Undesirable side effects of executing the policy: None so long as cool walls are promoted only in suitable climates (e.g., ASHRAE zones 1-4).

Policy model to follow: ASHRAE Standard 90.1-2019 addendum s recently expanded the standard's cool-wall provisions.

3.10 Expand definitions in existing standards to be more widely applicable to all evaporative surface techniques

Policy number: 10

Category: A3a (Evaporative envelope surfaces)

Author(s): Emmanuel Bozonnet

Summary: Generalize existing standards for green roofs or vegetated areas only to include all other evaporative envelope surface techniques. Depending on the level of detail of the existing standards, this may require further development of existing calculation tools and methods based on the state of the art and the most advanced existing standards.

POLICY MECHANISM(S)

Regulation	Information	Incentives	R&D	Standards
✓				✓

TECHNOLOGY TARGET

Specific	Agnostic
✓	✓

DISRUPTION(S) MITIGATED

Heatwave	Power Outage
✓	✓

What: Evaporative surfaces (e.g., green roofs, green façades, roof ponds) mitigate overheating of the building envelope and can even act as a heat sink under some conditions, for both indoor environments and urban surroundings. The evaluation of their cooling performance requires physical or empirical models that need to be integrated in the design process of building envelopes. To integrate evaporative envelopes into resilient cooling strategies, decision makers and designers need these specific models to be included in the building thermal regulations and/or standardized methods.

Why: Apart from scientific tools and applications, the real calculation of the cooling effect of evaporative envelope surfaces is limited to green roofs, when this is considered in some building regulations or standards. For example, the French thermal regulation RE2020 includes a specific physical model for green roofs. Thus, except for green roofs in some standards, evaporative surface models are not included, especially considering the modified surface heat balance.

How: The existing standardized calculation methods for green roofs are based on physical models that could be easily extended to other typologies of evaporative envelope techniques. A parallel process should define the various techniques that should be included for roofs and facades to check their validity under various conditions. Building performance standards are also evolving with policy frameworks, such as the EU directive on building performance, which is a legislative act that only sets targets, and leaves it up to the EU countries to choose how to meet those targets. In this European context, and to accelerate these developments, new directives could include specific targets for developing local standards to specifically include all evaporative surfaces.

Who: Standardization bodies/construction industry/academics could participate in the writing/definition process of new standards and/or regulations.

Where: Hot-summer climate countries without severe water restrictions.

Implementation timeline: Medium (1-5 years); time can vary with standardization and regulation implementation process. For general building regulation (non-specific), it can be accelerated if green roofs are already implemented, by giving the new evaporative envelope component as a simple variation of the existing calculation. Depending on the country and the existing building standards, another approach is to develop specific standards and recommendations for each typology of evaporative envelopes, which could be based on the same calculation methods.

Cost: The cost of the development and the implementation of evaporative surface standards (which is this policy recommendation) should be low. This recommendation does not change the higher cost of some evaporative surface techniques, such as green roofs, and even more expensive green façades, though it can help with correct sizing for cooling performance.

Potential significant undesirable side effects of executing the policy: None.

Policy model to follow: All existing standards that include green roofs can be used, such as the French thermal regulation RE2020.

3.11 Create performance requirements for double-skin façades to reduce risk of overheating

Policy number: 11

Category: A3b (Ventilated envelope surfaces)

Author(s): Emmanuel Bozonnet

Summary: Double skin façades can be designed both for winter and summer conditions. This passive envelope technique has been widely developed in northern countries for its architectural interests and its capabilities to increase solar gains in winter. However, under summer conditions, overheating of the cavity and its consequences on the building summer performance is a risk for this technique. Therefore, this recommendation aims to prevent overheating by developing minimum requirements for the cooling performance of double-skin envelopes. These recommendations might include new ventilation strategies for heatwave events, given the possible operation adaptability of double skin facades.

POLICY MECHANISM(S)

Regulation	Information	Incentives	R&D	Standards
✓	✓	✓	✓	✓

TECHNOLOGY TARGET

Specific	Agnostic
✓	

DISRUPTION(S) MITIGATED

Heatwave	Power Outage
✓	✓

What: Preventing overheating of double-skinned buildings by developing minimum requirements for this building envelope technique, that can be either passive or active. This should include recommendations on design, solar protections, materials, and ventilation strategies.

Why: Double-skin façades are widely adopted especially for high-rise buildings, and for their architectural attractiveness and natural light benefits. However, overheating is a risk for this technique in hot climates. Indeed, the air temperature in the cavity can be overheat noticeably depending on the design of the ventilation system and the air inlets. These design or operational issues can limit airflow rates. Combined with potentially high solar gains and weak solar shading, this can have a significant impact on air-conditioning performance, or indoor comfort. Well-designed ventilation can make this technique a very good and adaptable cooling strategy. Better consideration of local climate specificities is necessary for ventilated envelopes, which can be a resilient cooling technique with a good adaptability potential to future extreme events.

How: Parametric studies for various double-skin façades should give the potential benefits and penalties for each climate zone, considering extreme events such as heatwaves. Building regulations, which already exist for northern countries, mainly focus on heating season performance while some tropical policies are still not very precise on these techniques. The overheating risks should be identified considering these standards and literature reviews to identify the typical issues. Parametric studies for different climates should lead to adapting existing standards, either with minimum performance criteria of double-skin façades for summer, or by developing minimum requirements for a specific climate and double-skin façade technique (e.g., air inlets/outlets dimensions of a naturally ventilated double-skin façade).

Who: Construction industry can participate to develop these performance recommendations or to give minimum requirements adapted to their own products. These studies should be driven by policy makers to be used in recommendations, incentives, or adapted in building regulations.

Where: All climate zones.

Implementation timeline: Medium (1-5 years) to long (greater than 5 years), as some intermediate results and literature review could be integrated in existing standards for double-skin façades.

Cost: Low.

Potential significant undesirable side effects of executing the policy: None.

Policy model to follow: The published "best practice guidelines" from the EU project "BESTfaçade" can be a good reference for this policy development.

3.12 Boost passive cooling by funding, combined with scientific support and monitoring

Policy number: 12

Category: A4 (Heat storage and release)

Author(s): Peter Holzer

Summary: Boost the implementation of passive cooling, e.g., thermal mass activation, by a combination of funding and scientific support, including monitoring.

POLICY MECHANISM(S)

Regulation	Information	Incentives	R&D	Standards
	✓	✓	✓	

TECHNOLOGY TARGET

Specific	Agnostic
	✓

DISRUPTION(S) MITIGATED

Heatwave	Power Outage
✓	✓

What: Boost the implementation of passive cooling, e.g., thermal mass activation, by a concerted action of (a) funding of additional design costs (b) obligatory monitoring and participation in a scientific evaluation program and (c) a public information campaign.

Why: The success of passive cooling strategies such as thermal mass activation depends on a high-quality design, including thermal building simulation. Thus, it is a very effective action to specifically fund the design process and link the funding to participation in later monitoring and scientific evaluation.

How: The Government would fund part of the developer design costs. For example, in Austria, Europe, funding is offered in the range of 40,000 to 110,000 EUR, depending on the total costs of the project. The program is supported with professional advice and monitoring by a national scientific institution.

Who: The funding comes from the government. The developers are the recipients of the funding. A national research institution does professional advice, controls the quality of the projects and coordinates the monitoring.

Where: The principle of this policy action, which is combining funding of the design process with scientific advice and monitoring, is applicable without geographical limitations. However, there may be climate-specific risks, such as that of condensation from thermal mass activation in hot and humid climates.

Implementation timeline: Medium (1-5 years).

Cost: Costs for scientific support are low, in the range of one full-time equivalent per year. Costs for implementation are technology specific; for example, that for thermal mass activation could be about 2% of the total building cost. Costs for funding depend on the number of projects that are attracted by the program. This number and thus the overall budget for funding can be controlled by the funding authority.

Potential significant undesirable side effects of executing the policy: None.

Policy model to follow: In Austria, this model has been implemented for two years. See here (German only).

3.13 Advance the use of low energy ventilative cooling systems

Policy number: 13

Category: B1 (Ventilative cooling)

Author(s): Pierre Jaboyedoff

Summary: Advance the use of very-low-energy ventilative cooling systems designed for cross ventilation through the apartments and/or offices that use central vertical airshafts rather than air ducts.

POLICY MECHANISM(S)

Regulation	Information	Incentives	R&D	Standards
	✓		✓	✓

TECHNOLOGY TARGET

Specific	Agnostic
✓	

DISRUPTION(S) MITIGATED

Heatwave	Power Outage
✓	✓

What: Promote the use of very low energy ventilative cooling systems designed for cross ventilation through the flats without any duct. Such systems would include individual exhausts in a high performance vertical central shaft with one large exhaust fan on top to ensure 8-15 air changes per hour in residential multi-story buildings.

Why: Mechanically ventilative cooling is very often inefficient due to the high-pressure losses in the HVAC ducts and other components needed for high flow rates. Specific fan power (SFP) is often higher than 1 kW/(m³/s). It is often less efficient than using an efficient chiller.

How: Centralized ductless systems allow reducing the total pressure loss to 30-50 Pa. The cross-ventilation flow is balanced by a calibrated exhaust element between the flat and the central vertical shaft kept at a negative pressure. Actual design and testing in real scale in buildings has confirmed an extremely low SFP of 0.03 kW/(m³/s). A demonstration of the feasibility has been performed on a real scale in a building in India (see here).

Who: The technical documents should be elaborated by organizations like ASHRAE, REHVA, preparing informative and regulatory standards. Capacity building for professionals should be organized and become part of the curricula in civil/mechanical engineering.

Where: It is relevant in all warm climates, where most residential dwellings are equipped neither with AC nor with ducted mechanical ventilation systems (e.g., are naturally ventilated). It is especially recommended in dense urban contexts. In these conditions, the wind on the façades of the buildings is too low to provide sufficient pressure for a good cross ventilation at night.

Implementation timeline: Medium (1-5 years).

Cost: Low if it is integrated architecturally in the project at early stages. Easy to implement in buildings that are designed with central vertical airshaft(s).

Potential significant undesirable side effects of executing the policy: In some countries, the national fire regulations may require special additional provisions to be compliant.

Policy model to follow: None.

3.14 Implement policies for ventilative cooling

Policy number: 14

Category: B1 (Ventilative cooling)

Author(s): Mamak P.Tootkaboni & Vincenzo Corrado

Summary: Tailoring prescriptive and performance requirements in the process of implementation of ventilative cooling policies.

POLICY MECHANISM(S)

Regulation	Information	Incentives	R&D	Standards
✓			✓	✓

TECHNOLOGY TARGET

Specific	Agnostic
✓	

DISRUPTION(S) MITIGATED

Heatwave	Power Outage
✓	✓

What: Policies on ventilative cooling should be tailored to the specific climatic conditions and building categories, incorporating prescriptive paths—aimed at specifying the technical requirements of the ventilative cooling systems to be installed—with the performance path related to the indoor environmental quality (thermal comfort, indoor air quality [IAQ]).

Why: Ventilative cooling is not well-integrated in standards, legislation, and compliance tools as a cooling option for meeting the requirements of energy performance and thermal comfort. Ventilation is principally considered for IAQ purposes, and hence the suggested minimum air change rates for residential buildings and for industrial/artisan buildings are not sufficient for pursuing cooling using ventilative cooling strategies.

How: Set criteria for design of ventilative cooling systems with focus on thermal comfort and reducing energy use. They should influence the choice between natural and mechanical ventilation and the possible coupling of ventilative cooling with thermal storage.

Who: Standardization bodies should create the policies. National governments should execute the policies properly.

Where: In high performance and commercial buildings, where the cooling needs depend heavily on solar radiation and internal heat gains. Since the effectiveness of ventilative cooling depends on the outdoor temperature during the cooling period, ventilative cooling is more efficient in such buildings.

Implementation timeline: Medium (1-5 years).

Cost: Low to create the policy; medium to execute the policy.

Potential significant undesirable side effects of executing the policy: No significant side effect is expected.

Policy model to follow: None.

3.15 Establish evaporative cooling national standards

Policy number: 15

Category: B2 (Adiabatic/evaporative cooling)

Author(s): Anaïs Machard

Summary: Establish national standards specific for evaporative cooling (EC), with different standards for different types of EC.

POLICY MECHANISM(S)

Regulation	Information	Incentives	R&D	Standards
				✓

TECHNOLOGY TARGET

Specific	Agnostic
✓	

DISRUPTION(S) MITIGATED

Heatwave	Power Outage
✓	

What: The appropriate design of evaporative coolers can be enhanced through standards specific to the different types of EC: direct evaporative cooling (DEC) and indirect evaporative cooling (IEC). Such standards must include design and construction guidance, performance testing and minimum requirements.

Why: Evaporative coolers (EC) are promising as an alternative to compressive air-conditioning. In temperate climates, products start appearing on the market, however not all countries have standards to design DEC and IEC. India, Iran, Australia, USA (California), and Europe have established evaporative air coolers standards. However, not all countries have standards differentiating the different types of EC. For example, Australia's standard refers only to direct EC (DEC); indirect EC (IEC) is not standardized.

How: Establish national standards specific to evaporative air-coolers, with different standards for the different evaporative air-coolers type: DEC and IEC.

Who: Civil associations or organizations could be appointed to a knowledge-sharing body to frame the energy efficiency performance testing standards for different types of EC. It could also be led by a manufacturer association.

Where: Everywhere in the world except hot and humid climate zones.

Implementation timeline: Medium (1-5 years).

Cost: Low to implement, medium to execute.

Potential significant undesirable side effects of executing the policy: No negative effect known.

Policy model to follow: The European Standards DEC RS/9/C/004-2018 and IEC RS/9/C/005-2018.

3.16 Include water efficiency as criterion in evaporative air coolers performance and emphasize the thermal comfort gain in standards

Policy number: 16

Category: B2 (Adiabatic/evaporative cooling)

Author(s): Anaïs Machard

Summary: Integrate performance criteria related to water efficiency with energy performance to evaluate the overall cooling performance of the EC system in EC design and testing standards.

POLICY MECHANISM(S)

Regulation	Information	Incentives	R&D	Standards
				✓

TECHNOLOGY TARGET

Specific	Agnostic
✓	

DISRUPTION(S) MITIGATED

Heatwave	Power Outage
✓	

What: Integrate performance criteria related to water efficiency with energy performance–water consumption at different speeds, overall water quality (e.g., salinity level), water bleeding system and water bled-off (waste) rate, type of cooling pads, and evaporation rate–to evaluate the overall cooling performance of the EC system in mandatory standards. Water consumption and efficiency should be accounted for as a critical parameter to cover the overall performance of EC.

Integrate performance criteria to account for the gain in thermal comfort based on the overall efficiency to regulate indoor temperature and humidity. This could be done by comparing the indoor temperature and humidity with and without the use of EC at the testing conditions already defined in the standards.

Why: The refrigerant in evaporative air cooling is water. The hotter and drier the outdoor air, the more efficient is the cooler–if unlimited water is provided. Given that water scarcity might be the biggest issue of the 21st century, it is essential to integrate water consumption in the overall evaluation performance of evaporative coolers in standards.

The EC standards include a criterion named “cooling effectiveness”. An alternative thermal comfort criterion could additionally emphasize the gain in thermal comfort at specific indoor conditions.

How: Define water and thermal comfort criteria and implement them in existing or new standards.

Who: Standardization bodies should add this criterion in existing EC design and testing standards.

Where: Everywhere in the world except humid climate zones.

Implementation timeline: Medium (1-5 years).

Cost: Low to implement, medium to execute.

Potential significant undesirable side effects of executing the policy: None.

Policy model to follow: The two following European standards integrate a criterion for water consumption and water quality: DEC RS/9/C/004-2018 and IEC RS/9/C/005-2018.

However, water consumption is not integrated in the overall performance evaluation of these standards, and this could be improved.

3.17 Establish minimum energy performance standards (MEPS) for evaporative air coolers

Policy number: 17

Category: B2 (Adiabatic/evaporative cooling)

Author(s): Anaïs Machard

Summary: Establish minimum energy performance standards for evaporative air coolers.

POLICY MECHANISM(S)

Regulation	Information	Incentives	R&D	Standards
✓				✓

TECHNOLOGY TARGET

Specific	Agnostic
✓	

DISRUPTION(S) MITIGATED

Heatwave	Power Outage
✓	

What: Adopt a binding rule on the minimum energy performance standard (MEPS) for evaporative air coolers. Defined different MEPS for the different types of EC (direct DEC and indirect IEC).

Why: For reasons of cost, appliances are often marketed with an energy efficiency that is significantly below the technical possibilities. The binding definition of a Minimum Energy Performance Standard (MEPS) can solve this. MEPS has the potential to standardize this product segment and increase its mass adoption.

How: Pass a binding regulation that defines Minimum Energy Performance Standards (MEPS) for evaporative air coolers. This measure should be applied by either very big countries or by a union of more than one nation. A seasonal energy efficiency ratio (SEER) star rating bands should account for the evaporative effectiveness, on the EC type, on the cooling pad efficiency and on the overall cooling capacity.

Who: This policy has to be created by governments. The policy shall be executed by governmental bodies.

Where: Everywhere in the world except humid climate zones.

Implementation timeline: Short to medium.

Cost: The implementation costs are low. The policy may raise product cost.

Potential significant undesirable side effects of executing the policy: None, but the cooling potential is limited when the air is humid, and the technology is insufficient for extreme temperatures.

Policy model to follow: Iran has established MEPS for evaporative coolers, with a star rating (see here).

Otherwise, see the framework set by the European Community's eco design directive 2009/125/EC for the setting of ecodesign requirements for energy-related products, including chillers and air conditioners (here and here).

3.18 Build consumer awareness around evaporative air cooling as an alternative for air conditioning

Policy number: 18

Category: B2 (Adiabatic/evaporative cooling)

Author(s): Anaïs Machard

Summary: Build consumer awareness around evaporative air cooling (EC) as an alternative to compressive air-conditioning.

POLICY MECHANISM(S)

Regulation	Information	Incentives	R&D	Standards
	✓	✓		

TECHNOLOGY TARGET

Specific	Agnostic
✓	

DISRUPTION(S) MITIGATED

Heatwave	Power Outage
✓	

What: Build consumer awareness about the existence and effectiveness of EC as a sustainable space cooling system. Consumers must be provided information about EC to increase their adoption and usage. Incentivizing ECs would help even further the uptake of water- and energy-efficient EC. Behavior change campaigns could be implemented to facilitate consumers purchasing decisions for opting for a sustainable space cooling system.

Why: EC is an energy efficient and environmentally friendly (non-GWP refrigerant) based space-cooling solution. However, this technology for the residential sector might not be known from consumers, especially in temperate climates such as Europe. This policy action of guidance would encourage consumer awareness of the benefits of purchasing this technology.

How: Organize a behavioral campaign and provide material to help consumers gain knowledge on this space cooling technology. A pilot study to mainstream the technology could help prove its efficiency in improving thermal comfort in specific countries.

Who: National HVAC or industry association in direct contact with consumers could organize a campaign to disseminate information towards potential customers.

Where: Everywhere in the world except hot and humid climate zones.

Implementation timeline: Short (less than 1 year).

Cost: The implementation costs are low.

Potential significant undesirable side effects of executing the policy: None, but the cooling potential is limited when the air is humid, and the technology is insufficient for extreme temperatures.

Policy model to follow: None.

3.19 Establish minimum energy performance standards (MEPS) for chillers and air conditioners

Policy number: 19

Category: B3 (Compression refrigeration)

Author(s): Peter Holzer

Summary: Establish regulations on minimum energy performance of chillers and air conditioners.

POLICY MECHANISM(S)

Regulation	Information	Incentives	R&D	Standards
✓				✓

TECHNOLOGY TARGET

Specific	Agnostic
✓	

DISRUPTION(S) MITIGATED

Heatwave	Power Outage
✓	

What: Adopt a binding rule on the minimum energy performance standard (MEPS) for chillers and air conditioners.

Why: For reasons of cost, appliances are often marketed with an energy efficiency that is significantly below the technical possibilities. The binding definition of a Minimum Energy Performance Standard (MEPS) can solve this.

How: Pass a binding regulation that defines Minimum Energy Performance Standards (MEPS) for chillers and air conditioners. This measure should be applied by either very big countries or by a union of more than one nation.

Who: This policy has to be created by governments. The policy shall be executed by governmental bodies.

Where: The policy can be applied world-wide. It should be applied by either very big countries or by a union of more than one nation.

Implementation timeline: Short (less than 1 year).

Cost: The implementation costs are low. The policy may raise product cost.

Potential significant undesirable side effects of executing the policy: None.

Policy model to follow: Good examples include the regulations on the implementation of the European Community's eco design directive 2009/125/EC which is a framework for the setting of ecodesign requirements for energy-related products, amongst them chillers and air conditioners. See here and here.

3.20 Create mandatory chiller performance requirements to limit the lowest temperature for chilled water to above 14 °C

Policy number: 20

Category: B6 (High-temperature cooling systems using low-grade thermal energy)

Author(s): Pierre Jaboyedoff

Summary: Create mandatory chiller performance requirements for "high temperature" chilled water production to supply water above 14 °C.

POLICY MECHANISM(S)

Regulation	Information	Incentives	R&D	Standards
✓	✓			✓

TECHNOLOGY TARGET

Specific	Agnostic
✓	

DISRUPTION(S) MITIGATED

Heatwave	Power Outage
✓	✓

What: In the last three decades, radiant cooling and/or very low temperature differential sensible cooling elements (e.g., passive chilled beams) have become more popular in Europe. The tendency leads to cooling systems requiring "mildly" chilled water at a level above 14 °C or more, except for processes requiring humidity control (e.g., in hospitals).

Why: The recent improvement in performance of turbo maglev chillers at part load with adaptive condenser and chilled water temperature as per demand, and in combination with cooling tower outlet temperature within 1 K of wet bulb ambient temperature, makes it possible to significantly reduce the electric power for cooling (by more than 50%).

How: Integrate such mandatory conditions in the building energy code (HVAC related)—e.g., chilled water must not be produced by the chiller below 14 °C (or even a higher value).

Who: The national government agency in charge of the energy building codes (HVAC related) should issue a mandatory clause specifying the minimum temperature level allowed for chilled water produced at the evaporator outlet of the chillers (making mixing obsolete as often seen at the early day of radiant cooling). The information about slab cooling in conjunction with this code should be taught by the architecture and engineer associations and at universities and engineering colleges.

Where: It is relevant in all countries, with the exception of very high humidity level climates. In these regions, it is recommended to add a dedicated smaller chiller to produce lower temperature chilled water allowing it to cater to the dehumidification needs (they should not normally represent more than 10-30 % of the total loads).

Implementation timeline: Medium (1-5 years).

Cost: Low if it is integrated in the project at early stages.

Potential significant undesirable side effects of executing the policy: If the building envelopes are not tight, and not kept under a positive internal pressure, it may happen that condensation occurs on the cooling elements.

Policy model to follow: In Switzerland, a nationally building code (Swiss norm SIA 382/1:2014) is applied and successfully enforced.

3.21 Provide credit for occupant-controlled air movement in green building certification programs

Policy number: 21

Category: C1 (Comfort ventilation)

Author(s): Ed Arens & Hui Zhang

Summary: Inclusion of occupant-controlled air movement, such as ASHRAE Standard 55 Sections 5 & 6, in green building certification programs to credit group control of air movement.

POLICY MECHANISM(S)

Regulation	Information	Incentives	R&D	Standards
	✓	✓		✓

TECHNOLOGY TARGET

Specific	Agnostic
✓	

DISRUPTION(S) MITIGATED

Heat Wave	Power Outage
✓	✓

What: We recommend that green building rating programs such as LEED, WELL, and GreenGlobes specifically encourage the wider use of fan-induced air movement in design and retrofits by invoking the new comfort criteria given in ASHRAE Standard 55-2020 (*Thermal Environmental Conditions for Human Occupancy*) Sections 5 and 6. Section 5.3 specifies the boundaries of thermal comfort for different air speeds under two different levels of occupant control. Section 5.4 (and some European standards) increase the comfortable range of the Adaptive Model for different air speeds at higher temperatures, though the level of occupant control is not specified. Section 6 provides five classification levels for the effectiveness of various types of personal- and group-controlled comfort devices using the corrective power metric.

Why: Indoor air movement is an energy-efficient and occupant-responsive means of cooling occupants for their comfort. There are also associated health benefits from increased levels of indoor ventilative mixing, to its ability to help occupants survive extreme temperatures. Indoor air movement has never been part of conventional HVAC or comfort standards, which instead focused on operative temperature and humidity control, and on eliminating cold drafts. Only recently have the positive effects of air movement been properly addressed in standards and computer design tools, allowing their benefits to be exploited in design and retrofit practice. Therefore, green building rating systems should explicitly reference the ASHRAE Standard 55 Sections 5.3 or 5.4, and Section 6, to promote comfort, health, climate resiliency and energy efficiency.

How: Key building stakeholders in Annex 80, industry, academia, and other institutions need to propose text to the relevant green rating systems' committees or editors. The main suggestion is that they should rely on ASHRAE Standard 55 for specifying compliance with their rating requirements.

Who: The proposed revision to green building rating systems would be adopted by the individual programs, such as LEED, GreenGlobes, and WELL. These programs are referenced by architects, engineers, and developers applying for green building accreditation.

Where: This recommendation applies for any geography or at any scale addressed by green building certification programs; limited by the adoption within the building industry of these programs.

Implementation timeline: Short (under 1 year) to propose to the rating systems' organizations; formal implementation would depend on their processes and update cycles.

Cost: Low.

Policy model to follow: The governing standard is currently ASHRAE Standard 55-2020, *Thermal Environmental Conditions for Human Occupancy*.

3.22 Establish more explicit procedures for the design of group-controlled indoor air movement in building energy standards

Policy number: 22

Category: C1 (Comfort ventilation)

Author(s): Ed Arens & Hui Zhang

Summary: To assist design of fan-based cooling systems serving 'groups' (up to six occupants, or up to 84m^2 floor area) per control unit, provide more specific information for modeling compliant fan-cooled buildings in energy standards such as ASHRAE Standard 90.1.

POLICY MECHANISM(S)

Regulation	Information	Incentives	R&D	Standards
	✓			✓

TECHNOLOGY TARGET

Specific	Agnostic
✓	

DISRUPTION(S) MITIGATED

Heat Wave	Power Outage
✓	✓

What: At present ASHRAE Standard 90.1 *Energy Standard for Sites and Buildings Except Low-Rise Residential Buildings* provides for designing with elevated air movement in its performance compliance approach described in Normative Appendix G, Table G3.1. Section 4 allows modeling elevated temperature setpoints in HVAC systems that *automatically* provide occupant thermal comfort by means other than air temperature, provided that they follow the elevated air speed methodology given in ASHRAE Standard 55 Section 5.3.3. This is valuable permission, but burdens designers who at present are largely unfamiliar with what setpoint elevations are appropriate for different types of fan design. Standard 90.1 might provide more granular information about appropriate setpoint rises within the standard itself, perhaps in the form of a table derived initially from corrective power values given in Standard 55 Section 6. Some guidance about fan sizing and spacing might be added. It may also be that the current requirement for automated comfort control does not need to apply in some cases.

Why: Indoor air movement is an energy-efficient and occupant-responsive means of cooling occupants that has not in the past been part of conventional HVAC design. Only recently have the positive effects of air movement been properly addressed in standards and computer design tools, allowing their benefits to be exploited in design and retrofit practice. Designers are still unfamiliar with fan design and with the standards, and would be reassured in their designs with specific data and examples.

How: Annex 80 could propose text or tables to the SSPC 90.1 committee maintaining the standard. The current exception states only that designers should rely on ASHRAE Standard 55 elevated air speed method in specifying technical compliance. Alternatively, the Annex could prepare a paper for the ASHRAE Journal describing, confirming, and illustrating fan-integrated setpoint assumptions that can be safely used in the performance compliance approach. The paper would also lay out applicable design methods for fan spacing, such as the FanTool computer model.

Who: Members of Annex 80, and the SSPC 90.1 committee. We are targeting Standard 90.1 here because it serves as the model for many state and federal energy codes, which are referenced by architects, engineers, and developers applying for building permits. However, similar recommendations may also apply to ASHRAE Standard 90.2, Energy-Efficient Design of Low-Rise Residential Buildings.

Where: This recommendation applies to any regions referencing the ASHRAE energy standard.

Implementation timeline: Short (under 1 year) to propose new materials to the standards committees; formal implementation would depend on committee deliberation processes and standard update cycles. Similar time period for assembling a paper on the same materials for the ASHRAE Journal.

Cost: Low.

Policy model to follow: No model policy to follow. The referenced standard in Standard 90.1 is ASHRAE Standard 55-2020, Thermal Environmental Conditions for Human Occupancy.

3.23 Adopt personal comfort systems in green building programs/systems

Policy number: 23

Category: C2 (Micro-cooling and personal comfort control)

Author(s): Ed Arens & Hui Zhang

Summary: Green building rating systems should encourage the adoption of Personal Comfort Systems in designs for sustainable and resilient buildings.

POLICY MECHANISM(S)

Regulation	Information	Incentives	R&D	Standards
	✓			

TECHNOLOGY TARGET

Specific	Agnostic
✓	

DISRUPTION(S) MITIGATED

Heat Wave	Power Outage
✓	✓

What: Micro-cooling and personal comfort systems (PCS)—also known as Personalized Environmental Control Systems (PECS)— refer to devices, systems, and behavioral options available to occupants that allow them to individually control their comfort within the larger room environment, while potentially saving energy and increasing resilience. WELL, LEED, and GreenGlobes green building ratings can encourage PCS use by referencing the recently introduced classification methodology in Standard 55 Section 6 for crediting personal control over the thermal environment. Different types of PCS are awarded points for their respective "corrective powers"—abilities to offset uncomfortable conditions toward comfort, measured in temperature units. By specifically invoking this methodology, the rating systems will help publicize and increase the adoption of PCS in facilities management, and in energy-efficient building design and operation.

Why: Although it provides significant comfort and energy efficiency benefits, PCS is not explicitly encouraged in WELL and LEED green building rating systems, though these systems do require rating applicants to use ASHRAE Standard 55 to assure comfort in buildings. Since Standard 55 now provides data and a new method of rating the effectiveness of PCS systems in its Section 6 compliance documentation section, green building rating systems should refer to these new requirements explicitly.

How: Annex 80 would suggest proposed text to the relevant WELL, LEED, and GreenGlobes editors. IEA Annex 87: Energy and Indoor Environmental Quality Performance of Personalised Environmental Control Systems could also support this action. The proposed revisions would be adopted by these individual rating programs, which are used by architects, engineers, and developers applying for green building accreditation for innovative and sustainable buildings.

Who: The intended implementers would be the WELL, LEED, and GreenGlobes rating systems. The target audience would be architects/engineers applying for WELL and LEED accreditation who should consider PCS options for increasing their rating score.

Where: This applies at any geography or scale; limited by the adoption within the building industry of the WELL, LEED, and GreenGlobes standards and local equivalents.

Implementation timeline: 1-2 years.

Cost: Low.

Policy model to follow: ASHRAE Standard 55 Section 6 supplies the key metrics and data for classifying PCS.

3.24 Adopt personal comfort systems in ISO and EN standards

Policy number: 24

Category: C2 (Micro-cooling and personal comfort control)

Author(s): Ed Arens & Hui Zhang

Summary: Encourage the adoption of Personal Comfort Systems (PCS) in designs for sustainable and resilient buildings in ISO and EN standards.

POLICY MECHANISM(S)

Regulation	Information	Incentives	R&D	Standards
✓	✓			✓

TECHNOLOGY TARGET

Specific	Agnostic
✓	

DISRUPTION(S) MITIGATED

Heat Wave	Power Outage
✓	✓

What: Encourage use of micro-cooling and PCS in ISO standards, by integrating the ASHRAE Standard 55 Section 6.1.1 classification of personal control over the thermal environment into their indoor environmental quality rating systems. The term "personal environmental control systems" (PECS) is also used to describe personal comfort systems, especially if they include individual ventilative control of outside air.

Why: Although they provide significant comfort and energy efficiency benefits, PCS and PECS have not been explicitly encouraged in ISO standards. ASHRAE Standard 55 now provides a new method of rating the effectiveness of PCS systems in its Section 6 compliance documentation section. ISO might refer to these new requirements explicitly.

How: Key building stakeholders in Annex 80, industry, academia, and other institutions need to propose PCS text to the relevant ISO committees and support it throughout its evaluation. IEA Annex 87: Energy and Indoor Environmental Quality Performance of Personalised Environmental Control Systems could also support this action.

Who: ISO 7730 / EN-16798 standards. The target audience would be architects/engineers using ISO and EN standards.

Where: This applies for any geography or building type.

Implementation timeline: Medium (1-5 years).

Cost: Low.

Policy model to follow: ASHRAE Standard 55-2020, Section 6.1.1 method for classifying PCS effectiveness.

3.25 Disclose the performance of fans for personal comfort

Policy number: 25

Category: C2 (Micro-cooling and personal comfort control)

Author(s): Wendy Miller

Summary: Implement minimum performance standards and labeling/disclosure for ceiling fans and other fans for personal comfort.

POLICY MECHANISM(S)

Regulation	Information	Incentives	R&D	Standards
✓	✓			✓

TECHNOLOGY TARGET

Specific	Agnostic
✓	

DISRUPTION(S) MITIGATED

Heatwave	Power Outage
✓	✓

What: Regulated and voluntary building codes and standards that promote the use of ceiling fans and other fans for personal comfort need to be supported by minimum energy performance standards (MEPS) and labeling that adequately displays information about the quality, performance, efficiency and efficacy of products on the market.

Why: Some jurisdictions include the application of ceiling fans in building regulations, but may refer only to fan diameter rather than to the full aspects of fan performance. Fan performance factors includes efficacy (cubic meters per second per watt, which depends on blade diameter and motor and blade design), noise (particularly for overnight use), controls, and reversibility. Ensuring that these factors are included on product labels will help enhance consumer uptake and confidence. MEPS and mandatory labeling will limit ineffective products from the market.

How: Adoption of established energy performance standards and mandating labeling.

Who: National regulators to create the policy (borrowing from existing policies); fan manufacturers and retailers to execute the policy.

Where: Applicable to all buildings and climate zones. Limitations include room ceiling height, and climates with high temperature and humidity (i.e., limited capacity for evaporation).

Implementation timeline: Short (<1 year) to establish MEPS and labeling requirements; medium (1-5 years) to implement in the market.

Cost: Low to implement and execute.

Potential significant undesirable side effects of executing the policy: None known.

Policy model to follow: Energy-Star certified ceiling fans (USA) or CEL-017 Alternative Current Electric Fans (China).

3.26 Simulate the cooling effect of fans for personal comfort

Policy number: 26

Category: C2 (Micro-cooling and personal comfort control)

Author(s): Wendy Miller

Summary: Incorporate the cooling effect of fans into building thermal modeling / simulation software.

POLICY MECHANISM(S)

Regulation	Information	Incentives	R&D	Standards
	✓			

TECHNOLOGY TARGET

Specific	Agnostic
✓	

DISRUPTION(S) MITIGATED

Heatwave	Power Outage
✓	✓

What: Incorporate the cooling effect of enhanced air movement into building simulation software, especially software used for regulation compliance (building codes) and voluntary programs (e.g., Green Star, LEED).

Why: Some building simulation software has been developed on an assumption that buildings will need artificial heating and cooling systems (HVAC systems). The cooling effect provided by ceiling fans is not included in the software algorithms, and hence hybrid-mode buildings are not adequately examined or designed.

How: Incorporate fans (enhanced air movement) into simulation software to enable assessment of energy and comfort impacts of hybrid buildings (passive design + mechanical air movement, with or without space cooling).

Who: National regulators create incentives for software providers to incorporate enhanced air movement calculations into building simulation software used for regulation compliance or voluntary programs.

Where: Applicable to all building simulation software, for all climate zones and building types.

Implementation timeline: Medium (1-5 years).

Cost: Low to implement and execute.

Potential significant undesirable side effects of executing the policy: None known.

Policy model to follow: Australian House Energy Rating Scheme - approved software.

3.27 Define climate resilience key performance indicators

Policy number: 27

Category: Whole building

Author(s): Mamak P.Tootkaboni & Vincenzo Corrado

Summary: Define and incorporate climate resilience Key Performance Indicators (KPIs) into official reports.

POLICY MECHANISM(S)

Regulation	Information	Incentives	R&D	Standards
✓	✓	✓		✓

TECHNOLOGY TARGET

Specific	Agnostic
	✓

DISRUPTION(S) MITIGATED

Heatwave	Power Outage
✓	✓

What: Climate resilience KPIs should be defined, standardized, and inserted into official reports, such as energy performance certificates, energy audit reports, and building commissioning reports.

Why: To fulfill international objectives of environmental sustainability and zero emission, there is a need to enhance energy performance certificates and energy audit reports with more indicators related to life cycle environmental performance, indoor environmental quality, building smartness, and climate resilience.

How: Expand energy performance and thermal comfort key performance indicators (KPIs) considering future climate data, both long-term (future Typical Meteorological Years [TMYs]), short-term (heatwaves) assessment, and the effects of power outage. In addition, include KPIs to evaluate the resilience, vulnerability, resistance, robustness and recovery capacity.

Who: Standardization bodies should introduce the KPIs; policy makers should adopt them.

Where: No limitation.

Implementation timeline: Medium (1-5 years).

Cost: Medium to implement since some assessment procedures are not yet available in technical standards. Low to execute the policy.

Potential significant undesirable side effects of executing the policy: Difficulty for the final user to fully understand the meaning and importance of resilience KPIs.

Policy model to follow: None.

3.28 Implement resilient cooling strategies in the assessment tools and calculation methods

Policy number: 28

Category: Whole building

Author(s): Mamak P.Tootkaboni & Vincenzo Corrado

Summary: Assess resilient cooling strategies in future whole-building performance assessment tools and calculation methods.

POLICY MECHANISM(S)

Regulation	Information	Incentives	R&D	Standards
✓	✓		✓	✓

TECHNOLOGY TARGET

Specific	Agnostic
	✓

DISRUPTION(S) MITIGATED

Heatwave	Power Outage
✓	✓

What: At the international level (ISO), the technical standards relating to the energy assessment of buildings should be updated to take into account the evolution of climate data (climate change, heat waves) and the adoption of new resilient technologies. Examples of active working items include: revision of the standard ISO 15927-4:« Thermal performance and energy use in the built environment, Calculation methods, Hourly data for assessing the annual energy use for heating and cooling.»; new standard ISO 52016-3: « Energy performance of buildings - Energy needs for heating and cooling, internal temperatures and sensible and latent heat loads - Part 3: Calculation procedures regarding adaptive building envelope elements.»; and a new work item of ISO Technical Committee 205 "Building environment design" for developing the new ISO Standard on «Design and evaluation process of whole-building mechanical ventilation systems in residential buildings.»

Why: Current standardized calculation methods are mostly unfit to assess advanced technologies and adaptive components. Implementations of these methods are required, making it challenging to integrate resilient cooling strategies into calculations.

How: The above-described procedures should be developed and then incorporated in national technical standards and regulations.

Who: Standardization bodies should create the policies. National governments should execute the policies properly.

Where: No limitation.

Implementation timeline: Medium (1-5 years).

Cost: Medium to implement, since some assessment procedures are not yet available in technical standards; low to execute.

Potential significant undesirable side effects of executing the policy: None.

Policy model to follow: Common European standards that increase the accessibility, transparency and objectivity of the energy performance assessment in the Member States facilitating the comparison of best practices and supporting the internal market for construction products.—e.g., European mandate M/480 "Mandate to CEN, CENELEC and ETSI for the elaboration and adoption of standards for a methodology calculating the integrated energy performance of buildings and promoting the energy efficiency of buildings, in accordance with the terms set in the recast of the directive on the energy performance of buildings (2010/31/EU)."

3.29 Launch idea competitions for solutions in resilient cooling

Policy number: 29

Category: Whole building

Author(s): Peter Holzer

Summary: Launch national or international idea competitions for solutions in resilient cooling.

POLICY MECHANISM(S)

Regulation	Information	Incentives	R&D	Standards
	✓	✓		

TECHNOLOGY TARGET

Specific	Agnostic
✓	✓

DISRUPTION(S) MITIGATED

Heatwave	Power Outage
✓	✓

What: Governments or professional bodies launch ideas competitions for solutions in resilient cooling. They make calls for successfully executed projects, organize the Jury, and publicly honor the winners. The publicity of the award ceremony together with professional press work encourages developers and designers and teaches the public.

Why: Most resilient cooling technologies are intrinsically inconspicuous. Thus, they suffer from a lack of public awareness and from a lack of lobbying. In many cases the idea competitions raise awareness which would be helpful in calling attention to resilient cooling solutions.

How: Launch ideas competitions for solutions in resilient cooling. The competitions may be dedicated to specific technologies or targets. They may be organized by government or professional bodies, with contributions from academia, NGOs and other interested parties.

Who: This policy can be created and executed by governmental bodies, NGOs, and other interested stakeholders.

Where: The policy can be applied world-wide.

Implementation timeline: Short (typically 1 year).

Cost: There is a wide scope for costs depending on whether relevant prize money is donated or not. There are successful examples for competitions with and without prize money.

Potential significant undesirable side effects of executing the policy: None.

Policy model to follow: International Global Cooling Prize.

3.30 Take part in the work of IEA EBC

Policy number: 30

Category: Whole building

Author(s): Peter Holzer

Summary: Take part in the research and dissemination activities of the International Energy Agency's program of Energy in Buildings and Communities (IEA EBC).

POLICY MECHANISM(S)

Regulation	Information	Incentives	R&D	Standards
	✓		✓	

TECHNOLOGY TARGET

Specific	Agnostic
✓	✓

DISRUPTION(S) MITIGATED

Heatwave	Power Outage
✓	✓

What: Join the research and dissemination activities of the Energy in Buildings and Communities program (EBC) within the International Energy Agency (IEA), as a government as well as a research institution as well as an industry partner.

Why: The IEA Technology Collaboration Programs offer an excellent chance for scientific exchange and development, encouraging and supporting the implementation of resilient cooling.

How: As a government: sign a national implementing agreement and send a representative to the Executive Committee. As a research institution as well as industry: launch or join specific research programs, the Annexes, and get and exchange knowledge on an international level.

Who: Joining the IEA by signing a national implementing agreement has to be done by governmental representatives. Joining the research programs is open to research institutions as well as industry.

Where: Applicable world-wide.

Implementation timeline: Short (less than 1 year).

Cost: Low.

Potential significant undesirable side effects of executing the policy: None.

Policy model to follow: Relevant to resilient cooling is the IEA Technology Collaboration Program Energy in Buildings and Communities. Currently 25 nations are members of this Program.

3.31 Provide education and training to meet new requirements for codes and programs

Policy number: 31

Category: Whole building

Author(s): Amanda Krelling

Summary: Create education and training programs to help design teams and contractors more cost-effectively and reliably meet new resilience requirements for codes and other mandatory or voluntary programs.

POLICY MECHANISM(S):

Regulation	Information	Incentives	R&D	Standards
	✓			

TECHNOLOGY TARGET:

Specific	Agnostic
✓	✓

DISRUPTION(S) MITIGATED:

Heatwave	Power Outage
✓	✓

What: Create courses and training programs to instruct design teams and contractors about new resilience requirements included in existing and new codes and other mandatory or voluntary programs. An example of a new policy to which a course or training program could be created is a whole-building performance-based standard to assess resilience (see item 2.33).

Why: Proper training of teams involved in the design phase may improve compliance and even cost-effectiveness in the application of policies.

How: Develop courses and training programs to instruct design teams and contractors.

Who: Researchers and industry experts would develop the courses and training programs. Design teams and contractors would be trained.

Where: Applicable worldwide, with scale delimited by each country/region regulatory structure.

Implementation timeline: Short (less than 1 year).

Cost: Low to implement and to execute the policy.

Potential significant undesirable side effects of executing the policy: None.

Policy model to follow: In France, multiple certified organizations provide training programs specifically targeted to different audiences. These include private parties, such as training companies (e.g., APAVE), engineering offices (e.g., TRIBU), and the French architects association; and public parties, such as the CSTB (Scientific and Technical Center for Buildings), who produced the French building thermal regulation.

3.32 Prescribe strategies and technologies to deal with overheating

Policy number: 32

Category: Whole building

Author(s): Amanda Krelling

Summary: Prescribe strategies and technologies in codes and standards that can help buildings deal with overheating, even in heating-dominated climates.

POLICY MECHANISM(S):

Regulation	Information	Incentives	R&D	Standards
✓	✓	✓	✓	✓

TECHNOLOGY TARGET:

Specific	Agnostic
	✓

DISRUPTION(S) MITIGATED:

Heatwave	Power Outage
✓	✓

What: Prescription or recommendation of strategies and technologies in codes and standards to cope with overheating. Development of technical material to inform and guide design teams to adopt these strategies, which can also be fostered by available incentives to contractors. R&D should be conducted to support the choice of the most effective strategies and technologies.

Why: The prospected increase of heat-related extreme events worldwide highlights the need to re-assess the strategies and technologies adopted in buildings, even in notably heating-dominated countries, whose building stock is often unprepared to deal with overheating.

How: Development of a solid national or regional framework to encourage the adoption of strategies and technologies to cope with overheating, including codes, standards, training programs, and incentives, as well as R&D to support the choice of the best solutions for each context. Associated carbon emissions may also be accounted for when selecting solutions to minimize contribution to climate change.

Who: Researchers and industry experts would develop the regulations, standards, and training programs, and take part in R&D partnerships. Incentives may be developed and regulated by the government, power utilities, or other parties, depending on the strategy or technology.

Design teams would follow regulations and standards, and take part in training programs. Contractors may benefit from incentives.

Where: Nearly worldwide, encompassing countries and regions where overheating is significantly expected to increase in the near-medium future.

Implementation timeline: Short (less than 1 year) for training programs (information) and to launch incentive programs. Short to medium (1-5 years) for R&D. Medium to long (greater than 5 years) to develop and approve new regulations and standards.

Cost: Low to create regulations, training programs (information) and standards. Medium-high to fund R&D and incentives.

Potential significant undesirable side effects of executing the policy: Potential for fraud if the incentive programs are not adequately administered.

Policy model to follow: The Colombian Resolution No 000463 defines energy efficiency strategies eligible to receive tax benefits, including cool envelope materials, and advanced solar shading and glazing.

3.33 Establish a procedure to assess the thermal resilience of buildings, considering the occurrence of extreme weather conditions and other disruptions

Policy number: 33

Category: Whole building

Author(s): Amanda Krelling

Summary: Include a procedure to whole-building performance-based standards where the thermal resilience of a building is evaluated, especially assessing its response under stressful conditions (e.g., heat waves, power outages, future climates).

POLICY MECHANISM(S):

Regulation	Information	Incentives	R&D	Standards
				✓

TECHNOLOGY TARGET:

Specific	Agnostic
	✓

DISRUPTION(S) MITIGATED:

Heatwave	Power Outage
✓	✓

What: Develop whole-building performance-based procedures to assess the thermal resilience of buildings. These procedures could be established through new standards or could complement standards that already address the thermal performance and/or energy efficiency of new and existing buildings. They are typically based on building performance simulation.

Why: The prospected increase of heat-related extreme events worldwide highlights the need to assess buildings beyond typical climate and operating conditions in order to enhance resilience against present and future threats.

How: Develop a standardized framework to evaluate the thermal resilience of buildings when exposed to diverse conditions, from typical conditions (i.e., the current typical procedure in performance-based policies) to extreme conditions (e.g., including heat waves, power outages, and/or future climates). This framework should consider adequate key performance indicators (KPIs) that can assess aspects related to resilience, such as vulnerability, resistance, robustness, and recovery capacity. Examples of KPIs are the Indoor Overheating Degree (IOD) (HAMDY et al, 2017), the Passive Habitability (PH) (KESIK et al, 2022), the Thermal Autonomy (TA) (KO et al, 2018), and the Hours of Exceedance (HE) (CIBSE, 2013).

Who: Researchers and industry experts would develop the standards. Design teams would follow the standards.

Where: Applicable worldwide, but standards must be developed in light of local climate characteristics and building practices.

Implementation timeline: Medium (1-5 years) to long (greater than 5 years).

Cost: Low cost to implement the policy. Low-medium to execute, depending on the complexity of the standard.

Potential significant undesirable side effects of executing the policy: May increase the cost of construction if needed to adopt additional strategies and technologies to respond to extreme events.

Policy model to follow: At the international level (ISO), the technical standards relating to the energy assessment of buildings are being updated to consider the evolution of climate data (i.e., the occurrence of climate change and heat waves). Active working Items include the revision of the standard ISO 15927-4, which could provide the base for defining suitable scenarios for the evaluation of resilience under future and extreme climates.

3.34 Introduce stretch or reach codes to encourage building performance above the minimum requirements

Policy number: 34

Category: Whole building

Author(s): Stephen Selkowitz

Summary: "Stretch codes" and variants can provide design guidance and technical goals to designers and owners who want to exceed code minimum performance requirements.

POLICY MECHANISM(S)

Regulation	Information	Incentives	R&D	Standards
✓		✓		✓

TECHNOLOGY TARGET

Specific	Agnostic
	✓

DISRUPTION(S) MITIGATED

Heatwave	Power Outage
✓	✓

What: Traditional building codes prescribe minimum acceptable performance standards. They describe the least efficient building one is legally allowed to build, primarily using prescriptive criteria, although in some cases with performance-based tradeoffs. They are set at levels where the technology solutions to meet them are widely available via existing industry supply chains and are "cost effective". A new approach, "step codes" adds a series of incremental performance enhancements (e.g., 10%, 20%, 30% better than baseline) based on a tiered or stepped series of enhanced solutions in the requisite properties of the materials, components, and systems going into a building.

Why: Conventional prescriptive minimum standards are typically conservative and change slowly. They generally are limited by current practice rather than being a driving market force to enhance the efficiency of buildings. This approach has the potential to encourage and support leading-edge product and new product development as well as best current practices or new design practices.

How: These can be implemented in much the way that traditional codes are developed and implemented but they provide additional design and performance options that go beyond what the codes typically prescribe today. This means that they must be accompanied by the same administrative infrastructure that will then assess and confirm code compliance to new and more stringent levels of performance using existing product rating systems. The solutions tend to be whole building performance oriented although they could provide guidance on specific technologies and building systems that are expected to achieve the desired whole building targets. In some cases—e.g., where dynamic solutions with sensor-based control are utilized—documentation of proper commissioning can show compliance, or the appropriate regulatory entities could require that measured building performance data be provided to verify that performance was achieved.

Who: Local, state, and national code bodies would take the lead, working with researchers, industry groups and design communities to be sure the requirements are reasonable and executable. Stretch codes will generally be executed by the same regulatory bodies that administer conventional energy codes and standards. They might be coupled to utility rebate programs to provide incentives to achieve higher performance levels.

Where: The approach is applicable, in principle, over any climate, geography, and building scale although the technical details and potentially implementation details might vary considerably. For example, in cold climates we would expect the higher steps to dramatically reduce envelope thermal transmittance ("U-factor"); in very hot climates the focus might be on new dynamic shading or glazing solutions that reduce solar heat gain.

Implementation timeline: Generally similar to existing code cycles, typically 1-5 years.

Cost: Probably somewhat more costly than traditional prescriptive codes but perhaps less costly than performance-oriented code pathways where new software development might be needed.

Potential significant undesirable side effects of executing the policy: Potentially new approaches like this could be "gamed" to reduce the value of the exercise. It also adds some complexity and potentially administrative cost to the process of code compliance although this should be minimal if the enhanced options are well planned.

Policy model to follow: In the US, the Building Codes Assistance Project provides examples of successful solutions adopted at the city and state levels. Some examples are given for two states and two cities: Massachusetts, New York State, City of Santa Monica, City of Vancouver, BC – see here.

3.35 Adopt a performance-based heat resilience ordinance

Policy number: 35

Category: Whole building

Author(s): Haley Gilbert

Summary: Recommend localities adopt a residential building ordinance for performance-based heat resilience.

POLICY MECHANISM(S)

Regulation	Information	Incentives	R&D	Standards
✓				

TECHNOLOGY TARGET

Specific	Agnostic
	✓

DISRUPTION(S) MITIGATED

Heatwave	Power Outage
✓	✓

What: Localities are considering regulations with performance metrics to maintain safe indoor conditions for residential building occupants during heat and/or power outage events. These heat resilience metrics would allow for a variety of technologies to flexibly meet the performance requirement(s) depending on the residence. This is recommended for both existing buildings and new construction. It should be a requirement for rental properties where tenants rely on the building owner to maintain the property.

Why: The health impacts of extreme heat include heat stress, heat stroke, morbidity, and mortality. Therefore, it is important to develop a performance-based ordinance for heat resilience to safeguard building occupant health. This is especially important in rental homes as well as in low-income communities that are vulnerable to extreme heat.

How: Localities can work with national entities to develop (or reference if available) the best heat resilience metric for their climate and building stock (e.g., max indoor temperature). Code officials and tenant/housing departments need to support enforcement efforts. Building stakeholders need to develop resources to aid compliance (e.g., building modeling tools, monitoring compliance plan, factsheets, prescriptive checklist, tenant outreach). One example of performance metric would be "Standard Effective Temperature Unmet Degree Hours (SETUDH)". See Sun et al. (2021).

Who: Implemented by localities (city councils, mayors) with support from local health officials, residential building stakeholders, local code officials, and tenant/housing departments.

Where: Would be appropriate for widespread implementation anywhere there are heat-related deaths.

Implementation timeline: Short when there is local political support.

Cost: Low to execute if included in other building code; medium to implement depending on building design, operations, or technologies to meet requirements.

Potential significant undesirable side effects of executing the policy: Could lead to increased energy use if improperly implemented (e.g., installation of large air conditioners).

Policy model to follow: In Vancouver, Canada in the BC Energy Step Code (BCESC) and the City of Vancouver Zero Emissions Building Plan (ZEBP) there are limits for overheating. For spaces that do not use any mechanical cooling, temperatures cannot exceed "80% acceptability limits" for more than 200 hours during the summer months. The 80% acceptability limit is a specific temperature during the summer months at which overheating can be a concern, which varies depending on the building's location. This limit is calculated using a methodology defined in ASHRAE Standard 55. See here, p. 15.

3.36 Revise whole-building policies to account for future climate and heatwaves

Policy number: 36

Category: Whole building

Author(s): Mamak P.Tootkaboni & Vincenzo Corrado

Summary: Revise all building energy performance policies to account for future climate and heatwaves.

Policy mechanism(s)

Regulation	Information	Incentives	R&D	Standards
✓		✓		✓

Technology target

Specific	Agnostic
	✓

Disruption(s) mitigated

Heatwave	Power Outage
✓	✓

What: Revise performance parameters/ threshold values/recommendations related to cooling technologies to account for climate change and heatwave risks.

Why: Current building energy performance policies do not include measures that assure climate resiliency. This defect is caused by considering the current typical meteorological year (TMY) as the determinant factor in developing parameters, threshold values, or recommendations. Future climate data—both long-term (future TMYs) and short-term (heatwaves)—and the effects of power outages should be considered in policy development.

How: Investigate the cooling technologies for different building types and climate zones to determine the best fitting requirements according to different boundary conditions.

Who: National governments should create and execute the policies and incentives properly.

Where: No limitation.

Implementation timeline: Medium (1-5 years).

Cost: Low to medium.

Potential significant undesirable side effects of executing the policy: If there is greater need for resilience measures / passive survivability in increasingly extreme climates, costs may rise.

Policy model to follow: The French thermal regulation RE-2020 for the design of new buildings uses the 2003 heatwave to calculate the summer thermal comfort criterion. In France, 2003 is a reference heatwave that caused excessive morbidity and mortality, and is expected by climatologists to occur every 2 years by 2050. Using a past heatwave to calculate the summer thermal comfort criterion is an easy first step to account for climate change in the design of buildings.

3.37 Integrate climate resilience into whole-building policies

Policy number: 37

Category: Whole building

Author(s): Mamak P.Tootkaboni & Vincenzo Corrado

Summary: Harmonization of climate resilience policies with policies related to other related domains.

POLICY MECHANISM(S)

Regulation	Information	Incentives	R&D	Standards
✓	✓			✓

TECHNOLOGY TARGET

Specific	Agnostic
	✓

DISRUPTION(S) MITIGATED

Heatwave	Power Outage
✓	✓

What: Climate resilience policies should be fully integrated with policies concerning indoor environmental quality, energy efficiency, fuel poverty, decarbonization, and environmental sustainability, cost effectiveness, and safety of building occupants.

Why: Since different policies have different purposes, they imply recommendations which might be in contradiction with each other. Thus, climate resilience policies cannot be developed as standalone policies. For instance, different ventilation flow rates are determined when considering either indoor air quality, or cooling needs or cost effectiveness.

How: Investigate the accordance and conflicts between different policies and adopt multiparameter optimization procedures. The potential consequences of each policy for all other policies should be simultaneously considered.

Who: National and local governments.

Where: No limitation.

Implementation timeline: Medium (1-5 years).

Cost: Low to medium.

Potential significant undesirable side effects of executing the policy: If there is greater need for resilience measures / passive survivability in increasingly extreme climates, costs may rise.

Policy model to follow: None.

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ANNEX 80

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