19–21 October 2022,
Gatineau, Québec, Canada

Final Report

2022 Future Buildings Forum Think Tank Workshop

Existing Buildings:
Pathways to Net Zero Carbon 2035

FUTURE BUILDINGS FORUM

Cover picture: A view of Gatineau, Québec, Canada

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Executive Summary

The IEA Future Buildings Forum (FBF) Think Tank Workshop was convened in October 2022 in Gatineau, Canada, with the theme, 'Existing Buildings: Pathways to Net Zero Carbon 2035'. This Workshop was organised through the combined efforts of the IEA Buildings Coordination Group (BCG), its member ***Technical Collaboration Programmes (TCPs)***, and Canada as the host country. Its purpose was to identify the international collaborative research, development, and demonstration (RD&D) activities needed to unlock deployment of low and zero carbon technologies in existing housing and buildings and to generate new ideas to:

- Identify collaborative RD&D project concepts intended to be jointly carried out by the buildings-related TCPs that consider the information and data requirements of the receptors of the eventual outcomes of those projects;
- Identify collaborative focus areas to include in the future Strategic Plans of the buildings-related TCPs;
- Identify activities to strengthen the IEA Buildings Coordination Group and improve the collaboration between the IEA Secretariat and the buildings-related TCPs.

Over the three days of the forum, participants representing nine TCPs discussed how to bring the existing building stock to performance levels that would meet the international GHG reduction targets. The discussions were structured around four dimensions/sessions, namely:

'Deep' Energy Retrofit – Challenges and Opportunities

Addressing approaches and activities around energy retrofits of buildings that achieve a minimum energy consumption reduction of 40%.

Systems as Transformational Process

Dealing with reducing operational carbon in buildings and the thermal and electrical grids that serve them.

Technological Systems as Catalysts for Future Proofing Buildings

Addressing the operation and future proofing of retrofitted building systems.

Building Energy and Carbon Codes

Evaluating applicability of metrics and the integration of new technologies in energy and carbon codes.

The breadth of issues discussed in the four sessions was facilitated by the diversity of expertise and background of the participants: academia and government researchers, utilities, associations, policy, designers, developers, consulting engineers. Regardless of the issue or participant background, however, the urgency of what needs to be done was palpable throughout the workshop.

The participants identified collaborative RD&D project concepts that are included as part of this report. These project concepts could help with the development of the future Strategic Plans of the buildings-related TCPs. They are clustered in Appendix 2.

The collaborative activities, however, need a foundation on which to develop into full blown Annexes or Tasks, and the current inter-TCP collaboration structure is not conducive to cross-TCP collaboration. Given the urgency of meeting the GHG targets, the participants raised the challenge of improved collaboration repeatedly.

In response to the challenge of inter TCP collaboration, the FBF Workshop participants identified the following initiatives that need to be taken:

1. **Include 5-minute BCG TCP presentations into the agenda of each TCP's Executive Committee meeting:** Having such presentations as part of the meetings will provide the framework upon which subsequent discussions on new and existing Annexes / Tasks can be viewed and catalyse ideas for cross-TCP collaboration.
2. **Create a database of experts accessible to all BCG TCPs:** Researchers and national experts are aware of the expertise in their own, limited, domain. Establishing an international database of experts will facilitate the interactions and raise the potential for collaboration.
3. **Require new BCG TCPs Annexes / Tasks to carry out an analysis of opportunities for inter-TCP activities:** For instance, Operating Agents would be expected to use the database of experts to identify links to expertise in other TCPs.
4. **Create a process to evaluate and progress the research ideas generated through the FBF Workshop to develop full cross-TCP collaborative projects:** The first step would be to facilitate cross-TCP activities, and the next could be that online meetings are held, led by the respective Work session coordinators with the objective of further developing the collaborative projects. In this way, coordinated collaborative project proposals would be created from the outset for consideration by the relevant TCP Executive Committees.

While steps can be taken at the TCP level, the participants stressed the need for the IEA Secretariat to set in motion a process to review the options for formally facilitating such collaboration.

1. Introduction

Convened through the combined efforts of the *IEA Buildings Co-ordination Group (BCG)* member TCPs and the host country, the purpose of the Future Building Forum (FBF) Think Tank Workshops is to allow the International Energy Agency's (IEA) buildings-related *Technology Collaboration Programmes (TCPs)* to periodically discuss the research, development, and demonstration (RD&D) activities that will be needed over the upcoming five-year period, to achieve ambitious and disruptive deployment of technologies at scale by an agreed target date, typically 15 to 20 years ahead. These workshops are convened through the combined efforts of the BCG, member TCPs, and the host country.

The aim of the FBF Think Tank Workshop 2022 was to promote collaboration between the buildings-related TCPs by defining the RD&D activities that need to be carried out, prior to large scale deployment, for the buildings sector and for addressing the existing buildings, within the context of the IEA's 'Net Zero by 2050: A Roadmap for the Global Energy Sector' published in 2021.

Specifically, the purpose is to identify the international collaborative RD&D activities needed to unlock deployment of low and zero carbon technologies in existing housing and buildings and to generate new ideas to:

- Identify collaborative RD&D project concepts intended to be jointly carried out by the buildings-related TCPs that consider the information and data requirements of the receptors of the eventual outcomes of those projects;
- Identify collaborative focus areas to include in the future Strategic Plans of the buildings-related TCPs;
- Identify activities to strengthen the IEA Buildings Coordination Group and improve the collaboration between the IEA Secretariat and the buildings-related TCPs.

2. Structure of the workshop

The Forum's theme and subjects were developed collectively by an advisory board that was composed of the IEA Secretariat, the Chair of the Buildings Coordination Group (BCG) as well as representatives of the participating BCG TCPs. It was felt that the most significant challenge in decarbonizing the built environment rested with the existing buildings and as such, the Advisory Board developed four sessions:

'Deep' Energy Retrofit – Challenges and Opportunities

Systems as Transformational Process

Technological Systems as Catalysts for Future Proofing Buildings

Building Energy and Carbon Codes

These were developed into sessions lasting approximately three hours with approximately one hour devoted to presentations to set up the stage and frame the discussions, followed by two hours of discussion in breakout groups.

Responsibility for the content of each session was shared between the advisory board and two coordinators who were responsible for setting the stage for the session and wrapping up the discussion.

The ultimate design and operation of the workshop was handled through a professional facilitator that created the environment where all participants were encouraged to fully participate in the discussions.

The four sessions were bookended by an introductory session and a concluding one whereby the overall conclusions were presented, and next steps discussed.

3. Content of the workshop

Session 1: Welcoming comments — View from the bridge

October 19th, 2022, AM

Session Coordinators	
Meli Stylianou	Chair, FBF Advisory Board / Manager, Housing and Buildings R&D, Natural Resources Canada
Takao Sawachi	Chair, ExCo, Energy in Buildings and Communities TCP / President, Building Research Institute

To kick off the three-day workshop, Meli Stylianou, Chair of the FBF Advisory Board and Manager of Housing and Buildings R&D at Natural Resources Canada welcomed the participants, provided an overview of the agenda, offered some opening remarks, and noted that the FBF is one of the rare times this group of people are able to meet in person to find common interests and develop collaborative solutions. Mr. Stylianou also noted that the discussions stemming from the forum are only a starting point for continued collaboration beyond the three-day workshop in the form of working groups and future discussions.

Following Mr. Stylianou's opening remarks, Assistant Deputy Minister of the Energy Efficiency and Technology Sector at Natural Resources Canada, Drew Leyburne, set the stage for the forum. Mr. Leyburne underlined Canada's urgent need to reduce carbon emissions with an aim to achieve net-zero by 2050 across the economy with an interim goal of 37% reductions by 2030 for the built environment. Mr. Leyburne recognized that much of the heavy lifting to achieve Canada's carbon-reduction goals are to come in the form of building retrofits and underlined some of the initiatives that Canada is taking including research, new technology and codes. Mr. Leyburne also recognized other factors that need to be considered including industry's capacity to grow, building operation and optimization, and ensuring that buildings provide a safe, comfortable and productive environment for people. Recognizing the knowledge and expertise around the room, Mr. Leyburne encouraged the discussion of ambitious yet feasible solutions to meet the 2030 carbon goal.

Setting the Stage for Collaboration

Takao Sawachi, Chair, IEA EBC, was then invited to welcome participants and deliver a presentation on the importance of TCPs. Dr. Sawachi explained that in order to reach 2030 and 2050 goals, average energy efficiency of buildings must be significantly improved. TCPs were positioned as an integral means of improving energy efficiency through international collaboration and alignment on research and development projects. Within each TCP there are between 10 and 28 countries that collaborate in research projects that aim at achieving the Carbon reduction goals of the IEA. Dr. Sawachi's *full presentation* can be found appended to this document.

The Canadian delegate to the IEA End-Use Working Party, Philippe St Jean, was then invited to deliver a presentation on combining global efforts for building decarbonization. Mr. St Jean outlined the ways in which international collaboration can benefit sector transitions, lead to more widespread adoption of effective policies, accelerate innovation, create stronger signals for investment and establish a level playing field to ensure competition acts as a driver of the desired transition. Mr. St Jean outlined the approach informed by four core objectives that are being followed closely by the FBF process including providing a link to relevant TCP annexes and task information for quick and easy access, fostering TCP cross-exchanges by developing, analysing, and reviewing key analytical subsets, providing an entry point to users unfamiliar to the TCP network and developing products jointly with participation of non-building related TCPs. Mr. St Jean also described the four key characteristics that are commonly shared by successful collaborations:

1. A strong common interest in the specific topic across key stakeholders;
2. A champion or core group to shepherd an idea through the development stage;
3. Availability of resources for collaborative projects;
4. A sound process or incentive for collaboration.

These key characteristics were in mind when the Advisory Board developed the content of this event with the purpose of identifying international collaborative party activities needed to unlock the deployment of low and zero carbon technologies in existing housing and buildings. Mr. St Jean's *full presentation deck* can be found appended to this document.

Following the opening presentations, representatives from each TCP present at the workshop were invited to deliver a five-minute presentation addressing the following:

- The three most important issues they are currently facing in their Tasks / Annexes;
- What they expect as the three most important issues that they will need to face over the next five years;
- What TCPs can contribute to successfully address and resolve these issues.

The presentations were delivered by the following TCP representatives and can be found appended to this document.

TCP	Representative
Cities	*Helmut Strasser*
DHC	*Robin Wiltshire*
EBC	*Takao Sawachi*
ES	*Teun Bokhoven*
HEV	*René-Pierre Allard*
HPT	*Stephan Renz*
PVPS	*Costa Kapsis*
SHC	*Lucio Mesquita*
Users	*David Shipworth*
4E	*Casper Kofod — Not presented*

The session facilitator, Ms. Coutinho, along with Mr. Stylianou, then provided an overview of the process to take place over the three-day workshop. Each session would include introductory remarks by the session coordinators followed by a series of presentations by various experts designed to inform the discussion. Following the presentations, participants would then be instructed to select a topic of interest for each session and break themselves out into a corresponding breakout group. To achieve the most out of this process, each breakout group assigned themselves a facilitator to guide the discussion, a notetaker, a timekeeper and a rapporteur to present their group's results in plenary.

To familiarize participants with the process, Ms. Coutinho invited participants to take part in an opening table discussion to achieve the following goals:

- Get to know one another — explore work experience / personal information;
- Build commitment — develop group norms and build ownership for outcomes;
- Clarify expectations — hopes and concerns.

Session 2: 'Deep' Energy Retrofit — Challenges and Opportunities

Session Coordinators	
Paul Ruyssevelt	Vice Chair, Energy in Buildings and Communities TCP / Professor, UCL
Costa Kapsis	Task 15 Subtask Co-Leader, Photovoltaic Power Systems TCP / Assistant Professor, University of Waterloo

Objectives

1. Identify RD&D activity concepts that can be developed to address retrofit challenges to deliver net zero carbon emissions by 2050 in:
   - Single family houses / low rise multifamily buildings;
   - High rise multifamily buildings;
   - High-rise commercial and public buildings.
2. Discuss the balance to be drawn between retrofit measures that reduce energy demand and measures that decarbonise heating / cooling and electricity supplies.

Presentations

Introductory remarks were made by session coordinator, Paul Ruyssevelt, followed by four presentations centred around the results from research on minimizing operational carbon through deep energy retrofits including whole building retrofit, renovation of envelopes, replacement of the mechanical systems, decarbonisation of heating and cooling systems, and inclusion of embedded renewable energy technologies. The presentations, which can be found appended to this document, included the following:

1. *PEER — an Enegiesprong-inspired process presented by Mark Carver, Housing Team Project Coordinator, CanmetENERGY, Natural Resources Canada*
2. *Results and challenges associated with the deep retrofit of commercial buildings presented by Alexandre Zhivov, Operating Agent, EBC Annex 73 / Mechanical Engineer, US Army Network Enterprise Technology Command*
3. *Results and challenges associated with the deep retrofit of residential buildings presented by Manuela Almeida, Operating Agent, EBC Annex 75 / Associate Professor at the Civil Engineering Department of the Minho University*
4. *Implications of energy retrofits on IEQ presented by Bjarne Olesen, Operating Agent, EBC Annex 87 / Head of International Centre for Indoor Environment and Energy, Technical University of Denmark*

Breakout Discussions

Participants were asked to identify RD&D activity concepts that can be developed to address retrofit challenges to deliver net zero carbon emissions by 2050. The focus of the discussion was to include considerations for accelerating deployment.

The following prompts were provided for breakout room discussions:

- Depth of retrofit possible/desirable;
- Relevance of carbon intensities of energy supplies as context now and in future;
- Constraints and challenges for:
  - Envelope measures;
  - Fuel switching for heating and cooling;
  - Embedded renewable technologies.
- Consequences for:
  - Internal environment (IAQ, overheating etc.);
  - Fossil fuel supplies;
  - Electricity distribution networks and grids;
  - Supply chain and resources;
  - Embodied carbon.

Breakout Group A — Residential (single homes and apartment buildings)

Participants in the "Residential" breakout group were asked to identify three to five priority areas for research that will address the key challenges and support the acceleration of deployment.

The following points reflect the discussion in breakout group A:

1. Research is needed to determine when it is better to do a complete demolition-reconstruction vs. when to do a deep retrofit from the energy and carbon perspectives.
2. Evaluate the need for an "integrator" or concierge service to accelerate implementation. This will make sure everyone is heard and on the same page with regards to finance issues, policy, etc. to accelerate implementation.
3. Research is needed to determine a method in which code implementing authorities (Authorities Having Jurisdiction: AHJ's) can establish appropriate Key Performance Indicators (KPI's).
4. Research is needed to determine how to improve the rate of retrofit through standardization, digitization, robotics, etc.
5. Explore a range of solutions to manage the increase in PV load on the electricity network while considering the right environment to use each solution in terms of cost effectiveness and other factors.
6. Improve the understanding of the building stock. There is a need for better and more accessible information on the status of the current stock and what can be done with it.
7. Explore innovative ways to streamline construction.
8. Explore how to better enable and empower building owners.
9. Explore how to address technologies as they approach end of life
10. Research into standardized mechanical systems including plug-and-play concepts that are user-friendly.
11. Study bulk purchase programs from around the world, particularly related to solar.
12. Study social factors to achieve engagement/buy-in from homeowners.
    - What are ways that homeowners can be incentivized if not with cost-effectiveness?

Breakout Group B — Commercial and Public Buildings

Participants in the commercial and public buildings group were asked to Identify 3 to 5 priority areas for research that will address the key challenges and support the acceleration of deployment.

The following points reflect the discussion in Breakout Group B:

1. Determine the drivers of action for a deep retrofit and assess their impact.
2. Research to understand how market forces affect deep energy retrofits and understand how to best create value through incentives through:
   - Improved lifecycle costs;
   - Innovation in financing;
   - Ownership models.
3. Research is required on the role of smart buildings to gain additional insight on how things can be standardized and automated in deep retrofits.
4. Disseminate best practices and strategies in terms of recommissioning using digital tools and more easily accessed information such as guidelines.
5. Explore standardized labelling or disclosure around indoor environmental quality or embodied carbon.
6. Research to explore the application of different types of heat pump (air/water/ground source) in deep energy retrofits.
7. Evaluate the use of energy renovation passport (a program to indicate a building is performing at a certain level) for non-residential buildings including the timing and contribution of each stage of a retrofit.
8. Evaluate predefined systems through modeling various configurations more efficiently to get to implementation faster.
9. Evaluate the impact of refrigerants with differing global warming potential in deep retrofits.

Discussion Summary

Throughout the plenary report-out, cross-cutting themes that emerged included

- Generating user interest and participation;
- Communication and access to information through digitalization, databases etc., and;
- Standardization of technology, mechanical solutions and processes.

Session 3: Systems as Transformational Process

Session Coordinators	
Teun Bokhoven	Chair, ExCo, Energy Storage TCP / Chair, TKI Urban Energy
Robin Wiltshire	Chair, ExCo, District Heating and Cooling TCP / BRE Building Research Establishment

Objectives

Decarbonizing energy consumption in buildings and districts require an optimized interaction between a mix of renewable energy sources (Photovoltaics (PV), Solar Thermal, Ambient Air, Geothermal), a range of energy efficiency options (insulation, heat recovery, recycled heat, etc.), several flexibility options (Demand side management and energy storage), and the energy infrastructure (electricity, heat or cold). In this context, the interaction of energy sources, efficiency measures, flexibility options, and infrastructure are referred to as the 'building or district energy system'. We focus mainly on the existing building stock and districts while also examining the benefits of an integrated approach that includes new build districts. Transforming this system - from a carbon emitting process to a decarbonized and renewable system, was the scope of this session. For the existing building stock, this will most likely require a series of incremental steps.

Presentations

Introductory remarks were made by session coordinator, Teun Bokhoven, followed by four presentations related to the session topic that can be found appended to this document. The presentations were as follows:

1. *Deployment of renewable/recycled energy and flexible sector coupling in buildings presented by Teun Bokhoven, Chair ExCo Energy Storage TCP/Chair, TKI Urban Energy*
2. *Optimization and transition of district energy systems to lower temperatures presented by Robin Wiltshire, Chair, ExCo District Heating & Cooling TCP/BRE Building Research Establishment*
3. *Reducing CO_2 emissions in cities- key measures and state of the art cases presented by Helmut Strasser, Chair, ExCo, Cities TCP/Head of Energy at SIR*
4. *Transforming buildings into great citizens of the electric power system presented by Steven Wong, ISGAN Working Groups 6 and 9 / Senior Technical Advisor, Natural Resources Canada*

Breakout Discussions

In keeping with serving the occupants requirements and comfort, participants were tasked with exploring routes and research topics to optimize the interaction among various technological solutions which collectively can reduce the [greenhouse gas] CO_2 emissions to zero in buildings, districts, and cities.

Participants were asked to formulate the top three to five research topics and other measures such as legislation, policies, standards, etc. guided by the following discussion prompts:

- Interactions between various technologies;
- How to reach the optimal balance between the various technologies;
- How to implement identified technological solutions (in legislation, financial/business models, stakeholder-involvement etc.);
- How to manage this transformation process from the perspective of the user and the building owner(s).

Breakout Group A — System Optimization

The following points reflect the discussion in Breakout Group A:

1. Research is required to better understand impact of system optimisation on the user in particular:
   - What influences the acceptance of district energy systems to operate;
   - Definition of what data collection is necessary, possible;
   - How to improve user accessibility to the solutions;
   - Better define how to achieve comfort levels;
   - Improved robustness and credibility of flexibility demand resources;
   - What price incentives are necessary, possible.
2. Research to achieve a better understanding of the transition pathways.
3. Research to better coordinate energy supply (spatial and temporal) through digitalization and demand generated by “smart” systems.
4. Research to manage diversity in domestic renewable production options (photovoltaics, solar thermal, heat pumps, geothermal) to match diverse load patterns.
5. Define market constraints/mechanisms including the utilities side actions, legal structure, effective pricing incentives and how to encourage voluntary participation.
6. Improve real world assessment and reporting of GHG emissions in buildings.
7. Develop aggregated datasets for cost, emissions, and energy for buildings at a regional level.
8. Map available unexploited heat sources.
9. Research on development of integrated energy systems specifically for remote communities.
10. Identify solutions for rapid electrification, energy flexibility, prediction, and activation.
11. Develop case studies/websites to share practical experience on operating energy markets and evaluate carbon reduction outcomes.
12. Develop and expand digital platforms to share information and visualize energy flows.

13. Integrate Users TCP perspectives on occupant/operator behavior.
14. Obligate new TCPs/Annexes within the scope of the built environment to undertake literature reviews / interviews during planning and start-up phases to see what and when inter-TCP activities can be included.
15. Develop vision for future energy system and determine how buildings can contribute to national goals.
16. Define when storage is appropriate as a means of balancing impacts on the grid as a feasible economical option.
17. Develop scenarios for using interactive equipment.
    - Intercommunication and planned interaction between devices such as photovoltaics, heat pumps, electric vehicles and charging stations and storage.
18. Develop and apply model predictive control through artificial intelligence and/or machine learning for building energy systems.
19. Define when centralized systems are appropriate and when decentralized ones are (Consider a different way of thinking (decentralized vs. centralized supply).)

Breakout Group B — Districts and Cities

The following points reflect the discussion in breakout group B:

1. Define benefits of urban digital twins (UDTs) for the different stakeholders.
2. Consider implementation instrument:
    - Policies, regulations, and incentives;
    - Collaboration across stakeholder groups;
    - Financial and business models;
    - Non-financial arguments.
3. Quantifying benefits/limitations of district level vs. building level solutions (complexity, intervention, privacy).
4. Create database of demonstration projects (accelerate deployment).
5. Identify mechanisms to enable flexible operation (including potential financial incentives).
6. Consider the development of integrative entities for energy services.
7. Quantify/Define amount of flexibility required at the city level.
8. Quantifying energy wasted from different streams and the quality of this energy.
9. Research to improve data availability for planning purposes and forecasting.
10. Developing and documenting business models that can be broadly shared to create synergies.

Discussion Summary

Following the plenary presentations, session coordinator, Robin Wiltshire, offered some summary remarks in which he identified some cross-cutting themes. Dr. Wiltshire noted that flexibility came up in a variety of contexts and is something that can be explored across TCPs. The issue of data availability and harnessing data at different scales was also identified as a cross-cutting theme. Dr. Wiltshire mentioned that work needs to be done to ensure data is used in the most practical and beneficial way. Pathways to transition also came up in a variety of contexts as did coordination and synthesis between tools to allow for concepts such as urban digital twins to be successful.

Session 4: Technological Systems as Catalysts for Future Proofing Buildings

Session Coordinators	
Stephan Renz	Chair, ExCo, Heat Pump Technologies TCP / Beratung Renz Consulting
Georges Zissis	4E TCP / Professor Université de Toulouse Objectives (not present at the Workshop)

Objective

Come up with RD&D activity concepts to ensure that the following perform as designed:

- low-rise residential and small buildings;
- high-rise office and multifamily buildings;
- district energy systems;
- The systems fulfill future requirements for energy systems (i.e., digitalization, etc.).

Presentations

Introductory remarks were made by session coordinator, Stephan Renz. He briefly explained the objectives of this session. He mentioned that on the one hand, the session was about finding solutions for how technical systems can be installed in existing buildings today so that they function efficiently and can be operated according to demand. However, systems installed today must also meet future requirements, which may, for example, be changed by further improvements to the building (reduced energy requirements). The transformation of the energy system, which requires greater flexibility due to decarbonization and decentralization, can also have a substantial influence.

The session started with four presentations related to results from research on minimizing carbon emissions and issues arising from the construction and operation of retrofitted buildings and the district systems that serve them. The presentations, which can be found appended to this document, were as follows:

1. *Maintaining the performance of district systems presented by Lars Gullev, Vice Chair, ExCo, District Heating and Cooling TCP / Managing director at VEKS*
2. *Data and its use in performance monitoring and operation of buildings presented by Stephen White, Operating Agent for EBC Annex 81 / Energy Efficiency Domain Leader, CSIRO*
3. *Heat pumping technologies in existing buildings – Challenges and opportunities in the design, installation and operation of Heat Pumps presented by Caroline Haglund Stignor, Heat Pump Centre, Heat Pumping Technologies TCP*
4. *Advanced smart lighting must also be energy smart presented by Casper Kofod, 4E TCP/Director, Energy Piano*

Breakout Discussions

Participants were tasked with coming up with RD&D activity concepts to ensure that the following perform as designed:

- low-rise residential and small buildings;
- high-rise office and multifamily buildings;
- district energy systems;
- The systems fulfill future requirements for energy systems (i.e., digitalization, etc.).

Participants were guided by the following four prompts:

- Adopt a strategic future-oriented outlook;
- Consider the human as part of the system;
- Impact of digitalization;
- Education/training required.

Breakout Group A — Ensuring performance of housing (as part or not of district systems)

The following points reflect the discussion in breakout group A:

1. Research to redefine comfort considering climate, culture and building topology.
2. Research to address uncertainty in building performance including:
    - Measurement data collection and data analysis to support feedback using:
        - Feedback from occupants;
        - Information from digital permits;
        - Thermal imaging devices;
        - Smart thermostat devices;
        - Utility meters.
3. Develop approaches that use data other than energy (such as CO_2 emissions based on lifetime, or energy per satisfied client/user/consumer or other) to evaluate compliance and diagnose issues.
4. Develop key performance indicators to assess if performance is as expected and troubleshoot.
5. Research to create retrofit pathway passport: a document indicating the improvements made to a building.
6. Share global experiences on successful and unsuccessful initiatives.
7. Research to compare different ways technology interacts with people to determine what works well.
8. Research to assess minimum comfort level in new homes in terms of energy consumption to inform resiliency and flexibility.
9. Evaluate options to consider energy services as a business model.
10. Research to develop modularity of systems, with a view to ease of replacement of parts.
11. Develop models for sustained engagement with communities.
12. Develop case studies on disaster response in energy systems cataloguing lessons learned.
13. Develop framework to reframe solutions to be more socially acceptable.
14. Develop means to have easily available/understood data for consumers.
15. Identify low-tech solutions to meet the needs of those less likely to adopt new technologies.

Breakout Group B — Ensuring performance of buildings (as part or not of district systems)

The following points reflect the discussion in breakout group B:

1. Develop tools for educating and understanding the complexities concerning energy, carbon, and financial implications.
2. Develop new digitization use cases.
3. Develop methodologies for performance building stock modelling.
4. Develop advanced control of mechanical systems including fault analysis.
5. Case studies on air-tightness approaches such as aeroseals
6. Develop protocols for two-way communication between buildings and utilities.
7. Develop materials for training building operators on operation/feedback/fault detection/predictive controls
    - Training operators;
    - Continue developing prioritized diagnostics at the system level;
    - Pattern recognition for performance monitoring;
    - Develop effective predictive controls.

8. Research on digitalization such as:
    - Low-cost sensors and its impact on complexity;
    - Virtual sensors/metering effectiveness;
    - Online commissioning effectiveness;
    - Consider critical number and type of sensors needed;
    - E.g., sensors in F1 cars versus buildings;
    - Sensor calibration e.g., for CO_2, volatile organic compounds and occupancy sensors;
    - How much digitalization is enough (impact on energy consumption and resiliency).
9. Develop methodologies, and case studies for occupant-centric operation.
10. Develop/collect guidelines for comfort, energy, sensors, lighting as a service.
    - Explore business models, case studies and policy.
11. Develop/identify effective sub-metering and streamline measurement and verification protocols.
12. Develop methodologies for effective building transitions post-pandemic (addressing unoccupied downtown office buildings, for example).
13. Research to develop/identify/disseminate standards for digital systems and components.
14. Develop guidelines to get buildings and utilities to work together optimally.
15. Research to identify what works in facility management and continuous commissioning.

Discussion Summary

Session Coordinator, Stephan Renz, provided a summary of the plenary report-out in which he flagged data collection, digitalization and communication as cross-cutting themes that were discussed. This should lead to better integration of various components and systems, and enhance efficiency, responsiveness, flexibility and resilience of the building energy system. Mr. Renz also identified the need to train operators as well as the need for education to understand the complexities of the system.

Session 5: Building Energy and Carbon Codes

Session Coordinators	
Meredydd Evans	Operating Agent, EBC Energy Codes Working Group, Senior Staff Scientist and Team Lead, Joint Global Change Research Institute, Pacific Northwest National Laboratory
Takao Sawachi	Chair, ExCo, Energy in Buildings and Communities TCP / President, Building Research Institute

Objectives

Develop at least three RD&D activity concepts addressing:

- ▲ Metrics for building energy codes for **existing** buildings & carbon codes;
- ▲ ‘Users’ (building occupants, operators, occupiers, owners) and ‘utilities’ (including district heating systems) with respect to building energy and carbon codes (It is critical that users are able to see the effect of the codes on their energy bills and carbon emissions in a way that is meaningful to them, including comfort and cost.);
- ▲ Implementation of energy and carbon codes.

Presentations

Introductory remarks were made by session coordinator, Meredydd Evans. Many countries and subnational jurisdictions are exploring potential new, or expanded mandatory policies, to improve existing building energy performance and their carbon footprint in response to increasing climate targets. This session explored the metrics around the codes, the challenges with their implementation, as well as connections to end-user comfort and energy consumption. Given that the codes are meant to provide for buildings that are primarily for the use of their occupants, consideration to integrating their requirements was also addressed.

The presentations, which can be found appended to this document, were as follows:

1. *Building Energy and Carbon Codes – Considerations, opportunities, and challenges presented by Meredydd Evans, Operating Agent, EBC Energy Codes Working Group, Senior Staff Scientist and Team Lead, Joint Global Change Research Institute, Pacific Northwest National Laboratory*
2. *Metrics and Building Energy Codes presented by Alex Ferguson, Housing Team Project Leader, CanmetENERGY, Natural Resources Canada*
3. *EBC Annex 79: "Building codes and considerations for occupants" presented by Elie Azar, Operating Agent, EBC Annex 79, Professor in Architectural Conservation and Sustainability Engineering, Civil and Environmental Engineering Department, Carleton University*

Breakout Discussions

Breakout Group A — Building energy codes for existing buildings & carbon codes

Participants in Breakout Group A were asked to develop an RD&D activity concept addressing metrics for building energy codes for existing buildings & carbon codes — integrating new technologies (e.g. PV, EV charging, grid-interactivity/smartness) into building codes.

To guide their discussion, they were provided the following prompts:

- How have different jurisdictions assessed metrics for building performance standards? What are the unsolved questions?
- How do we best assess how these new policies are working to learn from them?
- What are meaningful metrics for other code policies, such as code-based retrofits, or codes for modifications to buildings?
- What are reasonable metrics for new technologies (building integrated renewables, smart meters, EV charging, heat pumps, and/or other new technologies that can help achieve decarbonization?)
- How do we best incorporate and link both input metrics for code compliance (e.g. assumptions on occupancy and behavior) and output metrics related to performance?

The following points reflect the discussion in breakout group A:

1. Research project combining all TCP work glued together by metrics including:
    - Capacity limits of the industry to apply the metrics, flexibility of use, and resilience.

2. Define machine readable metrics for buildings.
3. Develop guidelines for energy code compliance for existing buildings.
4. Develop/identify/disseminate metrics to support life cycle analysis in order to determine whether to retrofit or build new.
5. Compilation of lessons learned on different metrics used in different countries in terms of both building and appliances.
6. Develop pathways on how to get better with respect to each type of metric.
7. Create acceptance for developing metrics for existing/retrofitted buildings through careful stakeholder engagement.
8. Map needs and trigger points for action of different stakeholders (e.g. residents, financial institutions, etc.)
9. Research to develop resilience and flexibility indices to address the challenge of impact on climate resilience and the relationship between the electrical grid and buildings.
10. Create case studies presenting actual performance and model-based performance to achieve cost-effective assessment.
    - Investigate / evaluate what is done in different counties to access reliable operational data;
    - Determine effectiveness of various data collection methods;
    - Identify effective stakeholder engagement techniques;
    - Determine who owns/maintains the data.

Breakout Group B — The role of occupants in codes

Participants from Breakout Group B were asked to develop an RD&D activity concept addressing ‘users’ (building occupants, operators, occupiers, owners) and ‘utilities’ (including district heating systems) with building energy and carbon codes.

To guide their discussion, they were provided the following prompts:

- How might building performance standards and codes for existing buildings impact building users? How can codes affect comfort and cost?
- How do codes for existing buildings impact utilities? Areas of discussion may include utility incentives, operations, and costs.
- How do ‘users’ perceive and interact with new technology requirements in the code, and how can we make these transitions easier?
- How the district heating utilities are uniquely impacted and the options that better integrate district heating utilities and customers through codes.

The following points reflect the discussion in breakout group B:

1. Develop performance standards that account for occupancy needs.
    - Model/estimate performance for range of common variations in occupancy.
2. Evaluate utility monitoring and analysis for effective feedback to customers.
3. Research on how to consider the future conditions in codes and standards.
4. Research into the impact variable time of day prices have/reflect on low carbon energy availability that change throughout the year.

Breakout Group C — Intervention, incentives, and enforcement

Participants from Breakout Group C were asked to develop an RD&D activity concept addressing implementation of energy and carbon codes that considers intervention, incentives, and enforcement.

To guide their discussion, they were provided the following prompts:

- How are building performance standards being implemented?
- What are the enforcement challenges and implementation successes?
- How are incentives being used to implement building performance standards and retrofit code requirements?
- Are retrofit requirements working (e.g. when existing space is expanded or significantly modified)?
- What other implementation issues need to be considered? For example, are there particular implementation issues regarding new technology?

The following points reflect the discussion in breakout group C:

1. Intervention:
    - Research to evaluate the performance gap (Measurement and Verification);
    - Case studies/review of current approaches on Disclosure (time of sale) of energy performance;
    - Research on what is necessary, desirable, possible to be measured;
    - Understanding the impact of mandatory disclosure vs. requirement.
2. Incentives
    - Develop approaches to accelerate adoption of codes by the market;
    - Evaluate levels of subsidized improvements that are acceptable/desirable;
    - Research into approaches to financing retrofits;
        - Create links and generate interest in the financial sector;
    - Research on streamlining permitting process;
    - Research on determining the right incentives.
3. Enforcement
    - Research to develop automation/digitalization of enforcement;
        - Determine what effective enforcement mechanisms look like;
        - Consider affordability's impact on adoption/enforcement;
    - Explore voluntary disclosure and its effects;
    - Identify the impact of fines and their acceptability;
    - Develop processes to integrate input from inspections.

Discussion Summary

Session coordinator, Meredydd Evans, provided a summary of the plenary report out in which she described users, metrics, and implementation as having integrated threads. Ms. Evans mentioned that a theme heard from everyone was how to improve effectiveness and listed initiatives such as passports, a stepwise approach, disclosure programs and digitalization/machine learning. Ms. Evans also mentioned the importance of considering the needs of users, developers and financiers when making decisions around finding effective solutions.

Session 6: Consolidation of Session Results & Identification of Common Activities

Session Coordinators	
Meli Stylianou	Chair, FBF Advisory Board / Manager, Housing and Buildings R&D, Natural Resources Canada
Takao Sawachi	Chair, ExCo, Energy in Buildings and Communities TCP / President, Building Research Institute

Objectives

From the recommendations heard from sessions 2, 3, 4 and 5, participants were asked to identify common RD&D activities that could be undertaken by the participating TCPs focusing on the following areas:

- First concepts for cross-cutting TCP joint projects;
- Possible collaborative focus areas for inclusion in the future Strategic Plans of the buildings-related TCPs;
- Ideas for activities to strengthen the IEA Buildings-Coordination Group and improve collaboration between the IEA Secretariat and the buildings-related TCPs.

Breakout Discussions

During the final session of the workshop, each breakout session represented an opportunity to further discuss the results from sessions two through five. Participants were asked to first consolidate/aggregate similar ideas that were identified during the previous discussion and then identify common activities based on the level of impact on the desired results and the level of effort needed to achieve them in the short, medium, and long term. Groups were also tasked with identifying which TCP should lead and/or be involved in each initiative identified. In some cases, groups identified cross-cutting themes that became clear during their session's discussion.

Breakout Group A — 'Deep' Energy Retrofit — Challenges & Opportunities

1. Pathways
   - How to get a building in its existing state to its retrofitted state. Develop information for contactors doing work, the measures that must be taken etc.;
   - EBC to lead this category with input from User TCP.
2. Data/Metrics
   - How building performance is measured must be understood;
   - Understanding the building stock is critical before assessment;
   - Identify what is being measured. I.e., performance in terms of energy, comfort, etc.;
   - EBC to lead this work with input from ISGAN and User Group.
3. Market development and engagement
   - EBC to lead the work with input from Users group and Cities group.
4. Streamlining delivery (industrialization, standardization)
   - Accelerating process to getting the work done;
   - TCPs to be involved include HPT, EBC, PVPS, Users, SHC and ES.

Breakout Group B — Systems as Transformational Process

1. Develop vision of future energy systems and options at the building and district levels
   - Includes interactive equipment, storage, solutions for rapid electrification, etc.;
   - TCPs to be involved include EBC and Cities groups.
2. Model predictive controls
   - Use of artificial intelligence in controls;
   - Using model predictive controls to integrate renewable generation such as from photovoltaic systems;
   - Metrics to develop a capacity limiting index to predict flexibility;
   - TCPs involved include DHC, EBC, ES, and PV.
3. Digitalization
   - Coming together to determine what work streams with respect to digitalization are already in progress;
   - Identify required measured data at the building and larger clusters;
   - Definition of spatiotemporal resolution of information required by stakeholders;
   - Aggregation of collected data;
   - Identification of requirements and end-uses for Digital twins;
   - Involves all TCPs.
4. Quantifying benefits of district versus individual building solutions
   - Consider flexibility and boundaries;
   - TCPs involved include DHC, HP, ES and Cities.
5. Flexibility
   - Mechanisms to enable flexibility and flexible behaviour;
   - Quantifying flexibility;
   - Solutions for rapid electrification;
   - TCPs involved include ISGAN, ES, Cities, and EBC.

Breakout Group C — Technological Systems as Catalysts for Future Proofing Buildings

1. Data and information systems
   - Consider constraints mapping on data sources (e.g., privacy);
   - Consider minimum data collection and data; federation/management requirements;
   - Consider cybersecurity;
   - Consider lifetime of IT versus equipment;
   - All TCPs involved.
2. Enabling users/occupants
   - Develop user-friendly engagement tools/apps and educational materials and define user requirements;
     - All genders;
   - Evaluate trust issues and opportunities for user-centric feedback;
   - Keep user "in the loop" by considering app design/co-design, plug and play and users' perception;
   - TPCs involved include EBC, Users, HPT, HEV and 4E.
3. Equipment and system optimization and control
   - Investigate data collection/aggregation and accessibility across scales (edge versus cloud);
   - Select wholistic key performance indicators (KPIs) for optimization and maximize value across multiple "sub" KPIs;
   - Develop machine learning and artificial intelligence-based approaches for control and fault detection and diagnosis;
   - TCPs involved include HPT, EBC, 4E, ISGAN, SHC, DHC, and ES.
4. Enabling resilience and adaptability
   - Investigate thermal decay of individual buildings by type and size;
   - Evaluate how flexibility impacts resilience and adaptability;
   - TCPs involved include EBC, HPT, ISGAN, DHC, and ES.

5. Measurement and verification
    - Consider sensor quality and uncertainty and provide guidance on sensor use and placement;
    - Consider impacts of occupancy on measurement and verification and impacts of other boundary conditions;
    - Consider data consolidation/harmonization;
    - Consider user satisfaction and feedback quantification methodologies;
    - Involves all TCPs.
6. User services and business models
    - Share experiences;
    - Map tariff and charging approaches and evaluate their impacts;
    - Model the transition of the changing energy system and impacts on business;
    - Map risks;
    - Evaluate business models to facilitate improved performance;
    - Involves all TCPs.

Breakout Group D: Building Energy and Carbon Codes

1. Digital-first codes and artificial intelligence/Machine Learning
    - Determine effectiveness of data collection and ownership;
    - Interoperability to facilitate more advanced standards;
    - Consider the barriers to digitization of code compliance;
    - TCPs involved include EBC as the lead with support from ISGAN, DHC, Users, PVPS, HEV, HPT, and ES.
2. What metrics are being used and are they effective?
    - Consider what is mandatory versus voluntary;
    - Evaluate emerging needs;
    - Identify what metrics matter: Carbon, energy, resiliency, comfort;
    - Consider the basis for normalization/comparison;
    - Consider a toolkit of metrics “beyond the building” i.e. related to the electrical and district systems feeding it;
    - Strategies for weighting and prioritizing metrics;
    - TCPs involved include EBC as the lead with support from ISGAN, DHC, Users, PVPS, HEV, HPT, and ES.
3. Stepwise application of codes to accomplish policy ends
    - Develop strategies to build acceptance for decarbonizing existing buildings via regulation;
    - TCPs involved include EBC as the lead with interest from cities.
4. User/stakeholder engagement, interaction/needs assessment
    - Understand the role of different stakeholders from users to financers and beyond;
    - Develop approaches to influence the stakeholders: info dissemination, data analysis, other;
    - Consider the use of finance instruments to influence adoption;
    - Determine triggers, resulting intervention, and response;
    - TCPs involved include EBC as the lead with support from Users and Cities.

Concluding Discussion

Following session 6, it was recognized by Dr. Ruyssevelt that while the initial intent of the exercise was to develop more specific research proposals, most groups tended to amalgamate the topics into themes, which are helpful in determining the focus areas that can be fed into strategic plans. As such, Dr. Ruyssevelt pointed out some cross-cutting themes that were brought up across multiple sessions. These themes include data and metrics as well as engagement with consumers and markets.

Dr. Ruyssevelt then invited participants to point out additional themes that appeared to be cross-cutting throughout the workshop.

It was noted that a focus on acceleration is a priority which all proposals should be weighed against given how little time there is to meet the 2030 and 2050 targets. In order to help with acceleration, it was suggested that increasing the ease and level of collaboration among TCPs be evaluated in collaboration with the Buildings Coordination Group and with the support of the IEA Secretariat. To ensure momentum is not lost, earmarking responsibilities in the near future was seen as important.

It was also recognized that there are constraints beyond the structure of TCPs that hinder collaboration including achieving buy-in from various countries. It was noted that there are potential mechanisms to make collaboration easier, including free participation, but these mechanisms need to be agreed upon by all members around the table.

It was noted that a common issue that countries will be facing over the next few years will be massive investments. As such, it was suggested that well-packaged advice and common recommendations to policy makers is critically important. It was agreed that the passing on of information is something that can be improved upon, not just to policy makers but among TCPs. It was suggested that information sharing between TCPs be improved through the sharing of roadmaps and case studies. One recommendation was that information be shared among all TCPs when each new project is launched. It was recognized that all TCPs should have a means of knowing what kind of projects are ongoing to ensure there is no duplication. To improve communication between TCPs it was suggested that there be more frequent opportunities to touch base moving forward.

Mr. Stylianou and Dr. Sawachi offered some closing remarks and thanked participants for their valuable contributions before bringing the workshop to a close.

4. Key Findings and Directions

The workshop was deemed a success by the participants. A survey carried out after the workshop showed that over 88% being satisfied or very satisfied with the variety of presentations and a similar percentage evaluating their overall experience as either very valuable or extremely valuable.

The workshop participants stressed the importance of having the opportunity to interact with experts that are outside their circle of researchers and to learn about what was happening in other TCPs' activities. The 5 minute presentations by TCP representatives were particularly appreciated.

Furthermore, the urgency of what needs to be done was palpable throughout the workshop. Participants raised the issue repeatedly and it is something that would need to be addressed in all the TCPs, as well as the BCG and IEA Secretariat.

One important observation by the participants was that TCPs are not equipped to interact at the Annex/Task levels, leading to silos that need to be challenged. It is a fact that many tasks/annexes have critical opportunities for collaboration that are not explored. What came through at the workshop was that there are many synergies and a means is required to leverage these activities to arrive at holistic solutions that benefit from the diverse expertise in the TCPs silos.

Actions flowing from the Forum.

The actions listed below flow from the objective of the Future Buildings Forum which was to identify the international collaborative RD&D activities needed to unlock deployment of low and zero carbon technologies in existing housing and buildings and to generate new ideas to:

- Identify collaborative RD&D project concepts intended to be jointly carried out by the buildings-related TCPs that consider the information and data requirements of the receptors of the eventual outcomes of those projects;
- Identify collaborative focus areas to include in the future Strategic Plans of the buildings-related TCPs;
- Identify activities to strengthen the IEA Buildings Coordination Group and improve the collaboration between the IEA Secretariat and the buildings-related TCPs.

The forum has identified RD&D activities that are summarized and clustered as research activities in Appendix 2 and these activities are intended for inclusion in future Strategic plans of the buildings-related TCPs.

The workshop determined the following steps that need to be taken to strengthen the IEA Buildings Coordination Group and improve the collaboration between the IEA Secretariat and the buildings-related TCPs:

Include 5 min BCG TCP presentations into the agenda of each Exco meeting

The participants praised the brevity and the content of the presentations in Session 1. Having these 5 min presentations as part of each TCP's Exco will provide the frame which subsequent discussions on new and existing Annexes/Tasks can be viewed and catalyse ideas for cross-TCP collaboration.

Create a database of experts accessible to all BCG TCPs

Researchers and national experts are aware of the expertise in their own, limited, domain. Having an international database of experts will facilitate the interactions and raise the potential for collaboration.

Include requirement for new BCG TCPs Annexes/Tasks to carry an analysis of opportunities for inter-TCP activities

Operating agents could use the database of experts to identify links to expertise in other TCPs.

Create process to evaluate research ideas provided in the FBF report and develop cross-TCP collaborative projects:

1. Develop mechanism for cross-TCP Annexes/Tasks led by BCG/IEA Secretariat.
2. Develop online meetings to developing collaborative projects, based on research identified by the Forum, led by the Forum Session Coordinators.

Appendix 1: IEA Building Coordination Group

The IEA Building Coordination Group (BCG) is one of the End Use Working Party (EUWP)[1] sectoral coordination groups, functioning under the leadership of the EUWP Building Vice Chair (BVC) with the support of the IEA secretariat.[2]

The group contributes to enhance cross-TCP exchanges and collaboration on building R&I topics.

Regular participants in the group are 8 TCPs from the EUWP portfolio (Cities, DHC, EBC, ES, HPT, 4E, USERS, ISGAN) and 2 TCPs (SHC, PVPS) from the Renewable Working Party (REWP). Though, the selected topic for discussion within the BCG can require other TCPs to be invited. The BCG goals are:

- exchanging best practice for TCP collaboration and sharing ideas to improve coordination
- state-of-the-art overview to identify cross-cutting issues for further collaboration and dissemination of common shared messages on TCP outcomes to various stakeholders
- identifying cross-TCPs R&I synergies and priorities
- activating joint collaborative initiatives inspired by, or contributing to, IEA analysis
- identifying coordinated approaches to better inform the IEA on building R&I needs and data. BCG work, based on input from the TCPs, also feeds the Vice Chair reports to EUWP.

The EUWP 2022–2024 Strategic Plan[3] attributes a stronger role to sectoral Coordination Groups, as they are seen as “informal and flexible structures that allow for bottom-up initiatives in boosting TCP collaboration, dissemination and outreach”.

The BCG generally meets on an yearly basis to discuss news in the R&I portfolio and collaboration opportunities. Nevertheless more frequent contacts have occurred in the last years.

1 EUWP assists CERT by providing strategic guidance to IEA Technology Collaboration Programmes focussed on end-use technologies and sectors as well as facilitates co-operation among TCPs through the established ***Co-ordination Groups***. (from Working Party on energy End-Use Technologies - ***Mandate 2022-2024***)

2 Current EUWP building vice-chair (2021-2024) is Ezilda Costanzo (PhD eng. ENEA, IT) and the IEA Technology Innovation Unit officer supporting BCG is Chiara Delmastro (PhD eng.).

3 Working party on energy end-use technologies- ***Strategic plan 2022–2024***

2022 meeting focussed on the «Zero carbon ready» urgent R&I, with a 2030 perspective, followed by several webinars and exchanges, involving the IEA secretariat and the BVC, to finalise the joint report. HEV TCP contributed too. Since that date a Buildings TCP Working platform was established to share all useful documents and updates between the paper authors.

2023 meeting, the first the new Cities TCP participates in, will focus on supporting decarbonisation of cities and related knowledge transfer. This “urban level” discussion will allow building TCPs to address the cross-cutting nature of energy challenges and systems, sector-coupling and integration, as several TCP collaboration opportunities emerged from recent BCG and FBF works in this field.

The outcomes from BCG annual meetings are accessible to TCP chairs in the IEA TCP sharepoint.

In 2022, the Building Coordination Group delivered the Joint IEA-TCP on-line report *“Technology and Innovation Pathways for Zero-carbon-ready Buildings by 2030”* developing, reviewing and editing analytical substance. The report provides the vision of experts from building-related IEA TCPs and HEV TCP (transport) on how to help achieve some of the most impactful short-term milestones for the buildings sector outlined in the IEA’s Net Zero by 2050 Roadmap. Main outcomes of the joint effort are:

- Several R&D Priority themes for the spread of net zero carbon buildings
- Lay-out of innovation topics for future collaboration between TCPs
- Recommendations on how key buildings decarbonisation milestones to 2030 might be achieved
- Dissemination of TCP activities and R&I results

Figure 1: IEA TCPs participating in Building Coordination Group (2022)

Appendix 2: Compilation of research activities

'Deep' Energy Retrofit – Challenges & Opportunities

1. **Pathways**

   Research to:

   - Determine when it is better to do a complete demolition-reconstruction vs. when to do a deep retrofit from the energy and carbon perspectives;
   - Evaluate predefined solutions through modeling various pathways more efficiently to get to implementation faster. Including:
     - Consideration of low operational carbon solutions;
     - Evaluate impact of refrigerants with higher global warming potential in deep retrofits;
     - Determine the range of solutions to manage the increase in PV load on the electrical grid while considering the right environment to use each solution in terms of cost effectiveness and other factors;
     - Investigate standardized mechanical solutions including plug-and-play concepts that are user-friendly.
   - Explore how to address technologies as they approach their end of life.

2. **Data/Metrics**

   Research to:

   - How to best measure building performance;
     - Evaluate the role of smart buildings to gain additional insight on how things can be automated in deep retrofits;
     - Identify what is being measured. I.e., performance in terms of energy, comfort, etc;
     - Use measurement to explore standardized labelling or disclosure around indoor environmental quality and embodied carbon.
   - Develop case studies to disseminate best practices and strategies in terms of recommissioning using digital tools and more easily accessed information.

3. **Market development and engagement**

   Research to:

   - Determine how to improve the rate of retrofit through methods such as digitization, robotics, etc;
     - Explore innovative ways to streamline construction;
     - Evaluate the need for an "integrator" or concierge service to accelerate implementation. This will make sure everyone is heard and on the same page with regards to finance issues, policy, etc. to accelerate implementation;
     - Study social factors to achieve engagement of and acceptance by homeowners;
     - Determine the drivers of action for a deep retrofit and how they work;
     - Determine how to best create value through incentives;
       - Improved lifecycle costs;
       - Innovation in financing or;
       - Ownership models.
     - Better understand how market forces including finance, policy etc. affect deep energy retrofits;
     - Evaluate the effectiveness of the use of energy renovation "passport" for non-residential buildings to benchmark performance that includes the timing and contribution of each stage of a retrofit.
   - Identify ways that homeowners can be enabled, empowered, and incentivized (other than financial).

4. **Streamlining delivery (industrialization, standardization)**

   Research to:

   - Improve the understanding of the building stock;
     - There is a need for better and more accessible information on the status of the current stock and what can be done with it.

Systems as Transformational Process

1. **Develop vision of future energy systems and options at the building and district levels**

   Research to

   - To achieve a better understanding and required sequential steps in the transition pathway;
     - Identify solutions for rapid electrification integration, energy flexibility, prediction, and activation;
     - Better understand impact on the user, including impact of price incentives;
     - Better understand social license to operate;
     - Improve data collection, user accessibility;
     - Validate flexibility demand resources;
     - Better understand and quantify how buildings can contribute to national CO_2 reduction goals;
     - Identify and quantify what other stakeholders, such as utilities, finance institutions, training centres, municipal governments can do and how fast?
   - Define market constraints/mechanisms including the utilities side, legal structure, pricing incentives and voluntary participation;
     - Map available unexploited heat sources.
   - Evaluate the development of integrative components and sub-systems for ease of development and retrofit of energy systems;
   - Define/Refine implementation instruments;
     - Policies, regulations, and incentives;
     - Collaboration across stakeholder groups;
     - Financial and business models;
     - Non-financial arguments.
   - Develop integrated energy systems specifically for remote communities.

2. **Model predictive controls**

   Research to:

   - Develop and apply effective and industry-acceptable model predictive control through AI and/or machine learning for building energy systems.

3. **Digitalization**

   Research to:

   - Better coordinate supply (spatial and temporal) through digitalization and "smart" systems;
     - Develop and expand digital platforms to share information and visualize energy flows;
     - Define benefits of urban digital twins (UDTs) for the different stakeholders;
     - Improve data availability for planning purposes and forecasting;
   - Manage diversity in domestic renewable production options (photovoltaics, solar thermal, heat pump, geothermal) to match divers load patterns.

4. **Quantifying benefits of district versus individual building solutions.**

   Research to:

   - Develop aggregated datasets for cost, emissions, and energy for buildings at a regional level;
     - Improve real world assessment and reporting of GHG emissions in buildings;
     - Develop case studies/websites to share practical experience on operating energy markets and evaluate carbon reduction outcomes;
     - Define when centralized systems are appropriate and when decentralized ones are (Consider a different way of thinking (decentralized vs. centralized supply);
     - Quantifying benefits / limitations of district level vs. building level solutions (complexity, intervention, privacy);
     - Create database of demonstration projects (accelerate deployment);
     - Quantifying energy wasted from different streams and the quality of this energy;
     - Developing and documenting business models that can be broadly shared to create synergies;
     - Integrate Users TCP perspectives on occupant/operator behavior.

5. **Flexibility**

   Research to:

   - Define when storage is appropriate as a means of balancing impacts on the grid as a feasible economical option;
     - Identify mechanisms to enable flexible behaviour (including potential financial incentives);
     - Quantify/Define amount of flexibility required at the city level.
   - Examine the role of thermal grids in supporting the electricity grid:
     - Intrinsic flexibility of thermal grids, and thermal storage enables switching between CHP and heat pumps;
     - Devise tariffs to reward flexibility;
     - Develop sector coupling tools to optimise operation in different electricity markets.
   - Develop scenarios for using interactive equipment;
     - Intercommunication between devices (Photovoltaics, heat pumps, storage, electric vehicles).

Technological Systems as Catalysts for Future Proofing Buildings

1. **Data and information systems**

   Research to:

   - Define minimum data collection and data federation/management requirements;
   - Develop and share global experiences on successful and unsuccessful initiatives;
     - Develop new digitization use cases;
     - Develop guidelines for comfort, energy, sensors, lighting as a service;
       - Explore business models, case studies and policy.

2. **Enabling users/occupants**

   - Evaluate trust issues and opportunities for user-centric feedback;
   - Keep user "in the loop" by considering app design/co-design, plug and play and users' perception.

   Research to:

   - Redefine comfort considering climate, culture and building topology;
   - Develop tools for educating and understanding the complexities concerning energy, carbon, and financial implications;
   - Develop materials for training building operators on operation/feedback/fault detection/predictive controls;
   - Develop methodologies, and case studies for occupant-centric operation.

3. **Equipment and system optimization and control**

   Research to:

   - Develop key performance indicators to assess if performance is as expected and troubleshoot;
   - Research to develop modularity of systems (replace parts easily);
   - Identify low-tech solutions to meet the needs of those less likely to adopt new technologies;
   - Develop advanced control of mechanical systems including fault analysis;
   - Evaluate appropriate level of digitalization (impact on energy consumption and resiliency);
     - Evaluate critical number and type of sensors needed.
   - Investigate data collection/aggregation and accessibility across scales.

4. **Enabling resilience and adaptability**

   Research to:

   - Assess flexibility and minimum comfort level in new homes to inform resiliency and flexibility;
   - Develop effective sub-metering and streamline measurement and verification protocols;
   - Develop case studies on disaster response in energy systems cataloguing lessons learned.

5. **Measurement and verification**

   Research to:

   - Develop low cost and virtual sensors;
   - Provide guidance on sensor use and placement;
   - Consider impacts of occupancy on measurement and verification;
   - Develop methodologies for performance building stock modelling;
   - Address uncertainty in building performance through measurement and collection as well as data analysis to support feedback from stakeholders including occupants, and actions and inform evolving design practices, regulations, and codes.

6. **User services and business models**

   Research to:

   - Compare different ways technology interacts with people to determine what works well;
   - Evaluate options to consider energy services as a business model;
   - Develop models for sustained engagement with communities;
   - Develop guidelines to get buildings and utilities to work together optimally;
     - Develop means to have easily available/understood data for consumers;
     - Develop protocols for two-way communication between buildings and utilities including comfort;
     - Develop guidelines for energy as a service to improve adoption.

Building Energy and Carbon Codes

1. Digital-first codes and artificial intelligence/Machine Learning;

   - Determine effectiveness of data collection and ownership;
   - Interoperability towards more advanced standards;
   - Consider the barriers to digitization of code compliance.

   Research to:

   - Define machine readable metrics for buildings.

2. **What metrics are being used and are they effective?**

   Research to:

   - Develop report compiling lessons learned on different metrics used in different countries in terms of both building and appliances;
   - Develop metrics to:
     - support life cycle analysis in order to determine whether to retrofit or build new;
     - Integrate input from diverse TCPs to develop metrics such as:
       - Capacity limits;
       - Flexibility, including impact of variable time of day prices have/reflect on low carbon energy availability that change throughout the year;
       - Resilience.
     - Develop pathways on how to improve the performance against each type of metric;
     - Develop performance standards that account for occupancy needs;
       - Model/estimate performance for range of common variations in occupancy.
   - How to consider the future conditions in codes and standards.

3. **User/stakeholder engagement, interaction/needs assessment**

   Research to:

   - Develop guidelines for energy code compliance for existing buildings;
   - Develop strategies to build acceptance for decarbonizing existing buildings via regulation;
   - Create case studies presenting actual performance and model-based performance to achieve cost-effective assessment;
     - Investigate / evaluate what is done in different counties to access reliable operational data;
     - Determine effectiveness of various data collection methods.

Intervention

Research to:

- Evaluate the performance gap between designed/modelled performance and real monitored performance;
    - Identify a hierarchy of measurements (Important, nice-to-have);
- Develop case studies/review of current approaches on Disclosure (time of sale) and to understand the impact of mandatory disclosure vs. requirement.

Incentives

Research to facilitate market adoption

- Evaluate levels of subsidized improvements, determine the right incentives;
- Evaluate financing options for retrofits;
- Develop streamlined permitting process;
- Evaluate options for voluntary disclosure.

Enforcement

Research to develop automation/digitalization of enforcement.

- Determine what effective enforcement mechanisms look like;
- Consider affordability.

Appendix 3: Presentations


Existing Buildings:
Pathways to Net Zero Carbon 2035
2022 IEA Future Buildings Forum
Think Tank Workshop
Presentations
19th - 21st October 2022,
Gatineau, Québec, Canada

Session 1

October 19th, 2022, AM

Welcoming comments | View from the bridge

Session Coordinators

Meli Stylianou

Chair, FBF Advisory Board / Manager, Housing and Buildings R&D, Natural Resources Canada

Takao Sawachi

Chair, ExCo, Energy in Buildings and Communities TCP / President, Building Research Institute

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Welcome to IEA Future Buildings Forum

Takao SAWACHI

Chair, IEA EBC TCP

October 2022

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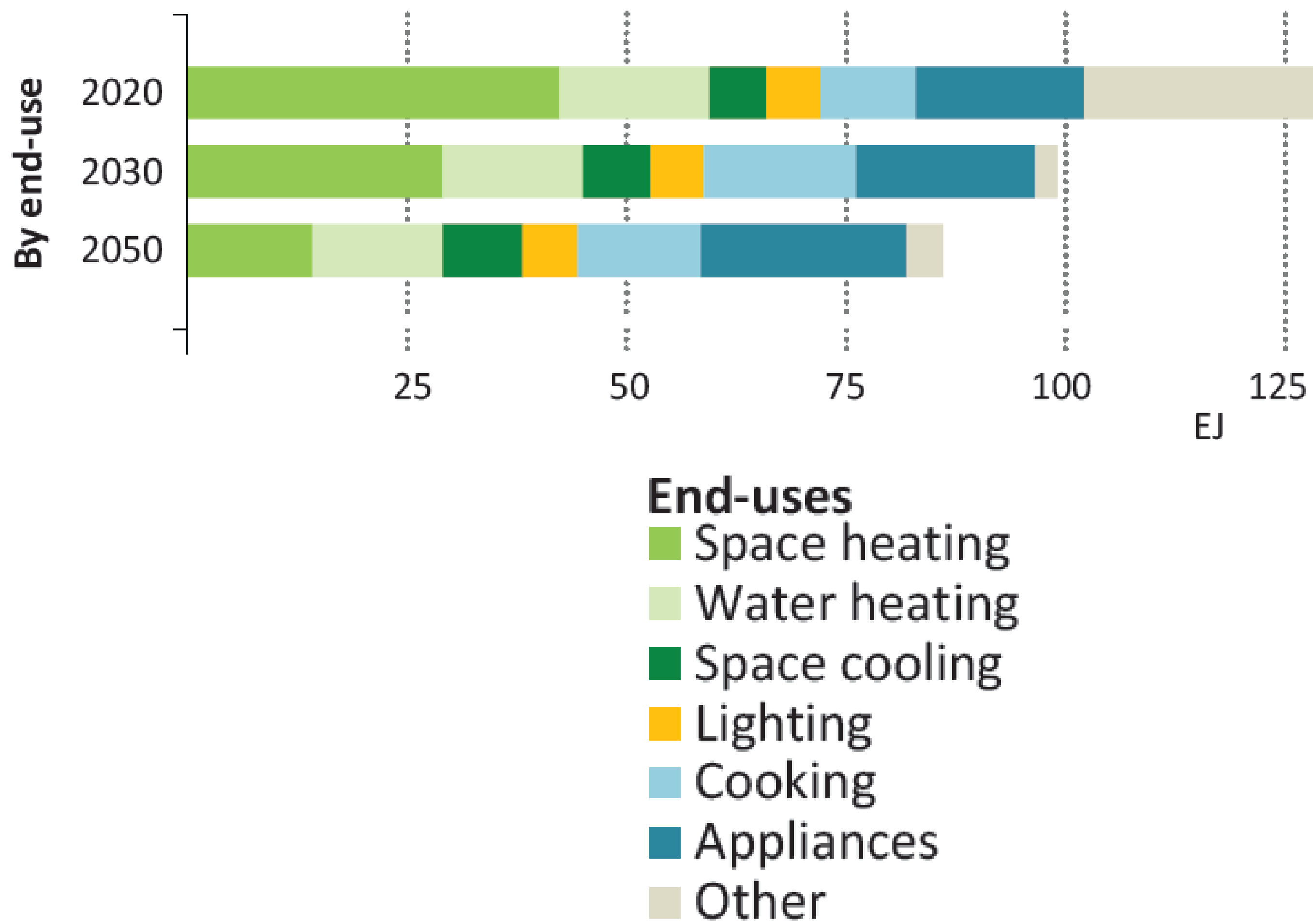
IEA Future Buildings Forum Think Tank Workshop - Existing Buildings: Pathways to Net Zero Carbon 2035

19th - 21st October 2022, Gatineau, Québec, Canada

Fig. 3.28 Net Zero by 2050, IEA, 2021



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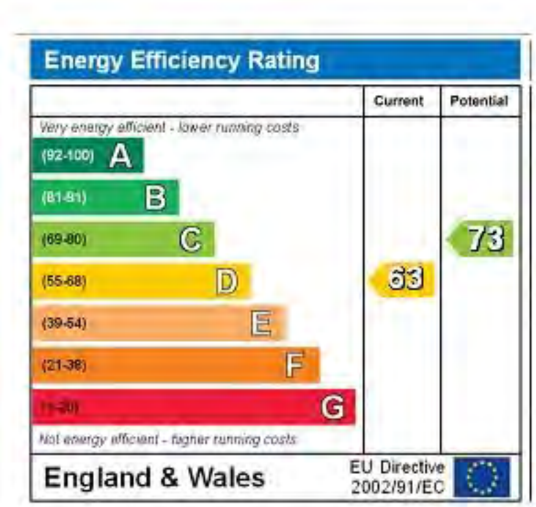
Reliable metrics are critically necessary!
Different kinds of metrics are to be developed further.



2/3

Energy certification by using metrics for energy use

To accomplish
Net Zero by 2050


Technology report

Renovation of near 20% of existing building stock to zero-carbon-ready by 2030 is ambitious but necessary

September 2022

3/3

Technology Collaboration Programme
by iea

Combining Global Efforts for Building Decarbonization

IEA Future Buildings Forum Think Tank Workshop

Existing Buildings: Pathways to Net Zero Carbon 2035

Philippe St Jean

Canadian delegate to the IEA End-Use Working Party | Deputy Program Director for Buildings and Communities Portfolio

October 19, 2022

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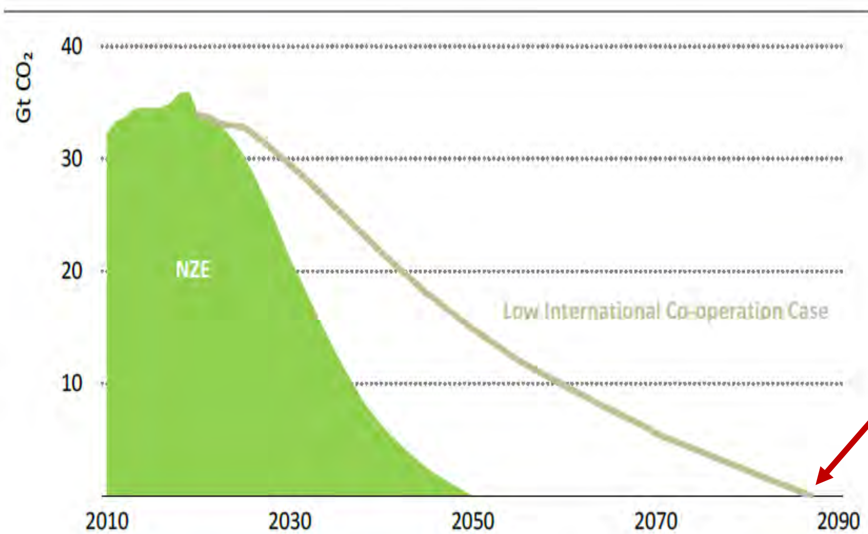
Net Zero by 2050: Strengthening International Collaboration

To reach the targets of the **IEA Net Zero Emissions by 2050 Scenario**, international **collaboration** needs to **accelerate** across all sectors.



Source: "Net Zero by 2050: A Roadmap for the Global Energy Sector", IEA, 2021

Without international collaboration, the transition to net zero global emission could be delayed by decades

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Collaborate Internationally to Increase the Economic Gains of Transition

What are the potential gains of strong international collaboration?

More widespread adoption of effective policies

Faster innovation

Stronger incentives for investment

Larger economies of scale

Level playing fields

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International collaboration is needed to decarbonize buildings

The building sector is currently not on track to meet the Net Zero by 2050 trajectory

Buildings operations account directly and indirectly for **approximately 30% of global energy** sector emissions.

Global **floor area** is expected to **increase by 75%** between 2020 and 2050, with **80% in emerging market and developing economies**.

Without **international collaboration**, the **transition** to net zero global emissions **could be delayed by decades**.

Value chains for building materials, appliances and equipment are **increasingly globalized**.

According to the **IEA Net Zero by 2050 Report**, effective decisions must focus on **decarbonizing the entire value chain**.

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Global collaboration in the building sector

International collaboration in the building sector is increasing, with international efforts to **improve energy efficiency**, **share best practices** and build momentum in decarbonizing the buildings sector.

iea	Within the framework of the IEA, the Technology Collaboration Programmes (TCPs) provide a platform for governments to work together to advance research, development and commercialization of energy technologies. There are 38 TCPs, each focusing on specific energy technology areas.	Specialized Programme
Global Alliance for Buildings and Construction	The GlobalABC is a global platform with 247 members, including 37 countries, for governments, the private sector, civil society and intergovernmental and international organizations to increase action towards a zero-emission, efficient and resilient buildings and construction sector.	Public-Private Network
World Green Building Council	A global action network of over 70 Green Building Councils around the world that aims to support and unite them to transform the building and construction sector across climate action, health and wellbeing and resource and circularity.	NGO Network
GBPN	A global network brings together over 300 experts, policy-makers, industry leaders and researchers from over 20 countries with the purpose of advancing policy reform on building energy performance. Connects local policy makers, building professionals and industry-leading experts.	Public-Private Network
C40 Cities	A global network of local governments (cities) taking urgent action to confront the climate crisis with a mission to halve the emissions of its member cities within a decade. C40 cities has significant funding from CIFF.	Network

Adapted from Energy Efficiency Hub EEB Task group Terms of Reference, 2022

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Enhancing collaboration between multilateral initiatives

Multilateral platforms can distribute the **cost and risk of innovation** across many actors, **facilitate the exchange of ideas** between sectors and across borders, **enable the exchange of good policy** practice among policy makers, and **support market deployment** by harmonizing performance standards and codes.

Co-ordination between multilateral initiatives can enhance impact and save resources

The TCP modernization strategy puts cross-initiative collaboration at the center

There is enormous scope for the TCPs to work with complementary platforms to accelerate innovation

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Collaboration opportunities within the Building Coordination Group

To maximize the impact of international collaboration efforts in addressing global energy and climate challenges, governments can pursue synergies between multilateral initiatives.

- TCPs strategic vision on IEA Net Zero by 2050's buildings milestones to 2030
  - Significant collaboration opportunities within the BCG across 9 TCPs and the new Cities TCP to meet the 2030 milestones
  - New IEA TCP on **Cities and Communities** created in 2022
  - Various **policy recommendations** around marker creation and standards, planning instruments, economic and financial instruments, and education and training
- The Future Building Forum (FBF) will capitalize on collaboration between the buildings-related TCPs.

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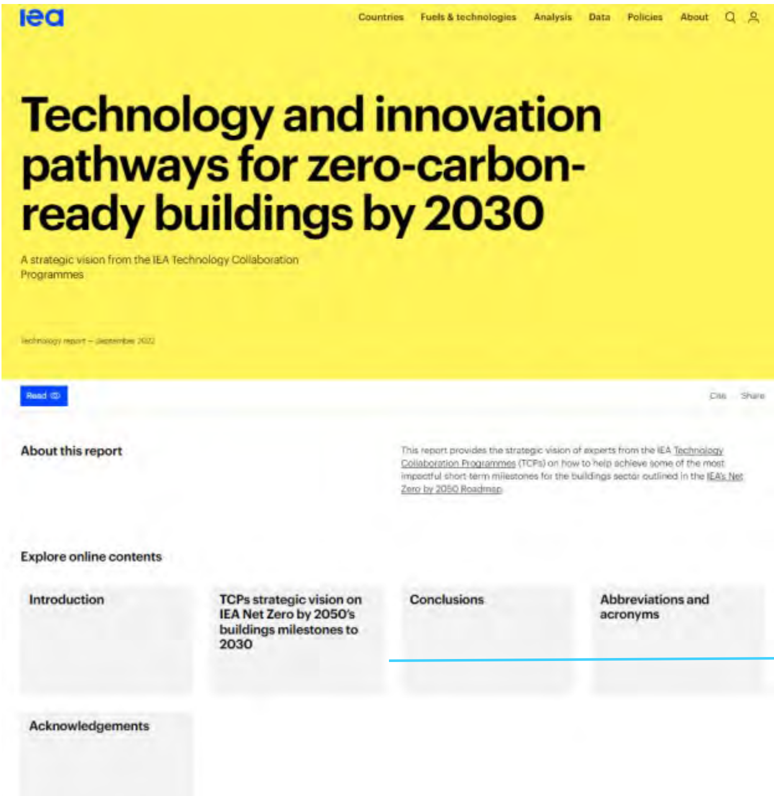
Publication webpage: landing page and access to different sections

https://www.iea.org/reports/technology-and-innovation-pathways-for-zero-carbon-ready-buildings-by-2030



Access to the different sections

Page 8

Project background: TCP vision referred to recent IEA analysis

A zero-carbon-ready building (ZCRB) is highly energy efficient and either uses renewable energy directly, or uses an energy supply that will be fully decarbonised by 2050, such as electricity or district heat. This means that a ZCRB will become a zero-carbon building by 2050, without any further changes (IEA Net Zero Report, box 3.4).

TCPs provided their vision on how to help achieve some of the most impactful **short-term (2030) key milestones** in the IEA analysis for the building sector.

*Key **milestones** in transforming the global buildings sector* (at 2030)	TCP vision author
All countries targeted for **zero-carbon-ready codes** for new buildings	EBC
20% of the **existing buildings** stock are renovated to the zero-carbon-ready level	EBC
About 600 million **heat pumps** are installed covering 20% of buildings heating	HPT
Approximately 100 million households are relying on **rooftop solar PV**	PVPS
Solar **PV and wind supply** about 40% of building electricity use	ES, ISGAN
350 million buildings connected to a **district energy network** (20% of heating needs)	DHC
Solar thermal technologies deployed in around 400 million dwellings	SHC
100% of global lighting sales in buildings are **LEDs** (by 2025)	4E
Residential **behaviour changes** lead to a reduction in heating and cooling energy use	USERS
By 2030 **Electric Vehicles** represent more than 60% of vehicles sold globally,	HEV

Common challenges

Urgent deployment and integration of available clean and efficient energy technologies

Innovation to achieve longer terms targets: lifetime perspective and systemic approach

Energy security: role of renovation, electrification (HP), RES integration and behaviour

- Improved technology performance (including noise, volume, aesthetics, health, maintenance/durability, controls)
- Reduced upfront costs of clean energy technologies (compared to fossil-based)
- Updated Code/Regulations (more evidence-based, easier to implement)
- Harmonized standards across countries
- New Tools and Processes (e.g. for integration into local planning)
- Impact improved by smart systems integration (HP PV, ES, Mobility) and interoperability
- Stakeholder awareness and better supply chain skills
- New suitable financial and business models
- Social inclusion and health

Innovation themes entailing further Collaboration

- Development of easy-to-use and reliable tools supporting **building codes**
- Life Cycle methodology to identify cost-effective **combinations of technologies** (including grids and H2)
- **Flexible operation, smart controls, system integration** with intermittent electricity generation and other electricity prosumers in the building (PV, ES, HP, EV, EBC, USERS)
- **Sector Coupling** and synergies across technologies and end-uses, in particular at the district and urban level (e.g. PV-SHC; HP-DHC; EBC, USERS) (reflected in new codes)
- **Energy data**, open-source models and protocols to maximise clean technologies uptake
- System solutions for **energy communities** and **positive energy districts** including necessary regulatory and social conditions (e.g. peer-to-peer models).
- Energy-efficient and cost-effective **cooling** strategies including district cooling

Collaboration opportunities within the BCG

2030 Milestones/TCP	Energy Storage	DHC	HPT	PVPS	SHC	EBC	USERS	EV	ISGAN
1. All countries targeted for **zero-carbon-ready codes** for new buildings (EBC BECWG)	System integration	New code metrics (including DHC and the e. grid.	MEPs and labelling schemes	Framework for BIPV	Solar planning	Behaviour **Cooling** HVAC calculation (tertiary b.), PECs	**Behavioural Insights**	EV Chargers/Grid Integration	**Smart meters** Tarifs/Codes
2. **Existing buildings** - 20% renovated to the ZCR level (EBC 75)	Storage systems design and control	Low temperature DH	**HP for NZEB**	System integration for deep retrofit	**Solar planning** Architecture Historic b.	**Flexibility** **Positive energy districts (PED)**	operation guidelines for PECS Hard to reach u.	EV Chargers/Grid Integration	Grids improvement
3. **Heat pumps:** 600 million are installed covering 20% of buildings heating (HPT)	ES design and control Climate & Comfort Box Hybrid networks (sector coupling)	**RES Integration in existing** b. **Digitalisation**	HP for NZEB Large HP for retrofit (tertiary) HP in multifamily b. Ground source HP hybrid systems Connected devices Sector coupling	System integration with solar PV		New business models Building renovation at building and district level	**Behavioural Insights** (impact campaign Hard to r. users		New business models
4. Approximately 100 million households are relying on **rooftop solar PV** (PVPS)	**ES modelling and optimisation**	System integration: maximise local use of energy	Integrated smart controls	Efficiency Aesthetics Integrated (BIPV) LC impacts 100% RES Power System		Building renovation at building and district level **PED**	**Behavioural Insights** Acceptability Peer to P.	EV Chargers/Grid Integration	

Ongoing collaboration | Possible, mentioned by Authors | Other opportunities

Collaboration opportunities within the BCG

2030 Milestones/TCP	ES -Energy Storage	DHC	HPT	PVPS	SHC	EBC	USERS	EV	**4E**	ISGAN
5. **Solar PV and Wind** supply about 40% of building electricity use by 2030 (ES - ISGAN)	**Compact Thermal ES** **ES Modelling**		Climate & Comfort Box	Integrated PV (BIPV) 100% RES Power System		**Positive energy districts** **Flexibility** B. Codes	**Peer-to-Peer, Community** **Social License**	EV Chargers/Grid Integration		**Grid solutions** **Flexibility markets**
6. **District Energy**: 350 million building units connected to a district energy network by 2030 (DHC)		Low T operation Hybrid networks District cooling Non-fossil low-T DH	Flexibility : HP in multi-vector energy systems and thermal networks HP in DHC		Solar DH- with higher T and digitalization Storage for DH	Demand Management of Buildings in Thermal Networks B. Codes	**Behavioural Insights** Acceptability			
7. **Solar Thermal**: 400 million dwellings use solar thermal by 2030 (SHC)	Compact thermal Storage	Solar DH			Solar planning Historic buildings Solar Cooling	PEDs Building Codes	Acceptability			
8. Targeting 100% **LED** lighting sales by 2025 (4E)					Integrated Solutions	B. Codes				
9. Residential **behaviour changes** lead to H&C energy reduction (USERS)	Confort and climate box	Smart district energy use			Solar neighborhood	PECS Behaviour B. Codes				**Smart meters** Tarifs/Codes

Ongoing collaboration — Possible, mentioned by Authors — Other opportunities

Successful Collaborations (The Future Building Forum)

The IEA handbook *Enhancing Collaboration between Multilateral Initiatives* identified four core characteristics that are commonly shared by successful collaborations between multilateral platforms

Shared Interest	**The FBF has identified a theme of strong common interest - within the context of the IEA's 'Net Zero by 2050: A Roadmap for the Global Energy Sector' – as well as break out sessions topics of common interest**
Forerunner	**The forum is lead by EBC as the champion TCP, and each break out sessions has dedicated sessions coordinators**
Resources	**You all have been given the necessary resources to attend this 3-day event, and may be able to pursue through your TCPs or research activities**
Process	**The 3-day workshop will consist of ;** **- Open table discussions and presentations from various TCPs** **- Breakout sessions on various topics** **- Consolidation of session results and recommendations, identification of common activities in plenary sessions**

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Future Building Forum

"The purpose of the FBF Think Tank Workshop 2022 is to identify the international collaborative RD&D activities needed to unlock deployment of low and zero carbon technologies in existing housing and building and enable Net Zero Carbon 2035"

…You have all the elements to succeed – now let's get to it

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Cities **TCP**

IEA Future Buildings Forum Think Tank Workshop

October 2022

Technology Collaboration Programme
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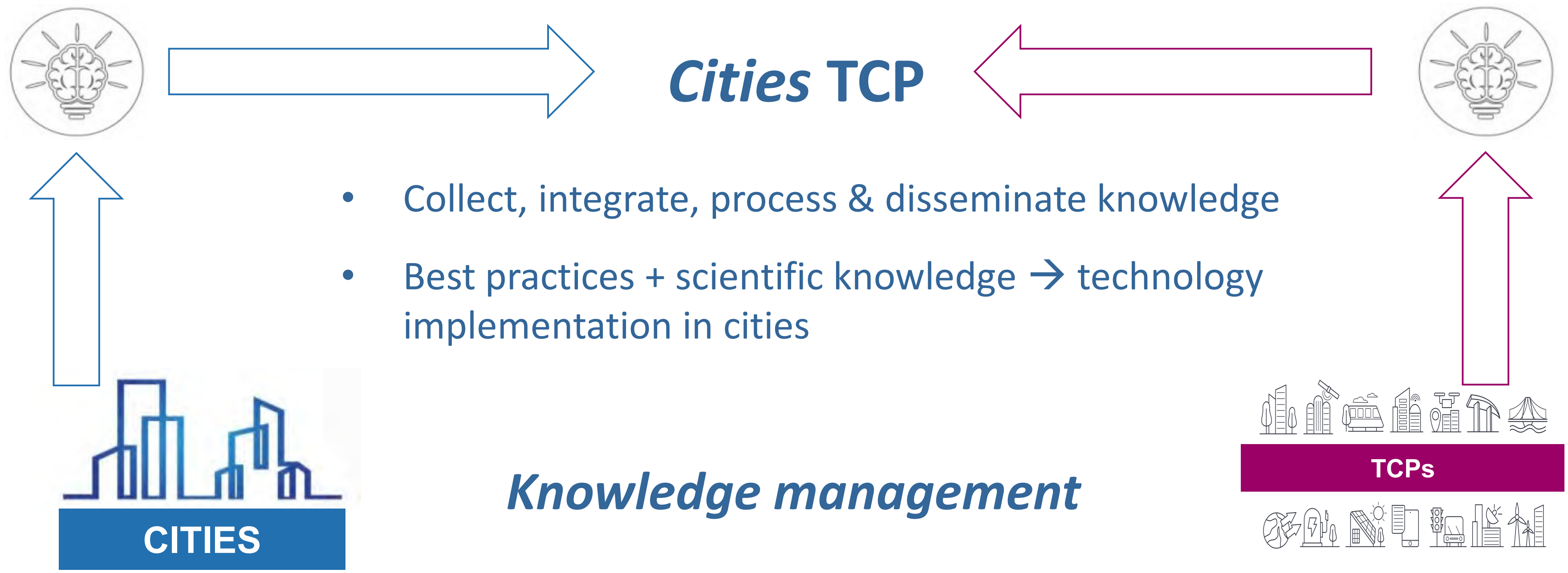
3 most important issues TCP Cities is facing

Accelerating of decarbonization efforts in cities by

1. **focusing on buildings, energy supply and mobility**
2. **supporting cities by know-how-transfer**
3. **supporting cities' governance and planning procedures**



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19th - 21st October 2022, Gatineau, Québec, Canada

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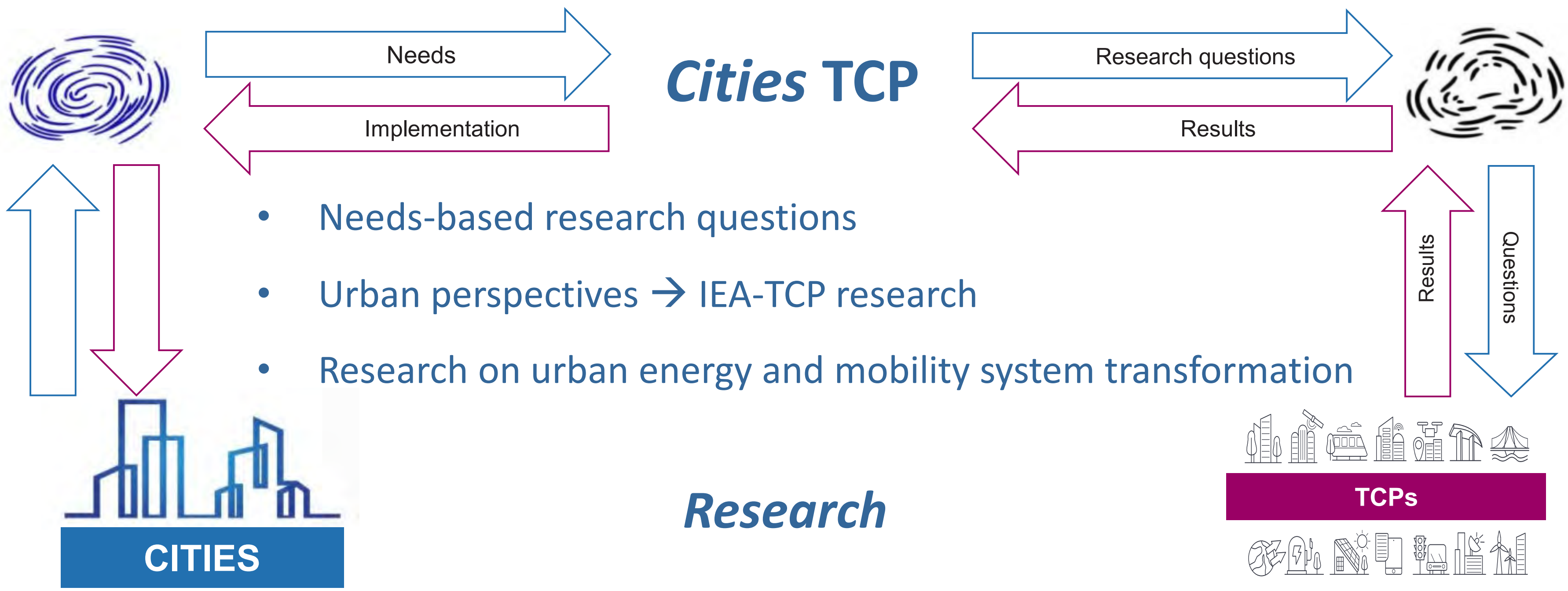

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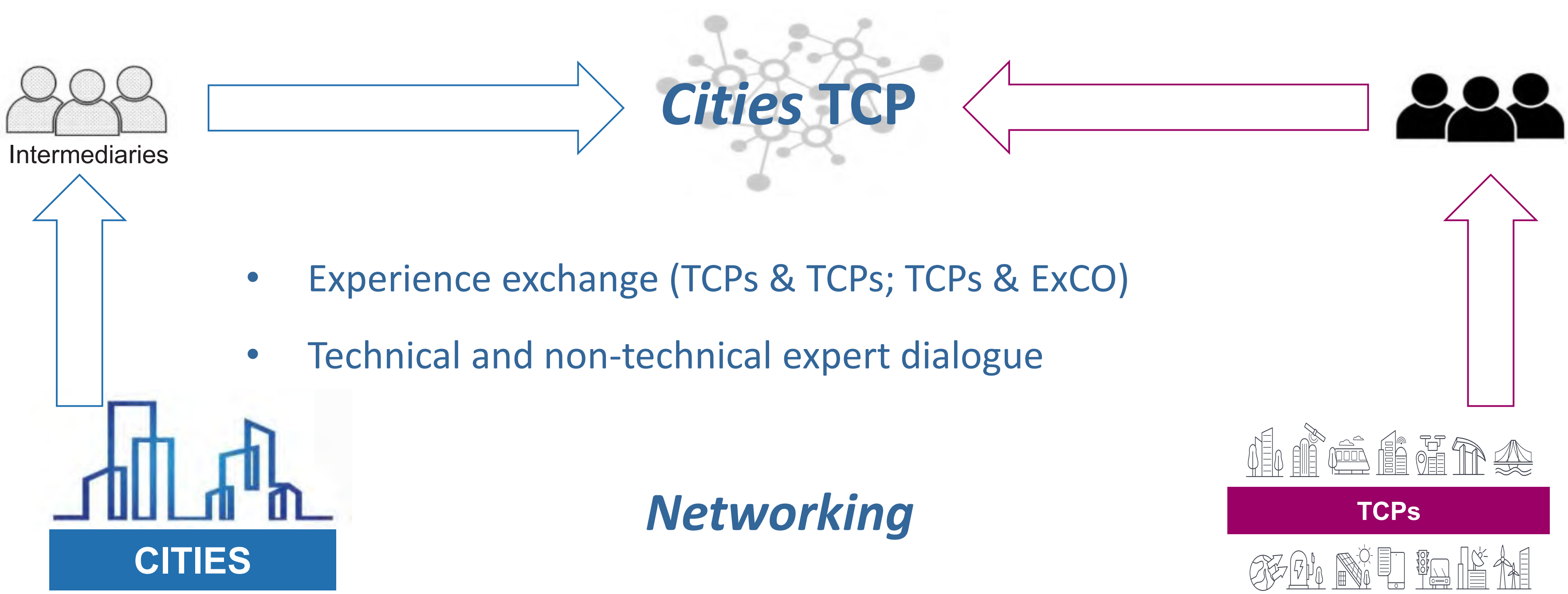

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3 most important issues the TCP will need to deal with over the next 5 years

1. Decarbonization of existing heat supply systems at city and community scale
2. Utilizing potentials of electricity production and storage at community scale
3. Transformation of urban mobility systems including changes in the modal split

→ Instruments for successful implementation

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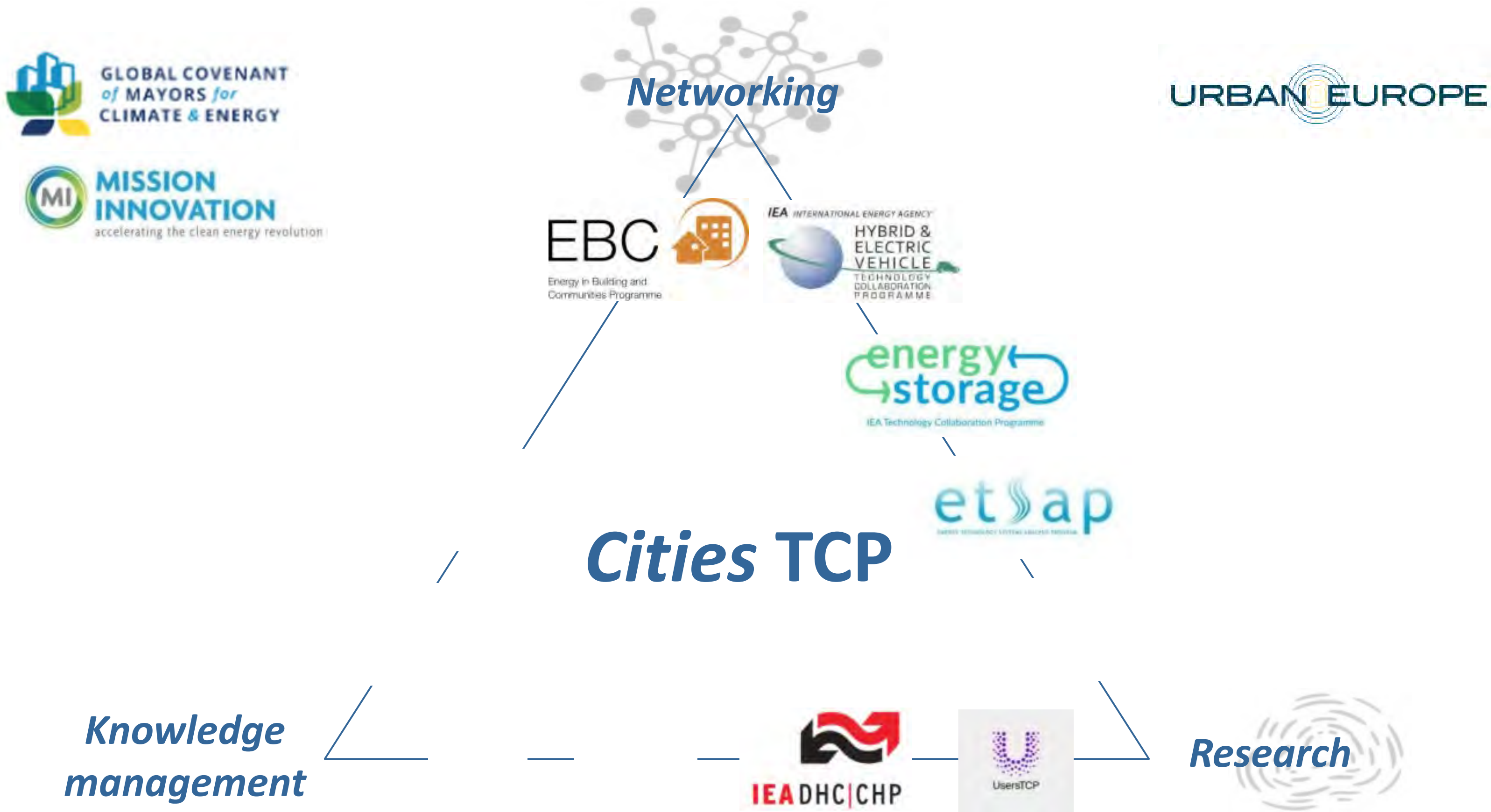
What other TCPs can contribute to successfully address and resolve these issues



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District Heating & Cooling

Robin Wiltshire

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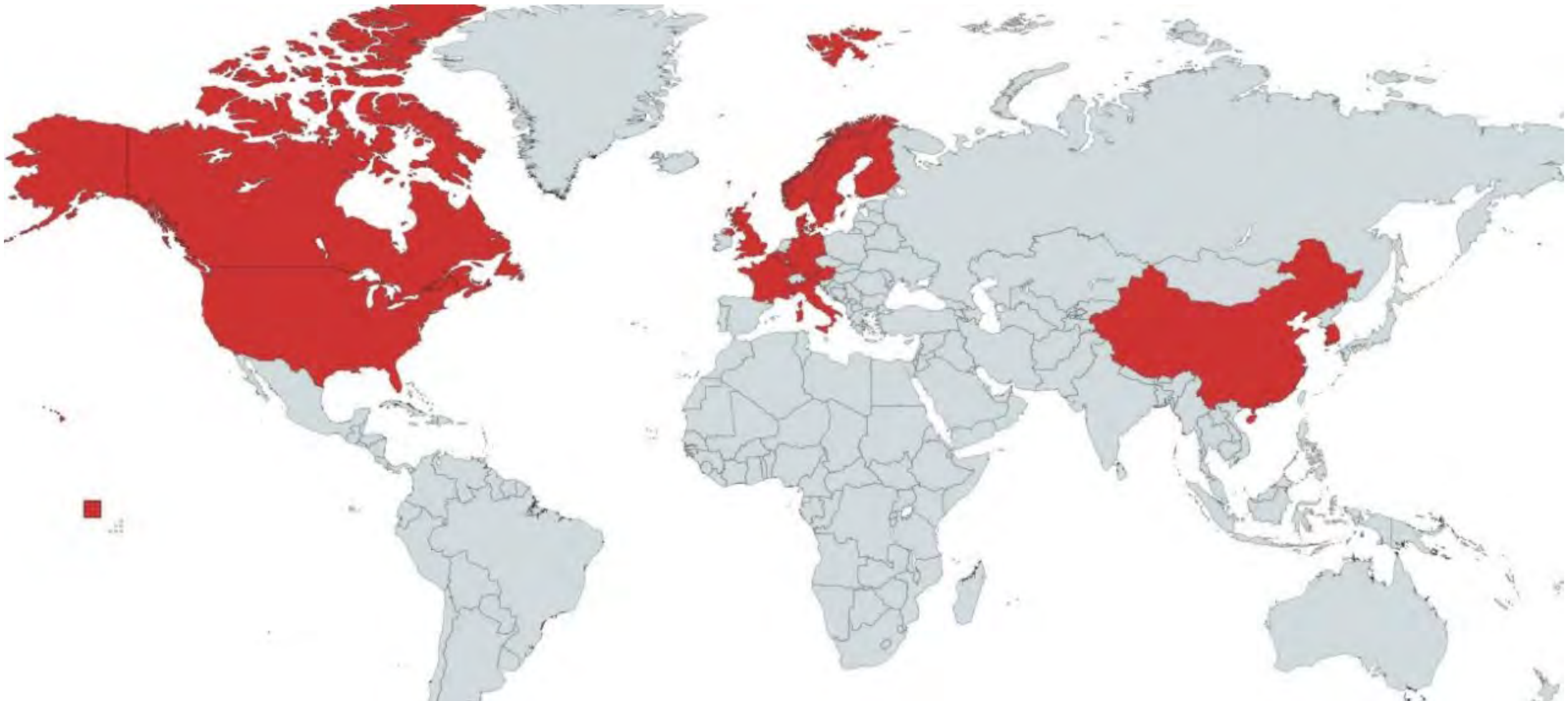
Who are the IEA DHC TCP?



Established in 1983, current members are: Austria, Belgium, Canada, China, Denmark, Finland, France, Germany, Italy, Korea, Norway, Sweden, UK, USA

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Three most important issues facing the DHC TCP

Barriers to more rapid growth arise from capital cost, skills shortages, lack of awareness.

DHC networks need state-of-the-art controls to optimise integration of renewables and enable prosumer participation.

DHC networks will increasingly synergise with other energy infrastructures to form a mutually supportive overall sustainable energy system.

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Three most important issues facing the DHC TCP over the next 5 years

The same issues can be expected to persist over the next 5 years.

DHC networks are inherently flexible; this flexibility needs to be rewarded financially.

Energy quality as well as quantity is important signalling the role of analysis based on exergy; with low temperature systems we will use the energy no one else wants.

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What other TCPs can contribute

Seek agreement where individual and where network solutions are most appropriate

Hybrid solutions involve multiple technologies; act together to devise ways forward

Use of renewables including deep geothermal: other TCPs study potential, DHC looks at integration.

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New Call for Proposals

New Call for Proposals just launched at www.iea-dhc.org

Call for Proposals states that 'Proposals which refer to other TCPs will be very welcome.'

Two-stage process: deadline for two-page outline proposals is 28 February 2023

Please alert your networks.


IEA DHC

IEA TECHNOLOGY COLLABORATION PROGRAMME ON
DISTRICT HEATING AND COOLING

ANNEX XIV
(1 May 2023 – 30 April 2026)

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Energy in Buildings and Communities (EBC)

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October 2022

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The current 3 most important issues

1. **Energy renovation of existing buildings**
   - Annex 73 (commercial) and 75 (residential)
   - Tools and guidelines for practitioners
   - Business models and policy recommendation

2. **Holistic solution sets on a community level**
   - Annex 82 (Energy flexibility), 83 (Positive energy district) and 84 (Thermal networks)

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The current 3 most important issues

3. Planning, construction and management process reducing the performance gaps

Annex 5 (envelope & ventilation), 69 & 79 (human behavior), 70 (real energy), 72 (Embodied), 74 (Living lab), 78 (Gas-phase air cleaning), 80 (resilient cooling), 81 (Data-driven), 85 (Indirect evaporative), 86 (Energy & IAQ), 87 (Personalized env. control) and 88 (heat pumps)

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The near future 3 most important issues

1. **For reducing performance gaps of energy and IEQ aspects, more thorough and extensive development of knowledge, methods and standards**

    - We need much more unbiased, scientific and practical tools to predict performances
    - Continuous thorough and extensive activities in EBC is indispensable

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The near future 3 most important issues

2. **Building Information Modelling (BIM) as a method enhancing productivity and as a container of energy & environment related components' information**

   Energy & environment related contents for DX and BIM shall be developed deeply enough.

2. **Guidance for businesses and policies on energy in buildings and communities incl. codes and standards**

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What TCPs can contribute to issues?

1. **Support standardization activities (TCPs' outputs transferred to ISO, CEN, ASHRAE or national standardization bodies)**

   Standards for public approaches for Net Zero by 2050 need much more efforts, which is to be supported by TCPs.

2. **Support practitioners with guidelines as TCPs' outputs**

3. **Support policies of IEA, regions and countries**

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Session 1

Contribution Energy Storage TCP

Teun Bokhoven, chair ExCo ES TCP

October 19th 2022

Technology Collaboration Programme
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Context to understand the answers to the questions

- Decarbonization calls for a renewables-based energy system
- Electricity moves into the heart of this system
- Energy storage becomes crucial for flexibility and sector interaction, helping to provide the right form of energy at the right place and time
- Energy storage gains in value and, consequently, in scientific, public, and political interest

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Most relevant issues for ES TCP (I)

Storage by its nature is an enabling technology, bridging the time gap between supply and demand and therefor it is important that:

- **System aspects**: In our future, renewable energy supply will most of the time not match the time of use and therefor flexibility + storage is required. The (electricity) grid have limits in accommodating all the peak supply and demand, also therefor flexibility (incl. storage) is a must!
- **Cost vs value:** the cost of storage system needs to be in balance with the value it has in the system. Therefor cost and efficiency are important objectives in all the work
- **Communication and awareness**: important to show the opportunities storage provides in the building (system).

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Most relevant issues for ES TCP (II)

Storage by its nature is an enabling technology, bridging the time gap between supply and demand and therefor it is important that:

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- **Cost vs value:** the cost of storage system needs to be in balance with the value it has in the system. Therefor cost and efficiency are important objectives in all the work
- **Communication and awareness**: important to show the opportunities storage provides in the building (system).

Most relevant issues to deal with over next 5 years

Resources are always (too) limited therefor:

- **What sectors:** Our work on energy storage need to address the most urgent issues, where can storage help deployment of renewables
- **What technologies:** Can we deal with all sort of options to serve the sectors (coupling): electrical, thermal (cold / heat), P2H, P2Molecules ; short term / long term; small capacities / large capacities. How to make the right choices?
- **Right mix:** We need to contribute to fast deployment of results, without limiting fundamental research and development

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What other TCP's can contribute

In relation to the built environment we have some good examples, but it could be intensified:

- With **HPT** (heat pumps) we work on integrated units – but this cooperation could be wider
- With **SHC** (solar thermal) we work on materials and reactors for compact storage, this is an ongoing activity
- We contribute with thermal seasonal storage work to the **DHC** (district heating and cooling)
- We would encourage stronger cooperation i.e. with **Isgan** (smart grids), **EBC** (building integration), **User** (behavioral impact) and **Cities** (planning aspects)

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Hybrid and Electric Vehicles (HEV)

IEA Future Buildings Forum Think Tank Workshop

October 2022

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Current 3 most important issues

Building EV readiness

Ownership and business models, and retrofits

Energy management

Residential, MURB & Commercial

Technology Collaboration Programme

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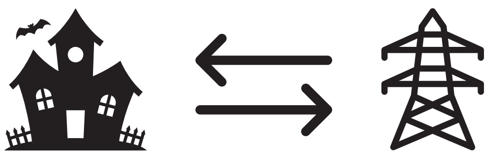
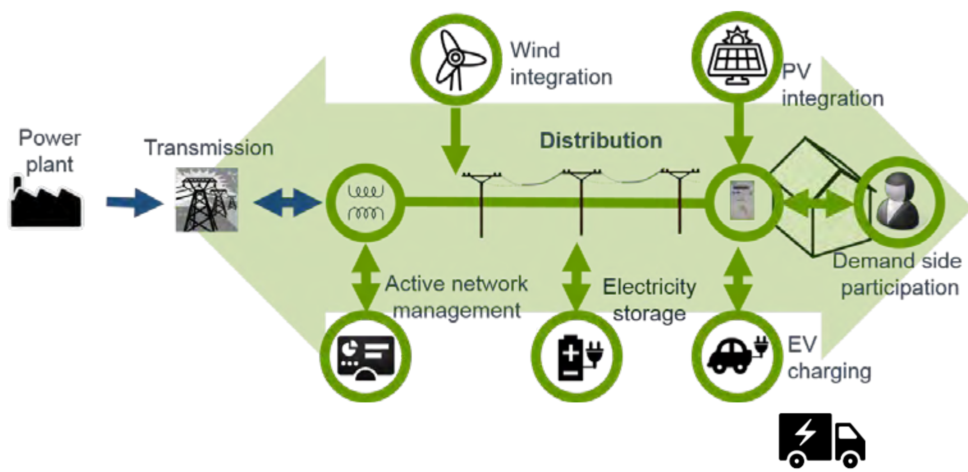
Near-term important issues



Increased communication and collaboration

Increased technical and regulatory support



Consider the broader energy system

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Examples of other TCPs that can contribute

EBC

Energy in Building and Communities Programme

energy storage

IEA Technology Collaboration Programme

ISGAN

INTERNATIONAL SMART GRID ACTION NETWORK

hev tcp

IEA PVPS

IEA Technology Collaboration Programme

Advanced Fuel Cells

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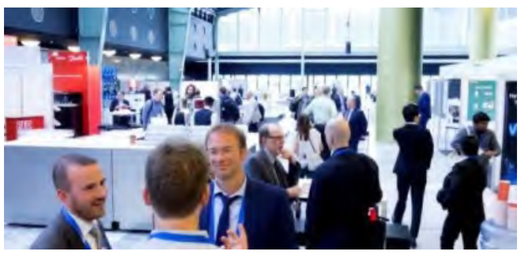
IEA Technology Collaboration Programme on Heat Pumping Technologies (HPT TCP)

14th IEA HEAT PUMP CONFERENCE
RENAISSANCE CHICAGO DOWNTOWN HOTEL
MAY 18—23, 2023 | CHICAGO, IL



17 member countries

***Several NEW countries in progress**

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19th - 21st October 2022, Gatineau, Québec, Canada

The 3 most important issues HPT TCP is facing (1)

Heat Pumps are smart, flexible, and integrated with other clean energy technologies

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The 3 most important issues HPT TCP is facing (2)

The transition of the cooling sector to efficient and affordable solutions – a growing market including emerging countries

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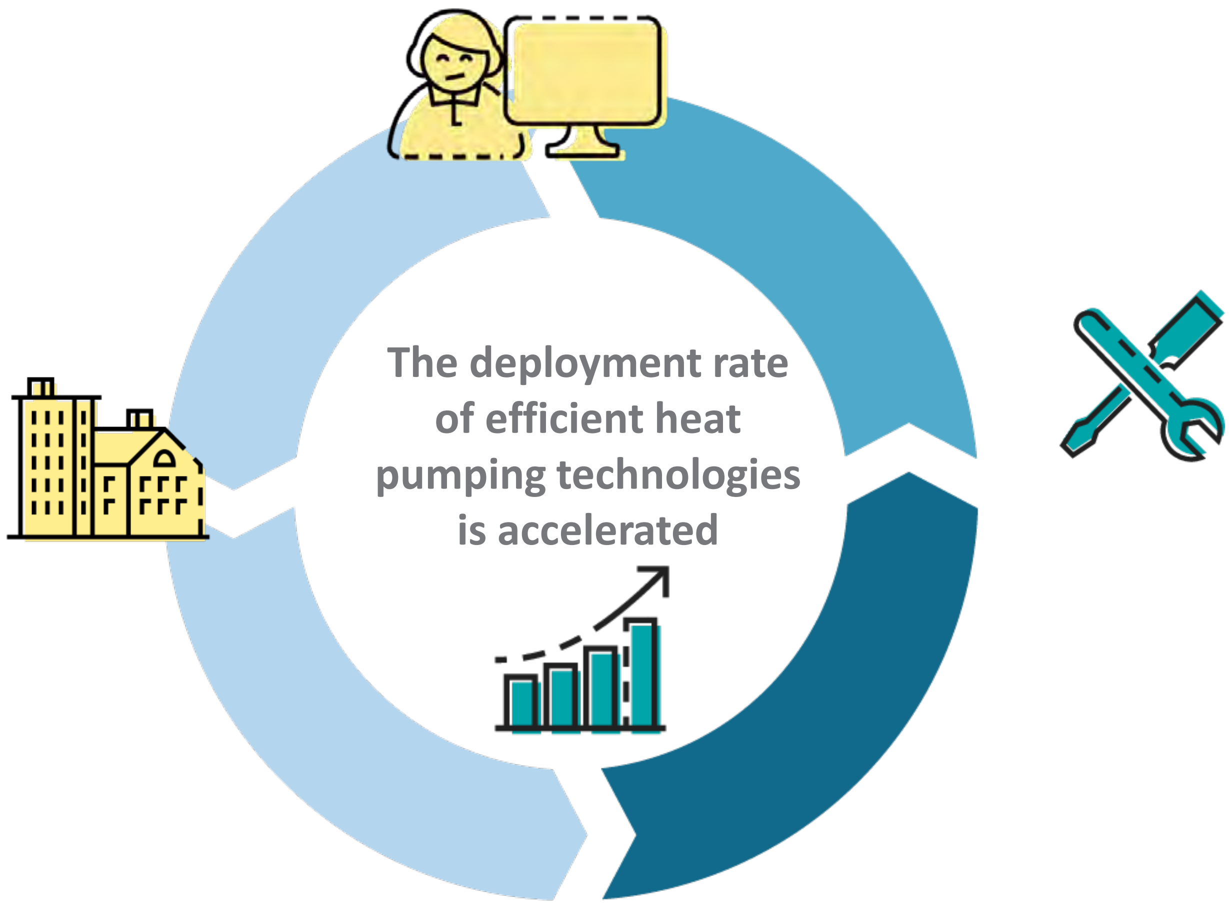
The 3 most important issues HPT TCP is facing (3)

Ensure skill and awareness of the technology,

skilled/trained actors, and support with tools in the whole value chain



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3 most important issues that we need to deal with over the next 5 years

1. **Digitalization and cybersecurity in connected systems**
2. **High efficiency in difficult buildings and difficult climates**
3. **Circular economy for heat pumps**




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What other TCPs can contribute to successfully address and resolve these issues

Inspiration, learning, and collaboration with other IEA TCPs and with other organizations

- Energy transition needs a cross-disciplinary approach
- Knowledge about other technologies
- Experts from non-technological areas of expertise
- Share knowledge, methods, tools, and models
- Learning from the deployment of other technologies

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Photovoltaic Power Systems Programme (PVPS) TCP

Presented by Costa Kapsis

Assistant Professor, University of Waterloo
Task 15 STC co-leader
ASHRAE TC 6.7 chair

on behalf of Daniel Mugnier, IEA PVPS Chairman

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October 19, 2022

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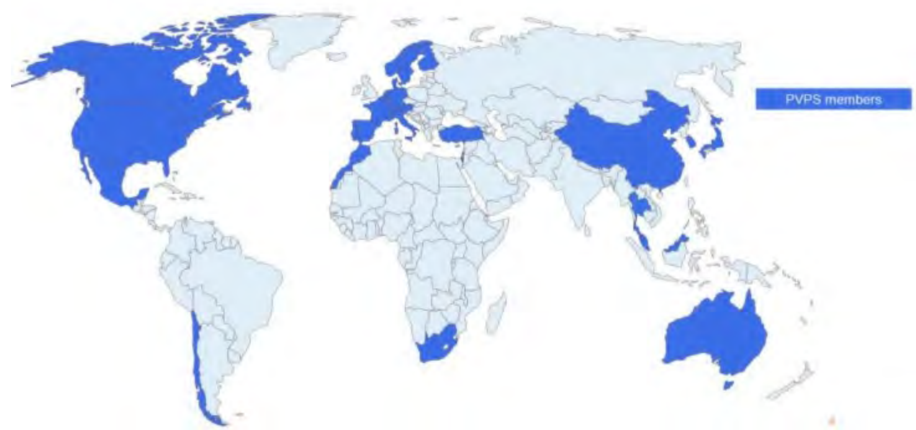
IEA PVPS in a Nutshell

Who Are We?

- **32 members** - 27 countries covering 5 continents, European Commission, 3 associations
- 8 active tasks, representing main stakeholders in R&D, industry, implementation and policy
- Covering a large majority of worldwide production, applications and markets
- Mission: "***To enhance the international collaborative efforts which facilitate the role of photovoltaic solar energy as a cornerstone in the transition to sustainable energy systems***"

Driving Forces

- Climate change mitigation & resilience of energy systems under extreme events
- Affordable & accessible energy for all
- Sustainable circular economy



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Active PVPS Tasks in Relation to Buildings

- **Task 15 – Enabling Framework for the Acceleration of BIPV.** *"Accelerate the penetration of BIPV products in the global market of renewables, respecting mandatory issues, aesthetic issues, reliability and financial issues."*
- **Task 14 – Solar PV in the 100% RES Power System.** *"Promote the use of grid-connected PV as an important source in electric power systems at the higher penetration levels that may require additional efforts to integrate dispersed generators."*
- **Task 1 – Strategic PV Analysis and Outreach.** *"Promote and facilitate the exchange and dissemination of information on the technical, economic, environmental and social aspects of PV power systems."*
- **Task 17 – PV and Transport.** *"Focuses on possible contributions of PV technologies to transport, as well as the expected market potential of PV applications in transport."*

SolarPower Europe

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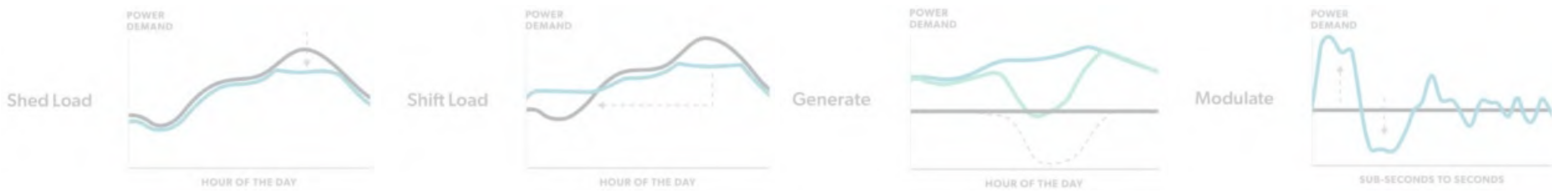
Current Technical Challenges

- **Smart Grid & Decarbonization**
  High PV penetration and other renewables, grid management issues, distributed energy resources, demand flexibility & resilience



- **Building Electrification & Decarbonization**
  BIPV, BAPV, PVT, heat pumps, energy conservation and efficiency measures, aesthetics, design, standards

- **Energy Storage & Electric Vehicles**
  Storage technologies, P2X, intermittent/short-term/seasonal storage, V2X

SOURCE: US DOE, 2021.

SOURCE: IEA PVPS TASK 15, 2022.

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Mid- & Long-Term Challenges

- **Switch to cleaner forms of energy** sources and building systems *(environmental imperative)*
- Maintain energy generation (and efficiency measures) **affordable for all** *(financial imperative)*
- **Balance electricity generation** with loads otherwise the grid may become unstable *(technical imperative)*
- **Enable integration and interoperability** of Distributed Energy Resources (DER) for resilience *(technological imperative)*
- **Support the electrification of transportation** sector *(transportation sector imperative)*

SOURCE: IEA EBC ANNEX 82, 2022.

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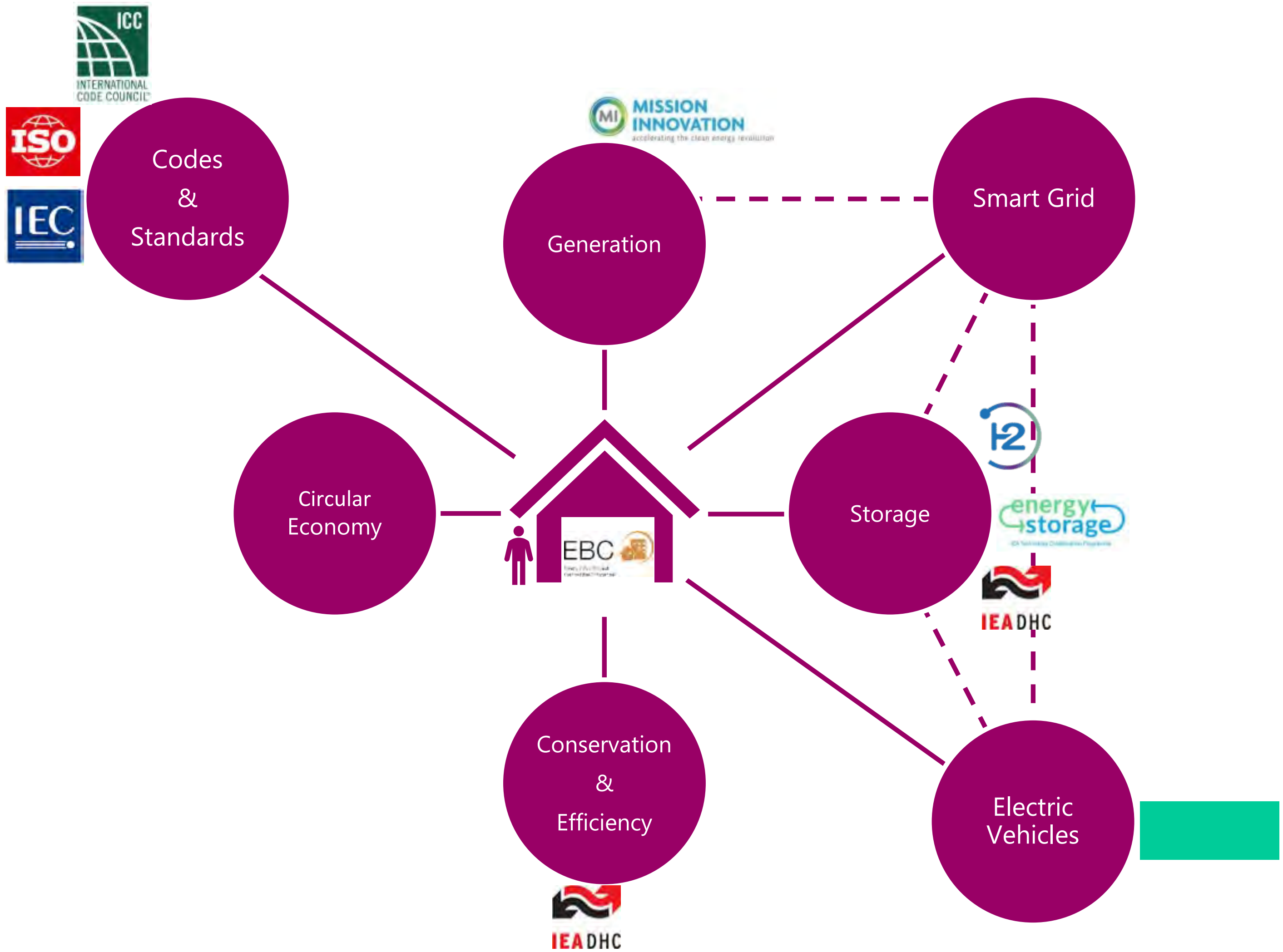
TCPs Collaborations to Address & Resolve Challenges



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SOLAR HEATING & COOLING PROGRAMME
INTERNATIONAL ENERGY AGENCY

Lucio Mesquita

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- **Established in 1977**
- **Currently 19 member countries and 9 member organizations**
- **Activities:** Projects (Tasks), Solar Academy, Solar Heat Worldwide, SHC Conferences and SHC Solar Award
- Solar heating and cooling defined as *solar energy technologies and architectural designs that* ***include active solar thermal heating and cooling, photovoltaic driven heating and cooling, passive solar building design and solar architecture***

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SHC
SOLAR HEATING & COOLING PROGRAMME
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3 most important issues SHC TCP is facing

- **Development of new and innovative SHC applications**
  - Tasks 62,64,65 (wastewater, solar cooling, process heat)
- **Further development of SHC equipment and solar buildings/communities**
  - Tasks 63, 66, 68, 69 (solar neighborhood planning, solar buildings, solar DH, solar water heating)
- **Advancement of cross-cutting technologies to enable SHC deployment, e.g., energy storage**
  - Task 67 (compact thermal ES)

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3 most important issues the TCP will need to deal with over the next 5 years

- Develop SHC solutions for a future with significant electrification of heating within most OECD countries
- Support further performance improvements, standardization and costs reduction
- Increase awareness and understanding on the potential and value of solar heating and cooling systems with thermal and PV technologies

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INTERNATIONAL ENERGY AGENCY

What other TCPs can contribute to successfully address and resolve these issues

- Support initiatives to evaluate the impact of SHC technologies in the decarbonization of buildings and communities, particularly for cross-cutting technologies
- Assist on the development and distribution of information to relevant stakeholders
- Collaborate on supporting new applications

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TCP collaboration

Current joint Projects (Tasks) and collaborations:

HPT (Heat Pumps), **SolarPACES** (Solar Power and Chemical Energy Systems), **ES** (Energy Storage), **DHC** (District Heating and Cooling) and **PVPS** (Photovoltaic Power Systems)

Potential for further collaborations with:

EBC (Energy in Buildings and Communities), **IETS** (Industrial Energy-Related Technologies and Systems, **Geothermal**, **ISGAN** (Smart Grids) and **IEAGHG** (CCS R&D)

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User-Centred Energy Systems

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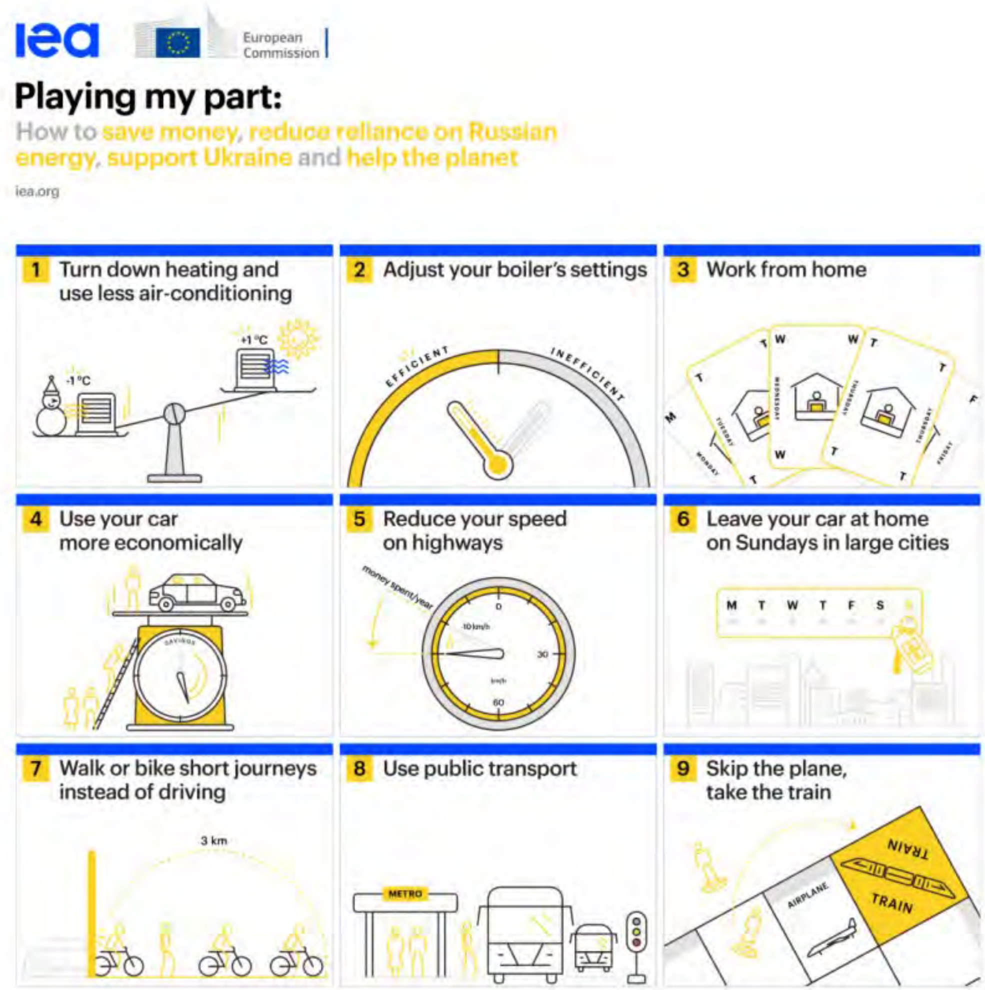
Users TCP: 2022-25 challenge 1 - Behaviours

- What behaviour change messaging works, for which groups in what contexts?
- What are the unintended consequences:
  - on marginalized groups?
  - for social media backlash?
- How large might an 'emergency' behavioural response be - and how long can it last?



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Users TCP: 2022-25 challenge 2 - Synergies

Maximising our Tasks' synergies and similarities

- Distributional impacts
- Community scales
- Fair outcomes
- Automation & authority
- Implications of differing motivations
- Underlying social and psychological mechanisms

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Users TCP: 2025-30 challenge area 1: Energy security, flexibility and resilience

- What does energy security look like to end-users?
- How much demand flexibility will come from BTM assets and under what circumstances?
- How does system resilience interact with consumers' interests in controlling their own assets?

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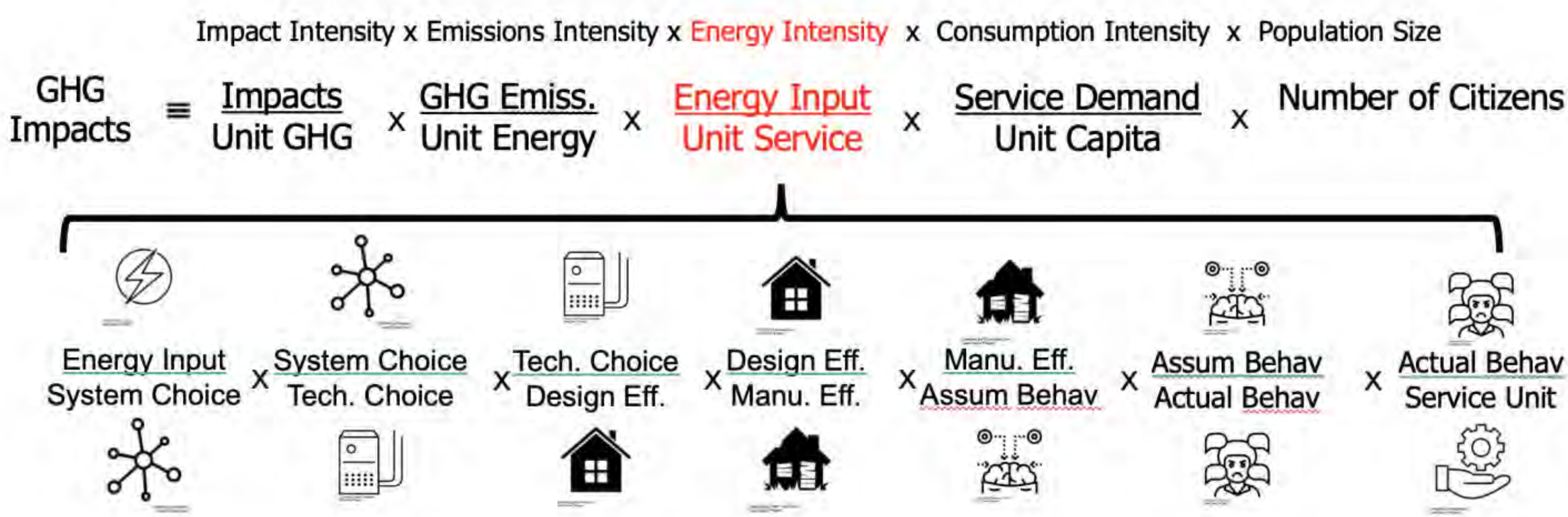
Cross-TCP collaboration: Energy Intensity

- Power system architecture that maximizes community self-consumption
- Characteristics that accelerate technology adoption
- Human dimensions of technology performance gaps
- Understanding technologists' assumed behaviour of occupants
- Designing systems for actual behaviour of occupants



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Cross-TCP collaboration: Consumption Intensity

- User-centred energy services design solutions
- Infrastructures' role in shaping energy service choices
- The impact of social structures on energy demand
- The role of end-user skills in shaping energy demand

Impact Intensity x Emissions Intensity x Energy Intensity x Consumption Intensity x Population Size

$$\text{GHG Impacts} = \frac{\text{Impacts}}{\text{Unit GHG}} \times \frac{\text{GHG Output}}{\text{Unit Energy}} \times \frac{\text{Energy Input}}{\text{Unit Service}} \times \underbrace{\frac{\text{Service Input}}{\text{Per person}}}_{\frac{\text{System options}}{\text{Services choices}} \times \frac{\text{Services choices}}{\text{Services volumes}} \times \frac{\text{Services volumes}}{\text{Per person}}} \times \text{Number of People}$$

- Service choices & service volumes = f{Capabilities, Opportunities, Motivations}
- f{possible, plausible, preferable}
- Service demand depends on social and psychological structures
  - **Temporal structures:** Work times; School times; holidays; etc
  - **Physical Infrastructures:** Cycling lanes; heat networks; etc
  - **Social structures:** Social norms; cultural expectations; social practices;
  - **Psychological structures:** Habits and routines; role modelling; etc
  - **Legal structures:** speed limits; property ownership; collaborative economy; etc
  - **Economic structures:** taxes & charges; subsidies; etc
  - **Knowledge and skills:** Information campaigns; skills training; etc

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4E TCP
Energy Efficient End-use Equipment

IEA Future Buildings Forum Think Tank Workshop

Casper Kofod

19 October 2022

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The current 3 most important issues

1. **Energy renovation of existing buildings**
   - Support a global transition to high quality LED lighting (SSL Annex)
   - Co-ordinate Approaches to promote Power Electronic based on wide-band gap technology
2. **Policy Guidance**
   - Align Effective Policies for Motor and Motor Systems
   - Reduce energy used in Smart Devices and interconnected Systems/Network (EDNA)

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The current 3 most important issues

3. **Planning, construction and management process reducing the performance gaps**
   - Connected Devices Alliance: Government and Industry platform for maximising energy efficiency outcome of Networked Devices
   - Monitoring the Performance Trends in major Appliances/Product over time

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The near future 3 most important issues

1. **Reducing performance gaps of energy efficiency with thorough and extensive development of knowledge and methods that can be used by practitioners and in regulation and standards**
    - 4E's thorough and extensive activities will continue to produce much needed unbiased and scientific guidance and practical tools

The near future 3 most important issues

2. **Technical performance data, system information and control strategies**

   To be used by the stakeholders but can also be used broader in cooperation with other TCP's in holistic NetZero activities.

3. **Successful ways to enable use of energy efficiency services and products**

   To be used by the stakeholders but can also be used broader in cooperation with other TCP's in holistic NetZero activities.

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What TCPs can contribute to issues?

1. **Support standardization activities (TCP outputs transferred to ISO, CEN or IEC)**

   Example: The SSL Annex runs Interlaboratory Comparison for Temporal Light Modulation to develop *Proficiency test for Accreditation due IEC TR 61547-1 and TR 63158*

2. **Support practitioners with guidelines as TCP outputs**

   Example: 15 Sep. 2022 the Motor System Annex published Key Finding on Digitalisation Technologies for Motor Systems

3. **Support policies of IEA, regions and countries**

   Example: 13 Oct. 2022 the SSL Annex published its new and updated "quality and performance requirements" for the most popular LED lamps and luminaires.

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Session 2

October 19th, 2022, PM

'Deep' Energy Retrofit – Challenges & Opportunities

Session Coordinators

Paul Ruyssevelt
Vice Chair, Energy in Buildings and Communities TCP / Professor, UCL

Costa Kapsis
PVPS Task 15 Leader, Photovoltaic Power Systems /
Research Scientist, Assistant Professor, University of Waterloo

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'Deep' Energy Retrofit – Challenges & Opportunities

IEA Future Buildings Forum Think Tank Workshop

M.Carver – Natural Resources Canada

October 19, 2022

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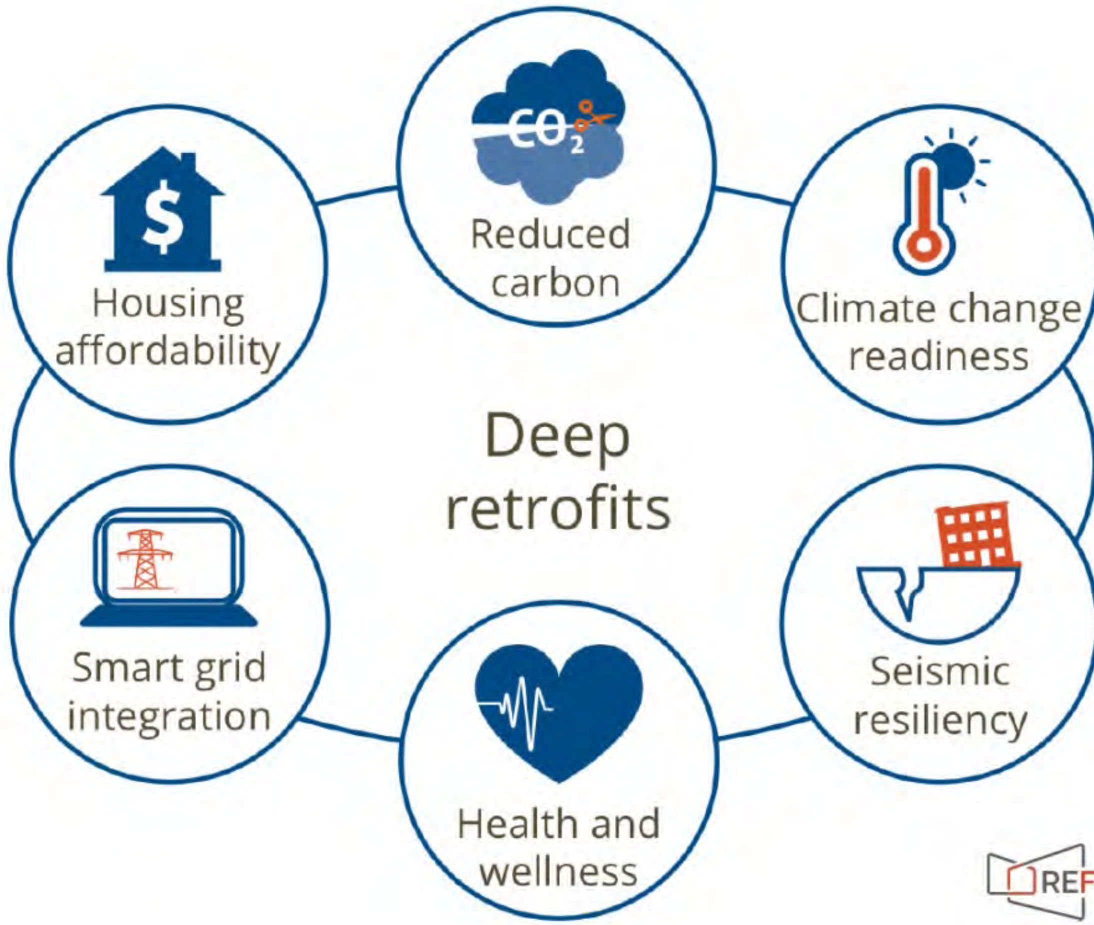
Defining Deep Retrofit



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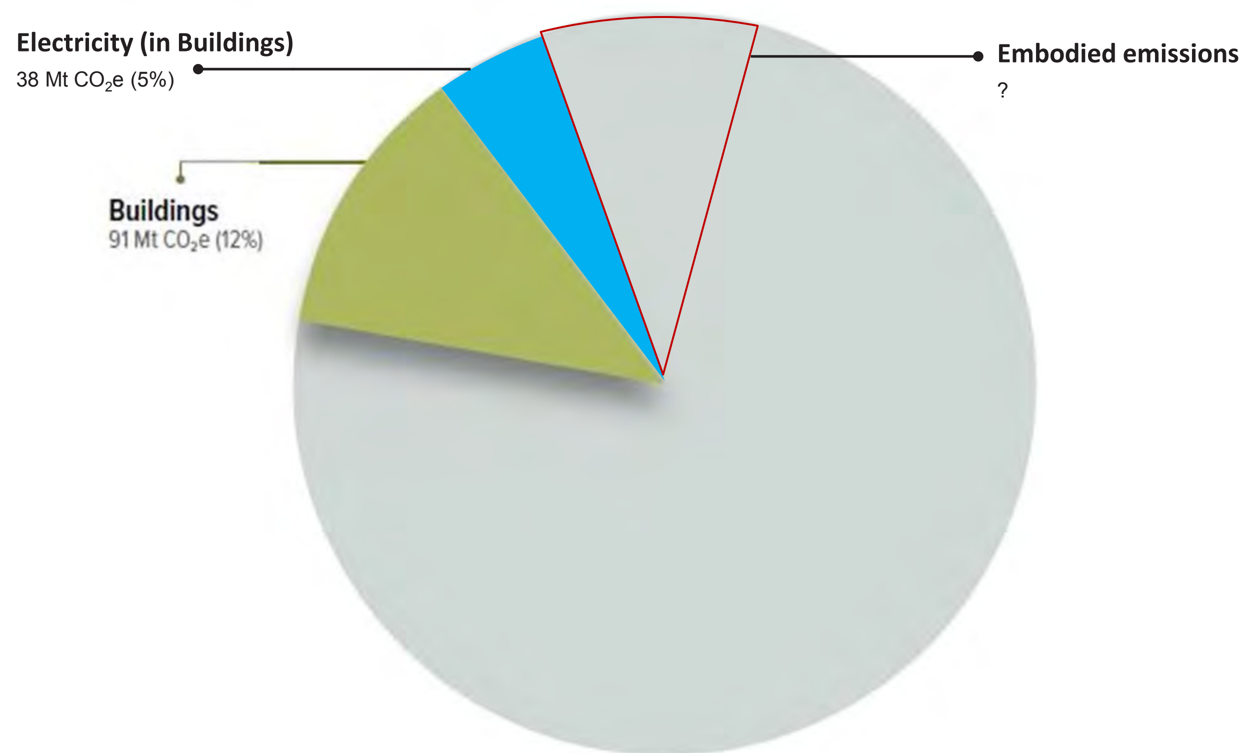
Canada's Buildings Emissions, 2019



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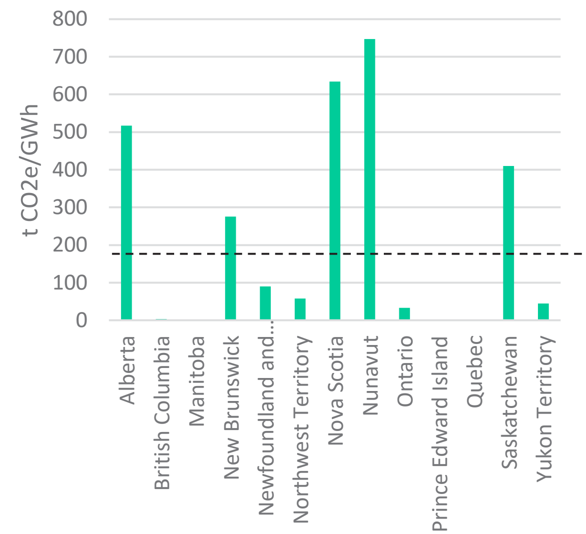
800
700
600
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400
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200
100
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t CO2e/GWh
Alberta
British Columbia
Manitoba
New Brunswick
Newfoundland and...
Northwest Territory
Nova Scotia
Nunavut
Ontario
Prince Edward Island
Quebec
Saskatchewan
Yukon Territory

PEER: Prefabricated Exterior Energy Retrofit

Problem: Traditional deep retrofits are slow, expensive, disruptive and rare.

NRCan's PEER R&D Project (2016-2022)

Goal: prefab building envelope retrofit solutions

Main research question:

Can prefabrication enable faster, more cost effective and less disruptive deep retrofits?

R&D Activities:

1. Building capture and panel design guidance
2. Panel prototyping
3. Building science implications

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Research Results

1. Demonstration Projects
2. Project Guide

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PEER Pilots and Demonstration

PEER Proof-of-Concept Pilot
Ottawa, ON
Units: 1
Net-Zero Ready
Completed 2017
Monitoring Ongoing

Sundance Housing Co-Op
Edmonton, AB
Units: 59
Net-Zero Ready
Construction Underway

Ottawa Community Housing
Ottawa, ON
Units: 4
Net-Zero Energy
Construction Complete
Monitoring Underway

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4 units, 3 bedrooms each
Built in 1960
7200$ in utilities annually
18 tons of CO2 emitted annually

4 units, 3 bedrooms each
Renewed in 2020
Net-Zero Energy annually
0 tons of CO2 emitted annually
Tenants in-suite during retrofit

Funded by the OERD's Green Infrastructure Program

Assemblies and Systems

	BaseCase	Net-Zero Retrofit	
Attic	27.6	60.0	*Eff. R-value, ft2.F/Btu*
Walls – Above Grade	13.7	45.4	*Eff. R-value, ft2.F/Btu*
Walls – Below Grade	1.3	32.5	*Eff. R-value, ft2.F/Btu*
Airtightness	7.5	2.3	*ACH@50Pa*
Space Heating / Cooling	90% AFUE gas / N/A	ASHP HSPF 9.0 / SEER 25	
Ventilation	N/A	ERV, SRE 84% (OC) 65 (-25C)	
DHW	Gas. EF 0.56	Hybrid HP. EF 2.7	
Renewables	N/A	35 kWp	

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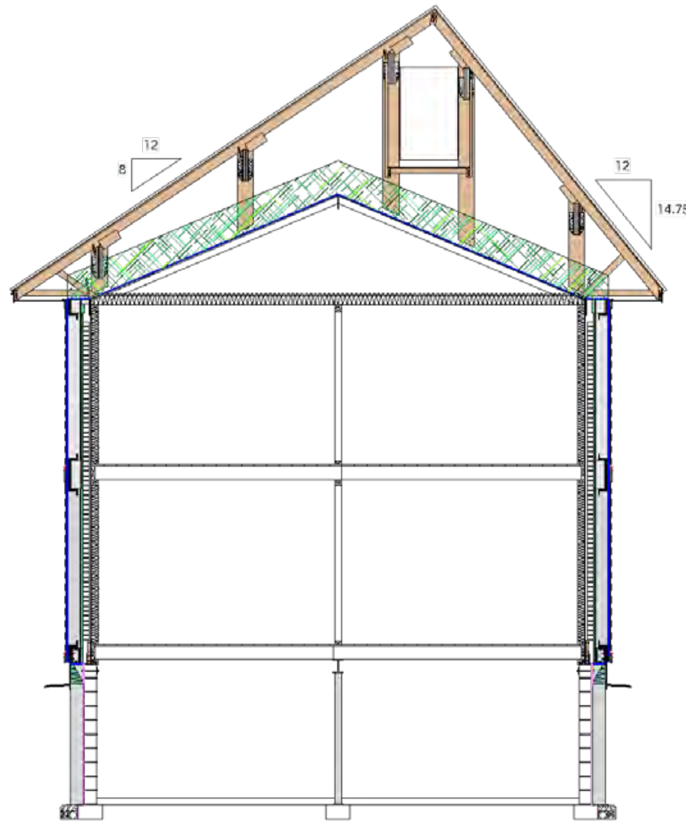

Before

After

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Construction

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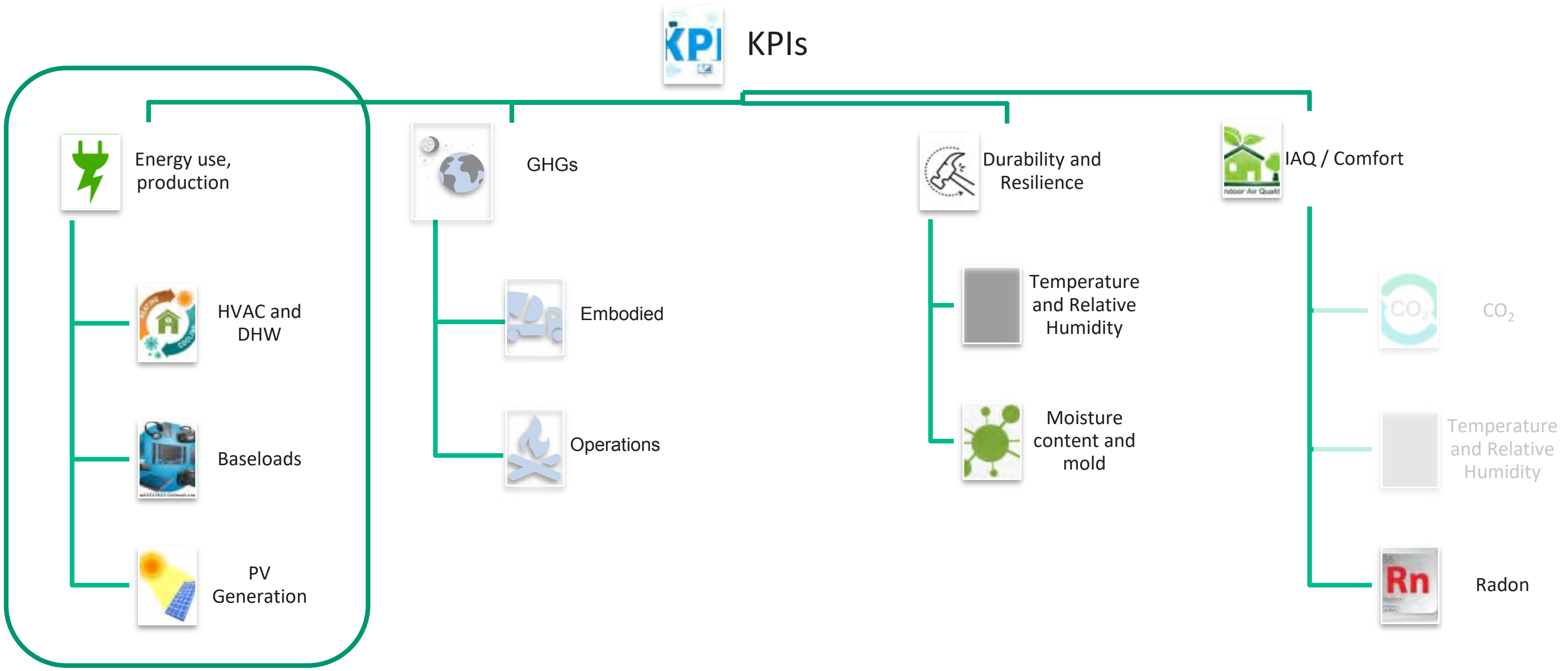
M&V



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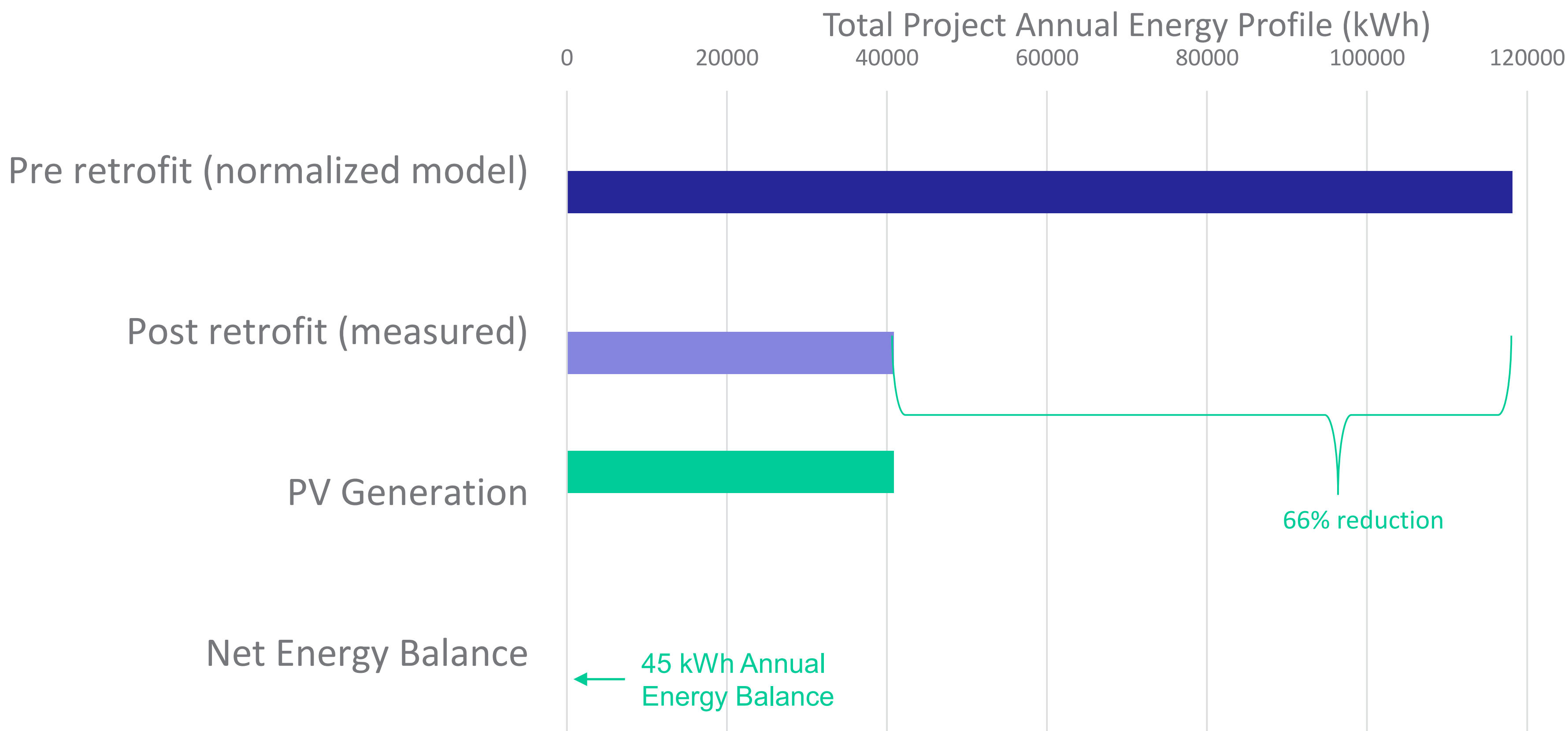
Energy Performance (Sept 2021 – Aug 2022)



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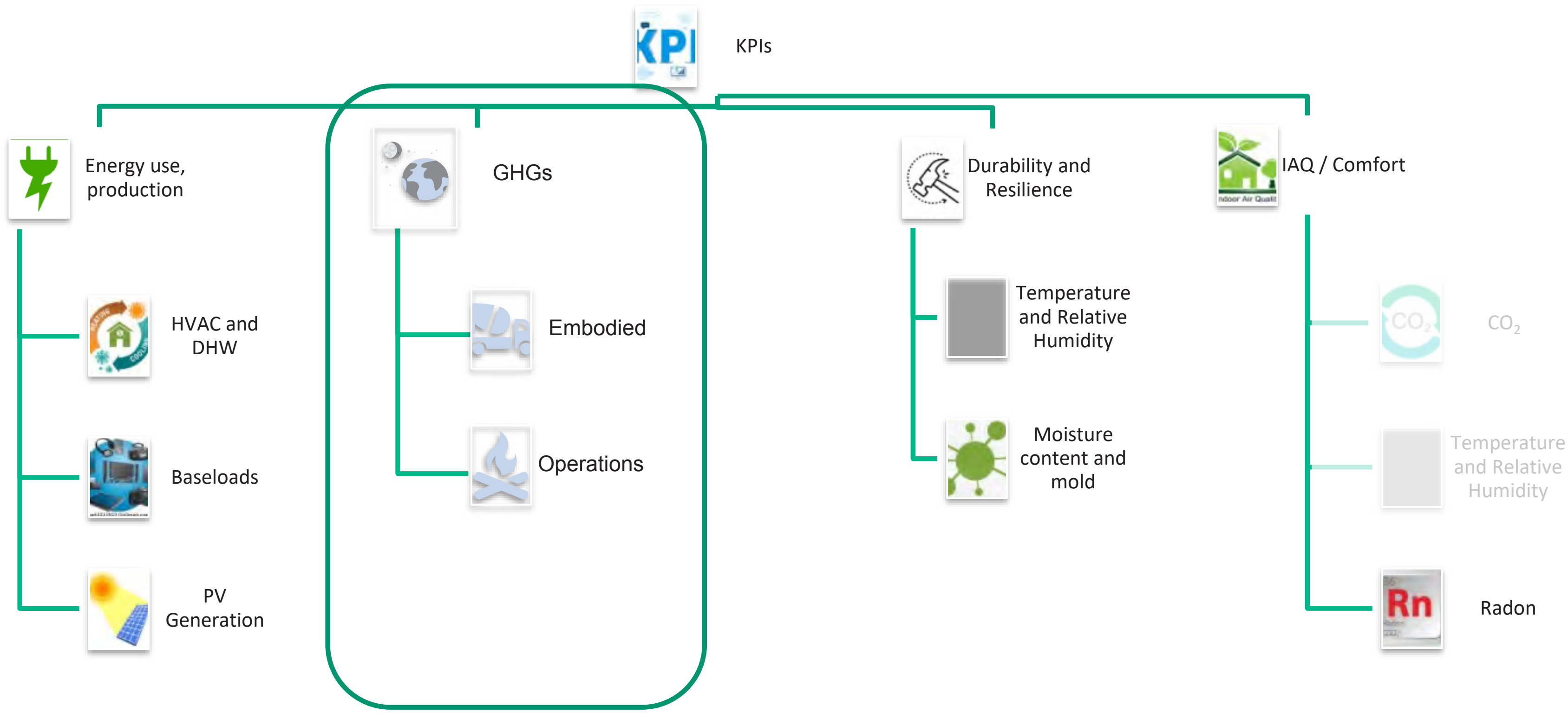

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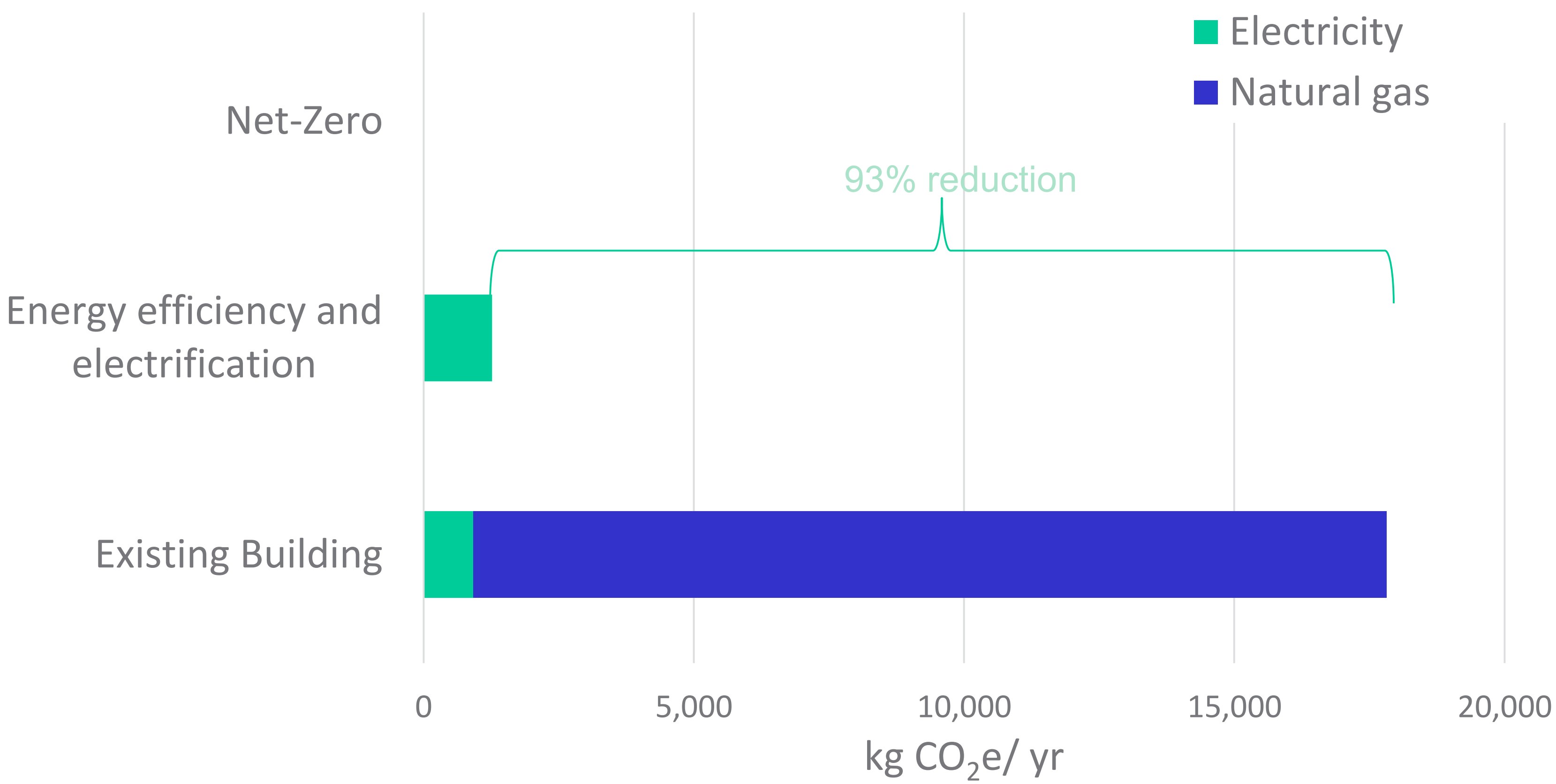
Operating Emissions



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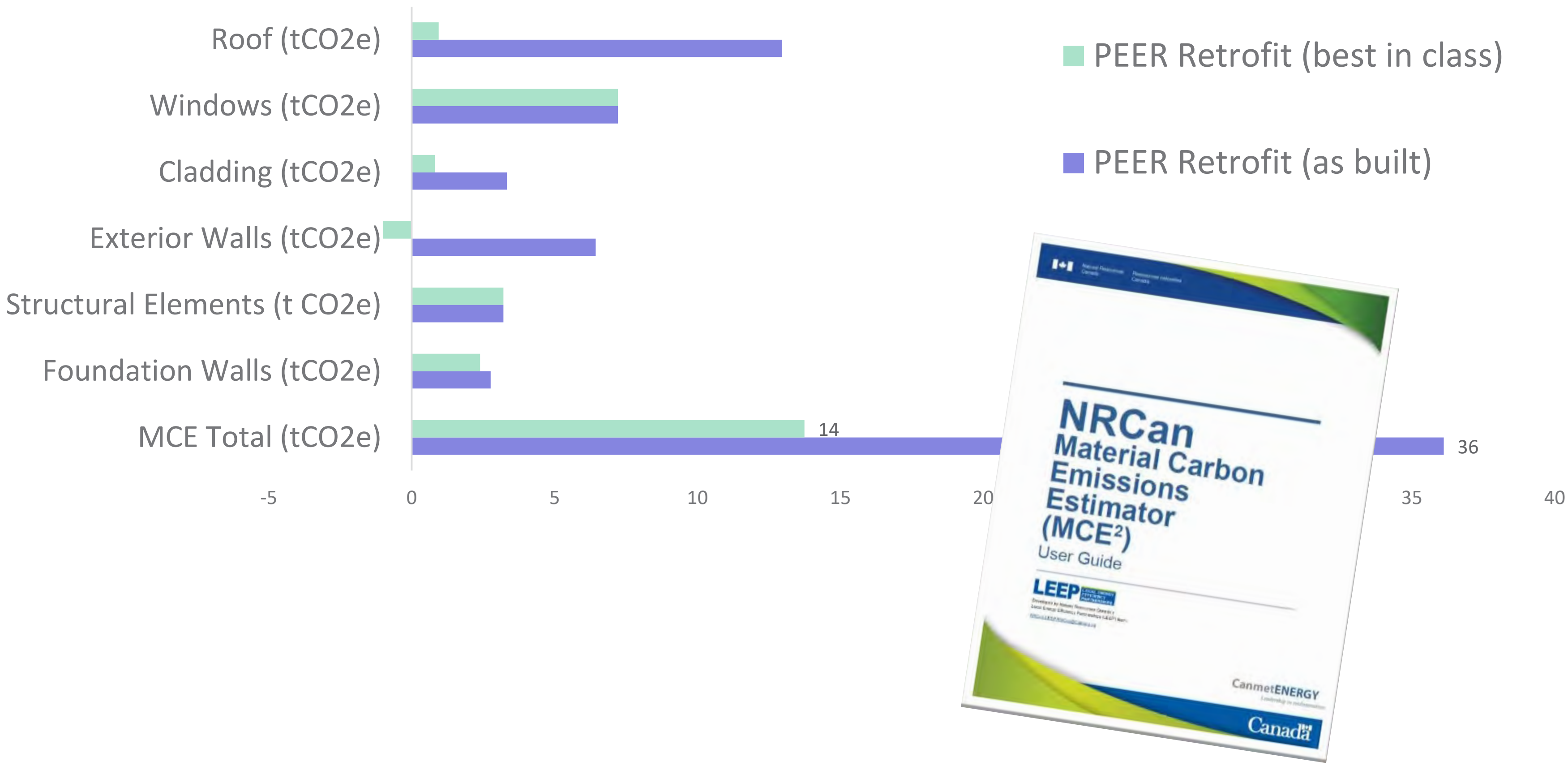
Building Enclosure Embodied Emissions



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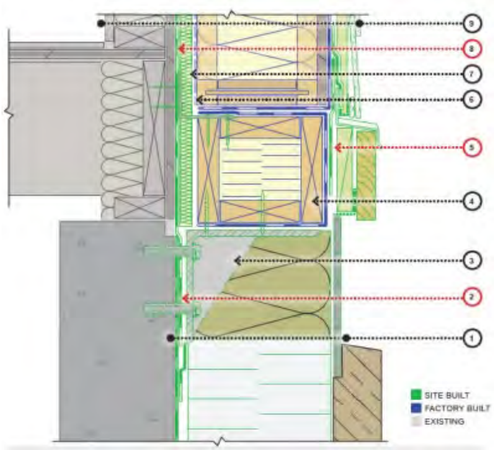
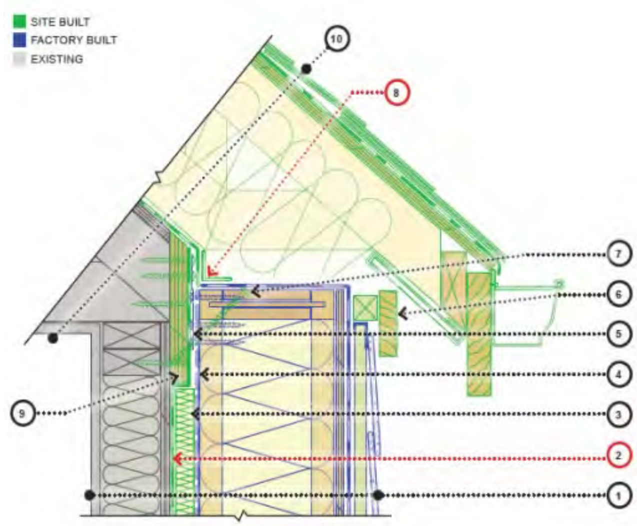
Project Guide

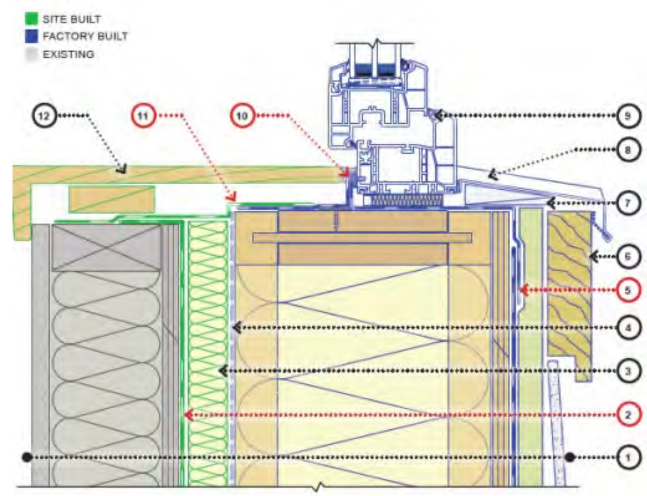
- Project Delivery
- Pre-design
- Building Capture
- Panel design
- Fabrication and installation



Base of Wall



Top of Wall



Window Installation

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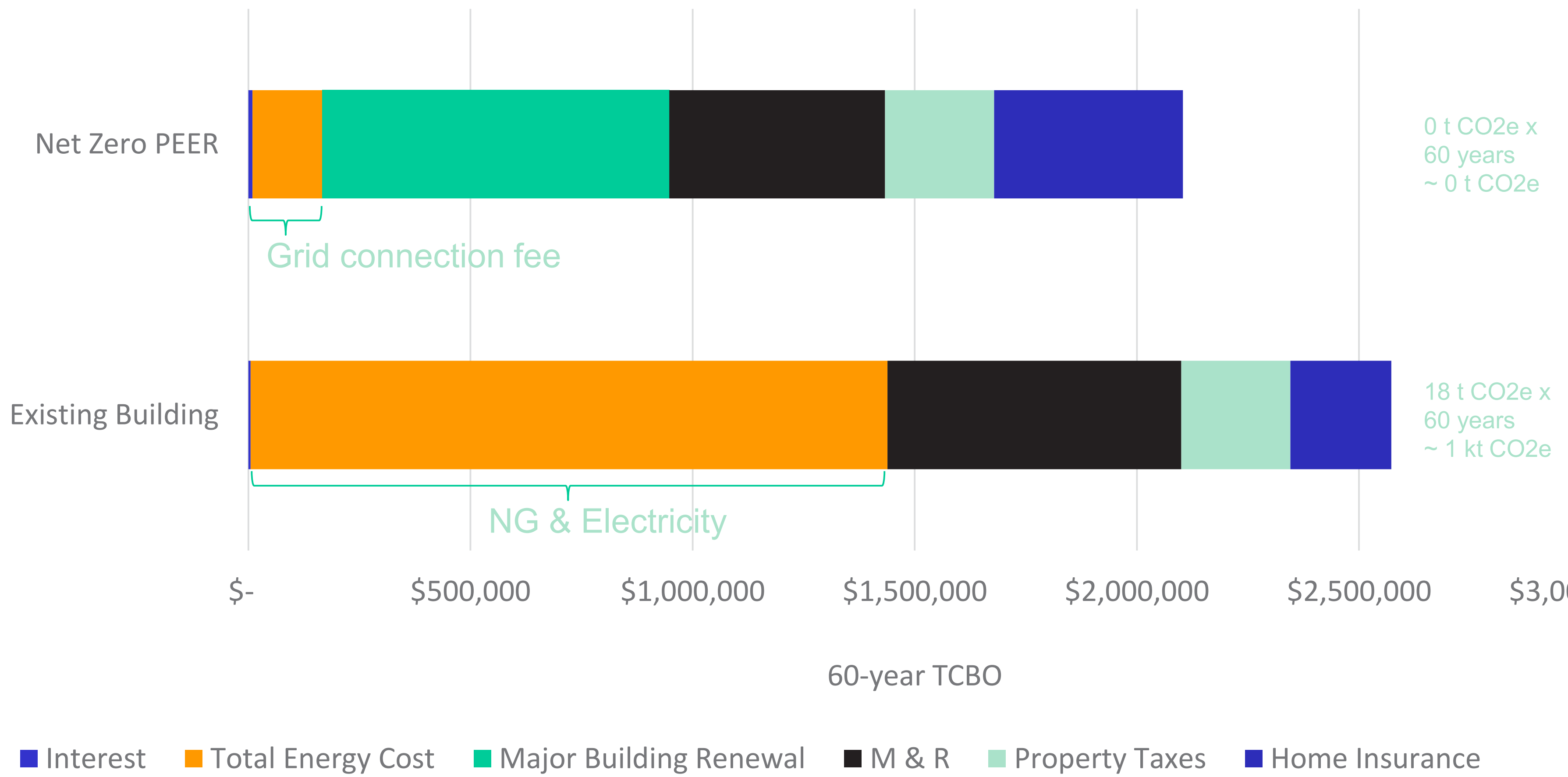
60 year Total Cost of Building Ownership



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Deep Retrofit Challenges

1. Cost
2. Industry capacity
3. Architecturally heterogeneous stock
4. Embodied carbon

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Thanks!

Mark Carver

(he, him, il)

R&D Project Leader, Building Envelopes
CanmetENERGY, Natural Resources Canada
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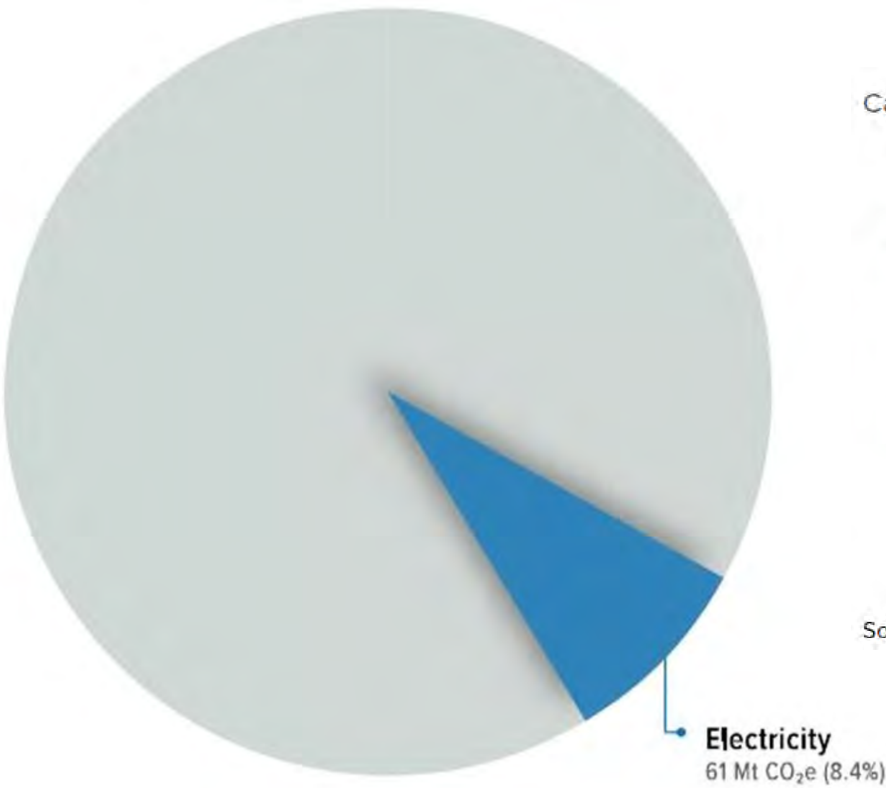
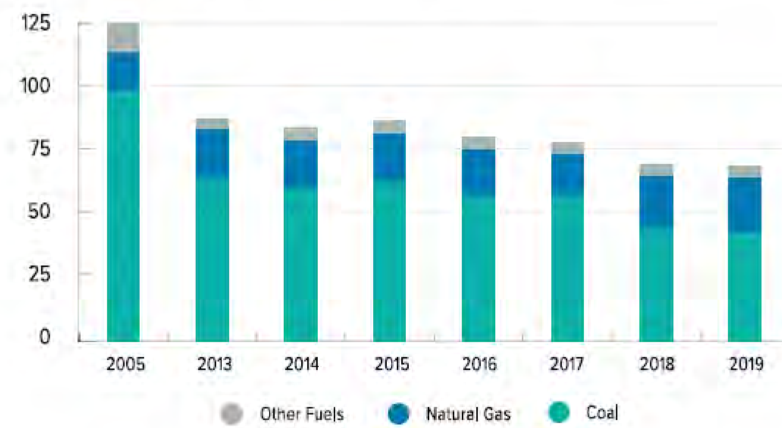
Carbon Intensity of Energy Sources

Canada's Electricity Emissions, 2019



Canada's Electricity Sector Emissions by Year



Source: NRCan Energy Fact Book

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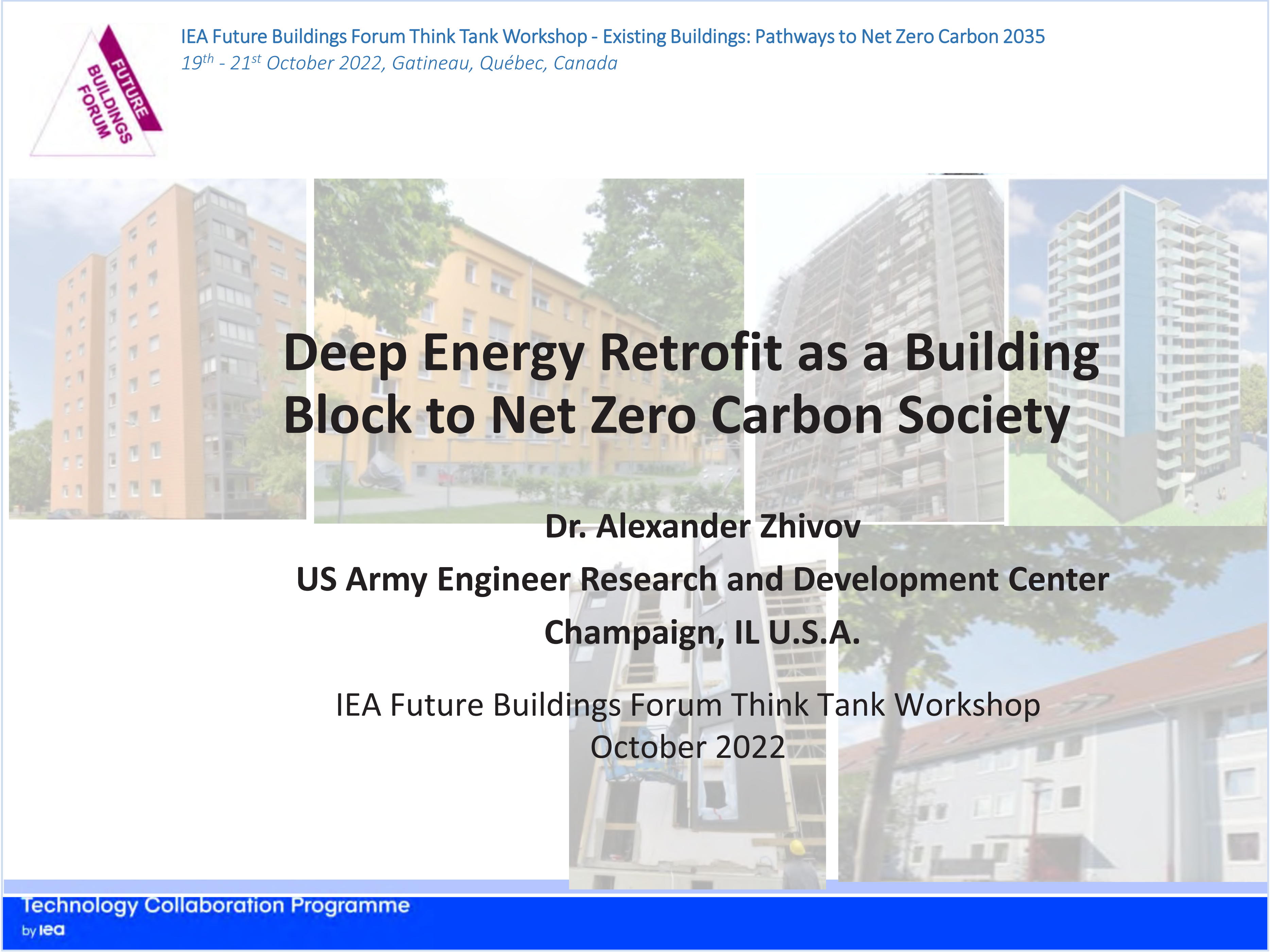
IEA Future Buildings Forum Think Tank Workshop - Existing Buildings: Pathways to Net Zero Carbon 2035
19th - 21st October 2022, Gatineau, Québec, Canada
FUTURE BUILDINGS FORUM
Deep Energy Retrofit as a Building Block to Net Zero Carbon Society
Dr. Alexander Zhivov
US Army Engineer Research and Development Center
Champaign, IL U.S.A.
IEA Future Buildings Forum Think Tank Workshop
October 2022
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Background

- Buildings are responsible for 40% of global energy consumption and 33% of greenhouse gas emissions.
- In the USA commercial buildings remain in use for many decades. About 12% of commercial buildings were built since 2003, the commercial building stock is still fairly old, with about half of all buildings constructed before 1980 (CBECS 2012)
- In most EU countries, half of the residential stock was built before 1970, i.e. before the first thermal regulations.
- Commercial, residential, and industrial buildings are responsible for nearly half of all global energy consumption and greenhouse gas (GHG) emissions.

Current requirements for existing buildings

- EU policymakers have long recognized the importance of energy-efficient buildings in mitigating climate change - starting with the Energy Performance of Buildings Directive (EPBD) and the Energy Efficiency Directive (EED) - but capturing that potential has posed a challenge. While the efficiency of new buildings has improved over time, most of Europe's existing building stock has yet to be affected by the energy performance requirements.
- In Europe alone, more than 220 million existing buildings – or 75% of the building stock – are energy-inefficient, with many relying on fossil fuels for heating and cooling
- In the USA there are no federal requirements for energy efficiency associated with major renovation projects
- ASHRAE has developed Standard 100 "Energy Efficiency in Existing Buildings," which has both site and source energy targets…only Washington State has adopted this standard so far.

What is DER ?

Annex 61 team has collected and documented 26 case studies from Austria, Denmark, Estonia, Germany, Ireland, Montenegro, The Netherlands and the USA in which site energy has been reduced by 50% or better.

Based on anaysis of trends in policies from around the world and best practices including those, documented in case-studies, IEA EBC Annex 61 team has proposed the following definition of the Deep Energy Retrofit:

This applies to buildings that are not historic/listed and have low internal loads (e.g., office/administrative buildings, dormitories/ barracks, education buildings, etc.)
Achieving DER in buildings with high internal loads (e.g., dining facilities, data centers, etc.) is possible, but more efforts have to be done to improve building processes

Typical Energy Efficiency Improvement Projects in Buildings

- A part of major building renovation*
- A part of minor building renovation
- Utility modernization projects
- Mechanical and electrical equipment/systems replacement
- System retro-commissioning
- Dedicated energy projects using an Energy Savings Performance Contract (ESPC) or Utility Energy Service Contract (UESC).

Energy Savings and Payback from Various Types of Energy Retrofits

Energy Retrofit Project Type	% Energy Savings	Simple Payback from Energy Cost Savings	Cost $/SF
Retro-commissioning (mostly HVAC- measures)	10 to 20	4 months to 2.4 years	$0.30
ESCO	20 to 40	3 to 12 years **	$2.50
DER with Integrated design (HVAC and thermal envelope)	30 to 60	7 to 12 years	$2.50
(Sources: Pike Research and LBNL)			

Fossil Fuel Reduction Strategies

Retrofitting existing building stock to net-zero carbon

on an individual building basis is usually cost-prohibitive and in many cases is not technically feasible.

Building cluster approach allows for more technical opportunities and increased cost-effectiveness:

Buildings have different load profiles over the day, week, and a year resulting in the diversity of energy use

Buildings have energy wastes that can be used by the building itself or by other buildings: waste heat recovery from chillers, grey water,…

Collecting and storing waste heat for future use can benefit from economy of scale.

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Core technologies bundles for DER

Category	Name
Building Envelope	Roof insulation
	Wall insulation
	Slab insulation
	Windows
	Doors
	Thermal bridges remediation
	Airtightness
	Vapor barrier
	Building envelope quality assurance (QA)
Lighting and Electrical Systems	Lighting design based on LED technologies, daylight and motion controls
HVAC	High performance motors, fans, furnaces, chillers, boilers, etc.
	Dedicated outdoor air system (DOAS)
	Heat recovery (HR) (dry and wet) with efficiency >70%
	Duct insulation
	Duct airtightness
	Pipe insulation

Minimum core bundle of technologies: building envelope related (insulation, air tightness, thermal bridge elimination), lighting, HVAC

While the passive house standard may be an overkill, a standard close to it may be appropriate. In the USA till this year federal building law required 30% better than the ASHRAE Std 90.1 2013 when LCC effective. This year the law has a reference to the ASHRAE Std 90.1 – 2019, which is more adequate for most climates except for cold climates (c.z. 7 and 8)

Additional insulation, tighter buildings, and mass buildings significantly improve building resilience when the building loses heating energy and shaves peaks when the building requires cooling. This can be taken in consideration when requirements to the building are established.

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Recommended Wall and Window R/U values

Country	U-value W/(m^2*K) (Btu/(hr*ft^2*°F)	R-value (m^2*K)/W (hr*ft^2*°F)/Btu
USA c.z. 1	0.76 (0.133)	1.3 (8)
c.z. 2	0.38 (0.067)	2.6. (15)
c.z. 3	0.28 (0.050)	3.6 (20)
c.z. 4	0.23 (0.040)	4.3 (25)
c.z. 5	0.19 (0.033)	5.3. (30)
c.z. 6	0.14 (0.025)	7.1. (40)
c.z. 7	0.11 (0.020)	9.1 (50)
c.z. 8	0.11 (0.020)	9.1 (50)

8

Site and Source Energy Use Reduction for DER Projects Using Core Bundles of Technologies

	Baseline			Base Case		DER			HPB	
Climate Zone	Total site EUI (100%) kWh/m2yr (kBtu/ft2 yr)	Site EUI for heating (100%) kWh/m2 yr (kBtu/ft2 yr)	Source EUIt, (100%) kWh/m2 yr (kBtu/ft2 yr)	Site energy use reduction, %	Source energy reduction ,%	Site energy use reduction,%	Site heating energy use reduction, %	Source energy use reduction, %	Site energy use reduction, %	Source energy reduction, %
Barracks, USA										
1A	1 (0)	398 (126)	1154 (366)	17	19	**39**	59	42	59	59
2A	33 (10)	380 (121)	1025 (325)	17	18	**41**	84	42	60	59
2B	17(5)	365 (116)	1008 (320)	17	18	**40**	80	42	61	61
3A	65 (21)	394 (125)	965 (306)	19	18	**45**	84	42	63	59
3B	37 (12)	326 (103)	812 (258)	15	14	**39**	82	37	60	57
3C	35 (11)	273 (87)	634 (201)	12	9	**33**	70	31	46	37
4A	103 (33)	397 (126)	869 (276)	20	16	**48**	85	25	65	59
4B	86 (27)	333 (106)	745 (236)	16	12	**42**	88	35	62	56
4C	111 (35)	330 (105)	678 (215)	18	12	**44**	86	35	62	55
5A	160 (51)	422 (134)	872 (277)	21	17	**51**	87	42	67	60
5B	133 (42)	362 (115)	733 (233)	18	13	**52**	88	37	65	57
6A	212 (67)	448 (142)	839 (266)	22	16	**55**	88	44	70	61
6B	192 (61)	414 (131)	773 (245)	21	14	**53**	89	41	69	60
7	283 (90)	508 (161)	878 (279)	24	18	**59**	88	47	73	63
8	417 (132)	630 (200)	978 (310)	24	18	**64**	92	52	77	67
Office Building, USA										
1A	24(7)	261 (83)	815 (259)	30	27	**48**	91	45	66	64
2A	60 (19)	285 (90)	814 (258)	32	28	**46**	63	43	70	65
2B	81 (26)	314 (100)	862 (273)	36	29	**49**	87	41	73	91
3A	82 (26)	288 (91)	771 (245)	34	28	**47**	63	43	71	64
3B	68 (22)	251 (80)	680 (216)	30	23	**51**	92	41	66	58
3C	45 (14)	183 (58)	507 (161)	26	16	**41**	96	30	59	51
4A	96 (30)	271 (86)	685 (217)	35	26	**50**	89	38	69	60
4B	71 (22)	227 (72)	593 (188)	31	21	**50**	95	37	63	54
4C	76 (24)	206 (65)	513 (163)	31	18	**48**	96	33	63	52
5A	107 (34)	270 (86)	656 (208)	35	25	**50**	87	37	69	58
5B	83 (26)	223 (71)	552 (175)	31	20	**50**	95	35	64	53
6A	121 (39)	265 (84)	606 (192)	36	23	**52**	88	36	69	55
6B	118 (38)	254 (81)	575 (182)	34	22	**51**	88	34	68	55
7	145 (46)	278 (88)	594 (189)	39	24	**54**	87	36	71	55
8	218 (69)	340 (108)	634 (201)	42	27	**59**	83	39	76	58

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DER of Dining Facilities Vs. HPB Renovation (with an improvement of internal processes)

Climate Zone	Baseline			Base Case		DER			HPB	
	Site EUIh kWh/m² yr (kBtu/sq ft yr)	Site EUIt kWh/m² yr (kBtu/sq ft yr)	Source EUIt kWh/m² yr (kBtu/sq ft yr)	**Site Energy %**	Source Energy %	**Site Energy %**	Site Heating Energy %	Source Energy %	**Site Energy %**	Source Energy %
1A	29 (9,198)	604 (191)	1616 (512)	**2%**	3%	**15%**	29%	16%	**40%**	40%
2A	147 (46,626)	706 (224)	1687 (535)	**11%**	9%	**22%**	45%	20%	**48%**	36%
2B	111 (35,208)	744 (236)	1897 (601)	**10%**	9%	**22%**	43%	22%	**50%**	40%
3A	307 (97,377)	840 (266)	1766 (560)	**16%**	12%	**17%**	43%	23%	**57%**	45%
3B	201 (63,755)	749 (237)	1704 (540)	**16%**	12%	**26%**	52%	23%	**51%**	42%
3C	196 (62,169)	645 (205)	1371 (434)	**8%**	7%	**26%**	29%	14%	**46%**	32%
4A	459 (145,590)	964 (306)	1832 (581)	**20%**	15%	**30%**	47%	25%	**63%**	43%
4B	333 (105,624)	854 (271)	1753 (556)	**22%**	16%	**30%**	53%	25%	**58%**	45%
4C	434 (137,660)	897 (284)	1665 (528)	**19%**	14%	**27%**	43%	22%	**61%**	44%
5A	572 (181,432)	1071 (340)	1932 (612)	**19%**	17%	**31%**	45%	42%	**67%**	50%
5B	470 (149,079)	972 (308)	1833 (581)	**24%**	18%	**33%**	52%	23%	**64%**	48%
6A	733 (232,500)	1215 (385)	2041 (647)	**21%**	17%	**33%**	45%	28%	**71%**	54%
6B	681 (216,006)	1177 (373)	2035 (645)	**24%**	19%	**35%**	50%	29%	**69%**	53%
7	938 (297,524)	1420 (450)	2257 (715)	**22%**	19%	**36%**	47%	31%	**75%**	58%
8	1376 (436,453)	1863 (590)	2731 (866)	**18%**	17%	**39%**	64%	34%	**82%**	66%

Dining Facilities compared to Barracks and Office Buildings have high ventilation, cooking, and sanitation loads, which make core envelope package much less effective.

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Temperature Decay in the Building when Heating is Interrupted @ outside T = -40ºF (-40ºC).

Building Parameters	Mass Building			Frame Building		
	Pre-1980	Low Efficiency	High Efficiency	Pre- 1980	Low Efficiency	High Efficiency
Walls R-value, °F·ft²·hr/Btu ([m²·K]/W)	20.5 (3.6)	40 (7.0)	50 (8.8)	20.5 (3.6)	40 (7.0)	50 (8.8)
Roof R-value, °F·ft²·hr/Btu, °F·ft²·hr/Btu ([m²·K]/W)	31.5 (5.5)	45 (7.9)	60 (10.6)	31.5 (5.5)	45 (7.9)	60 (10.6)
Air Leakage, cfm/ft² at 0.3 in. w.g. (L/s.m² @75Pa)	0.4 (2)	0.25 (1.25)	0.15 (0.75)	0.4 (2)	0.25 (1.25)	0.15 (0.75)
Window U-value, F·ft²·hr/Btu [W/(m²·K]	Double Pane 0.56 [3.18]	Double Pane 0.30 [1.70]	Triple Pane 0.19 [1.07]	Double Pane; 0.56 [3.18]	Double Pane 0.30 [1.70]	Triple Pane 0.19 [1.07]
MaxTTR Habitability (60 °F)	1 hour	3 hours	10 hours	< 1 hour	2 hours	4 hours
MaxTTR Sustainability (40 °F)	20 hours	36 hours	51 hours	10 hours	18 hours	24 hours

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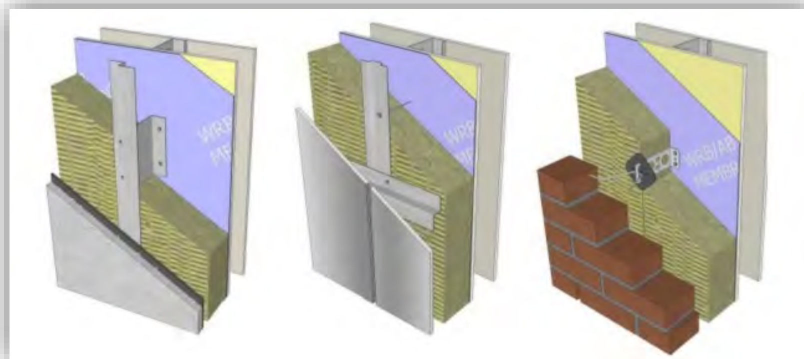
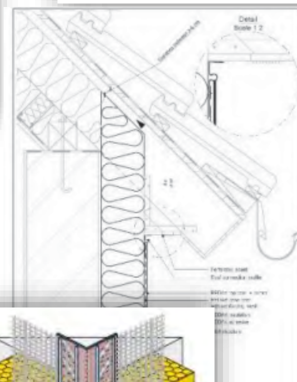
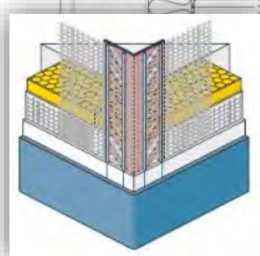
Product Delivery Quality Assurance Process

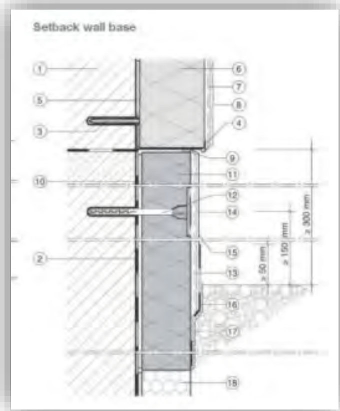
- Formulate detailed technical specifications (e.g., statement of work [SOW] or Owner's Project Requirements (OPR), against which tenders (i.e., bids) will be made, and verification of understanding of these specifications by potential contractors;
- Specify in the SOW/OPR areas of major concern to be addressed and checked during the bid selection, design, construction, commissioning, and post-occupancy phases;
- Clearly delineate the responsibilities and qualifications of stakeholders in this process.

Examples of Wall Insulation Installation









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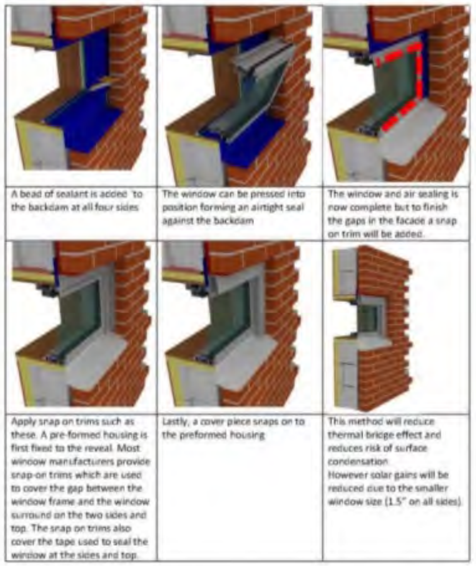
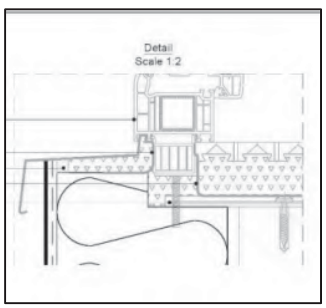
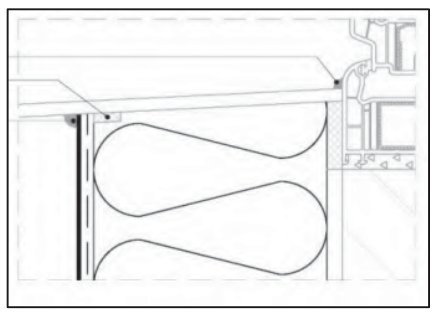
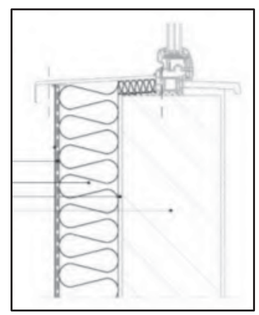
Examples of Window Installation









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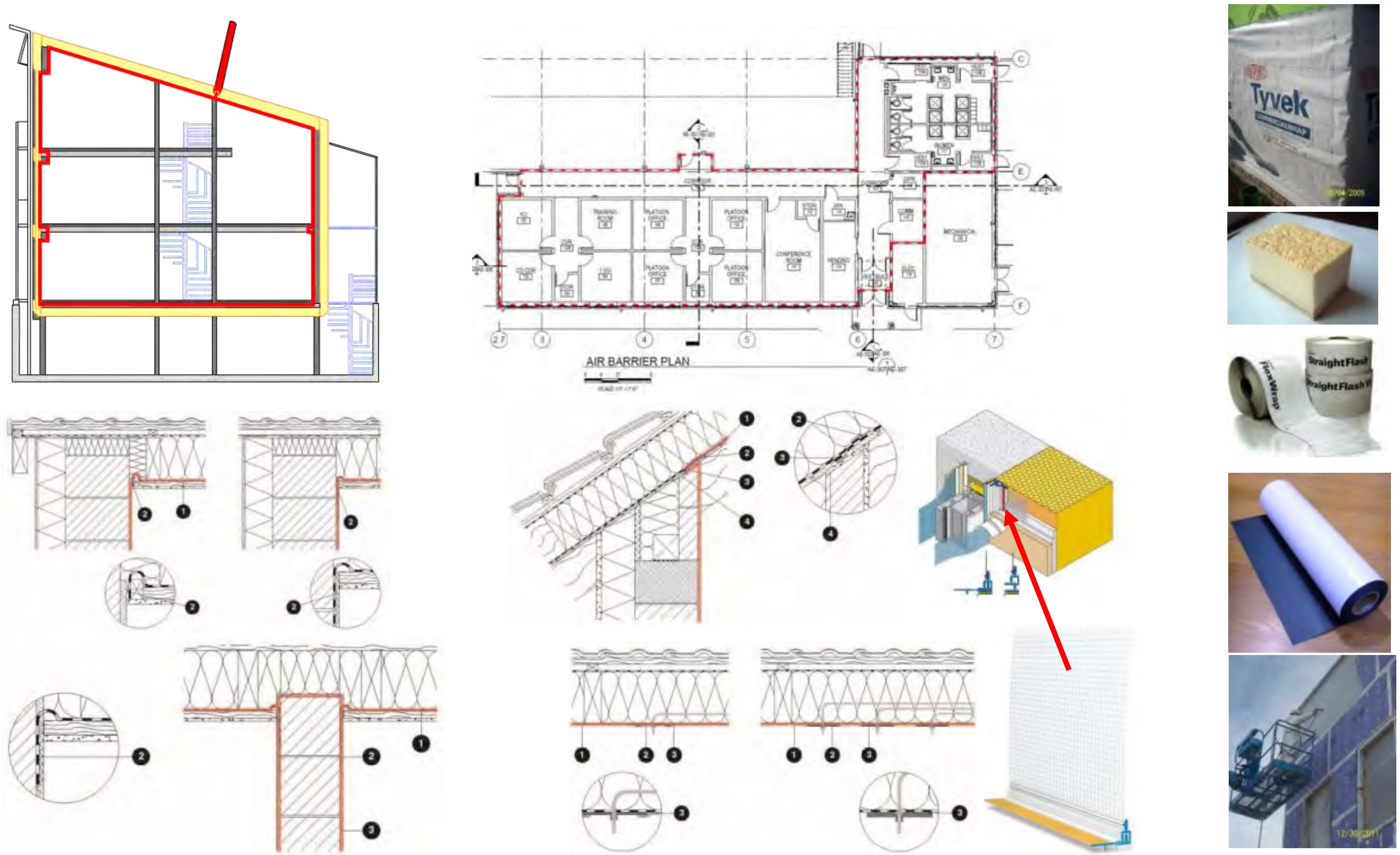
Air Barrier with Major Renovation



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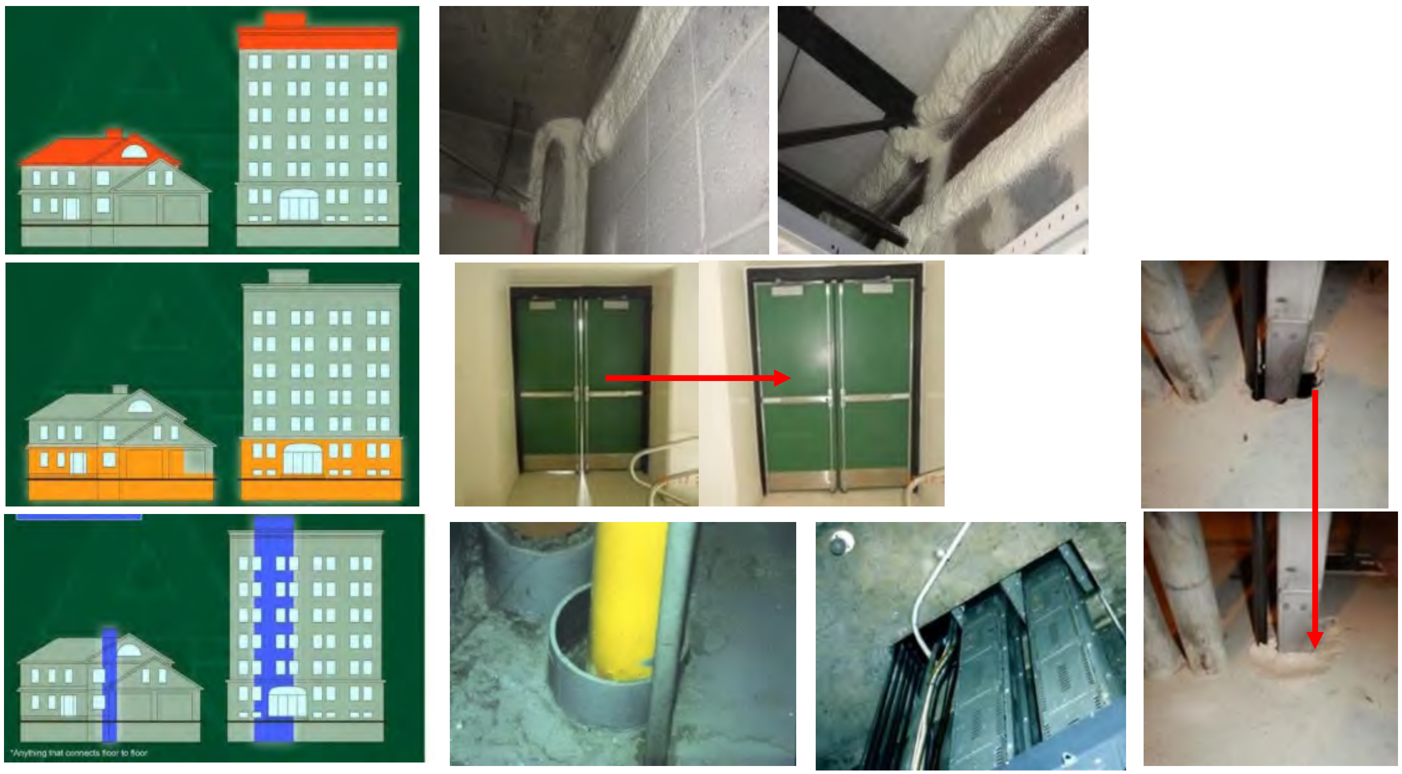
Building Airtightness Improvement (Minor Renovation)



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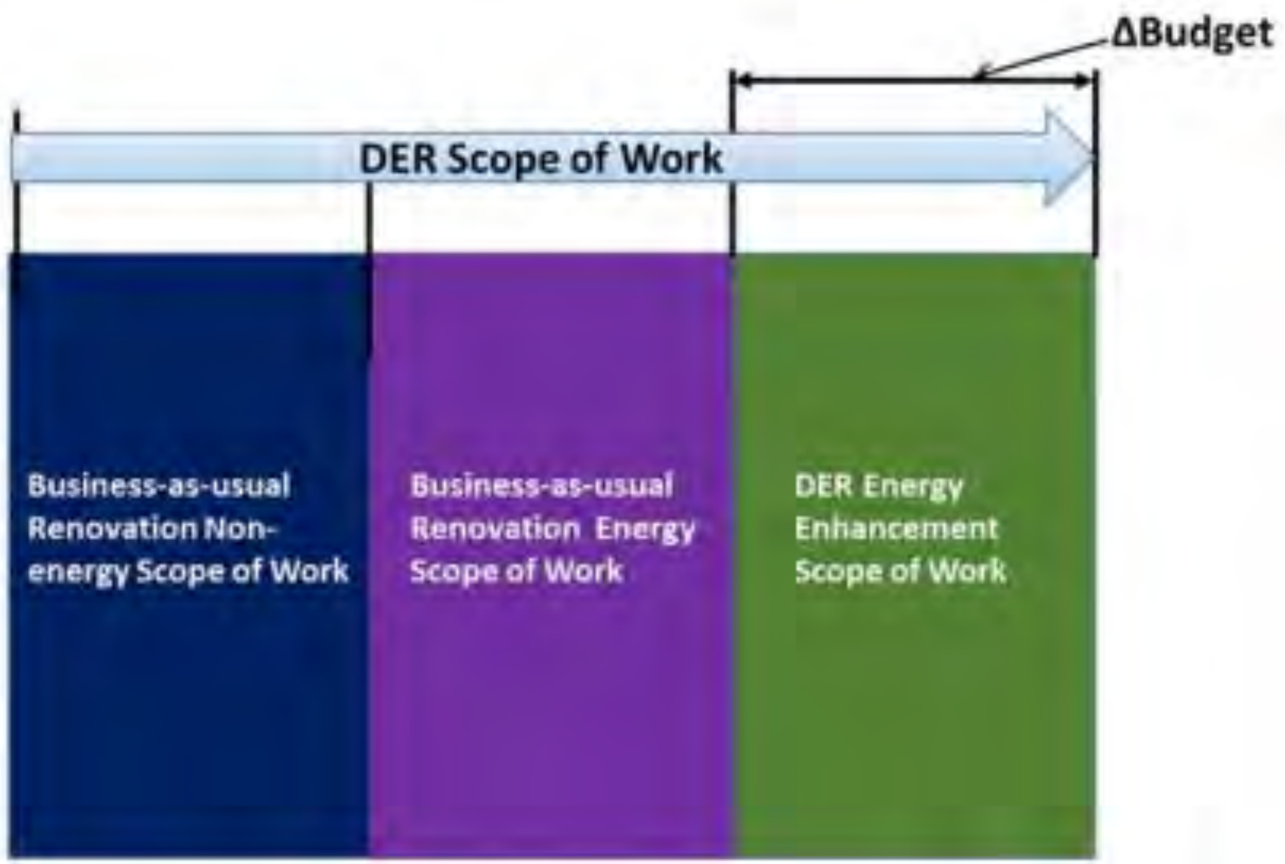
Scope of work of DER project



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How To Make DER Cost Effective?

- Investment cost reduction
  - Some energy-related improvements included in a DER, e.g., building envelope insulation and mitigation of thermal bridges, installation of high-performance windows, and air tightening of the building envelope, are expensive and are rarely included in the scope of a major renovation
  - However, reduction of heating, cooling, or humidity loads resulting from the implementation of these DER measures will result in a smaller and sometimes simpler HVAC system, which will reduce both initial investment and capital replacement costs related to these systems.
- Timing a DER to coincide with a major renovation will improve the cost-effectiveness by reducing the incremental cost to achieve the DER:
  - Building is typically evacuated and gutted;
  - Scaffolding is installed; single-pane and damaged windows are scheduled for replacement; building envelope insulation is replaced and/or upgraded; and
  - most mechanical, electrical, lighting, and energy conversion systems (e.g., boiler and chillers) along with connecting ducts, pipes, and wires will be replaced.
  - A significant sum of money covering the cost of the energy-related scope of the renovation designed to meet the minimum energy code is already budgeted in a typical non-energy renovation.

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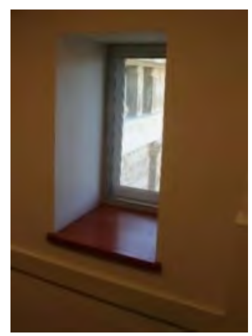
Example of Usable Space Increase (Attic Renovation at Rock Island Arsenal)







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The Value of Deep Retrofits

Benefits of DERs include:

- Direct cost savings
- Indirect cost savings and values beyond energy cost savings
- Supporting Policy Mandates for Energy and Greenhouse Gas Emissions Reductions
- Supporting agency mission
- Replacing aging infrastructure and improving building system reliability productively
- Increasing resilience
- Hedging risks associated with energy cost volatility
- Maximizing the value of federal appropriations

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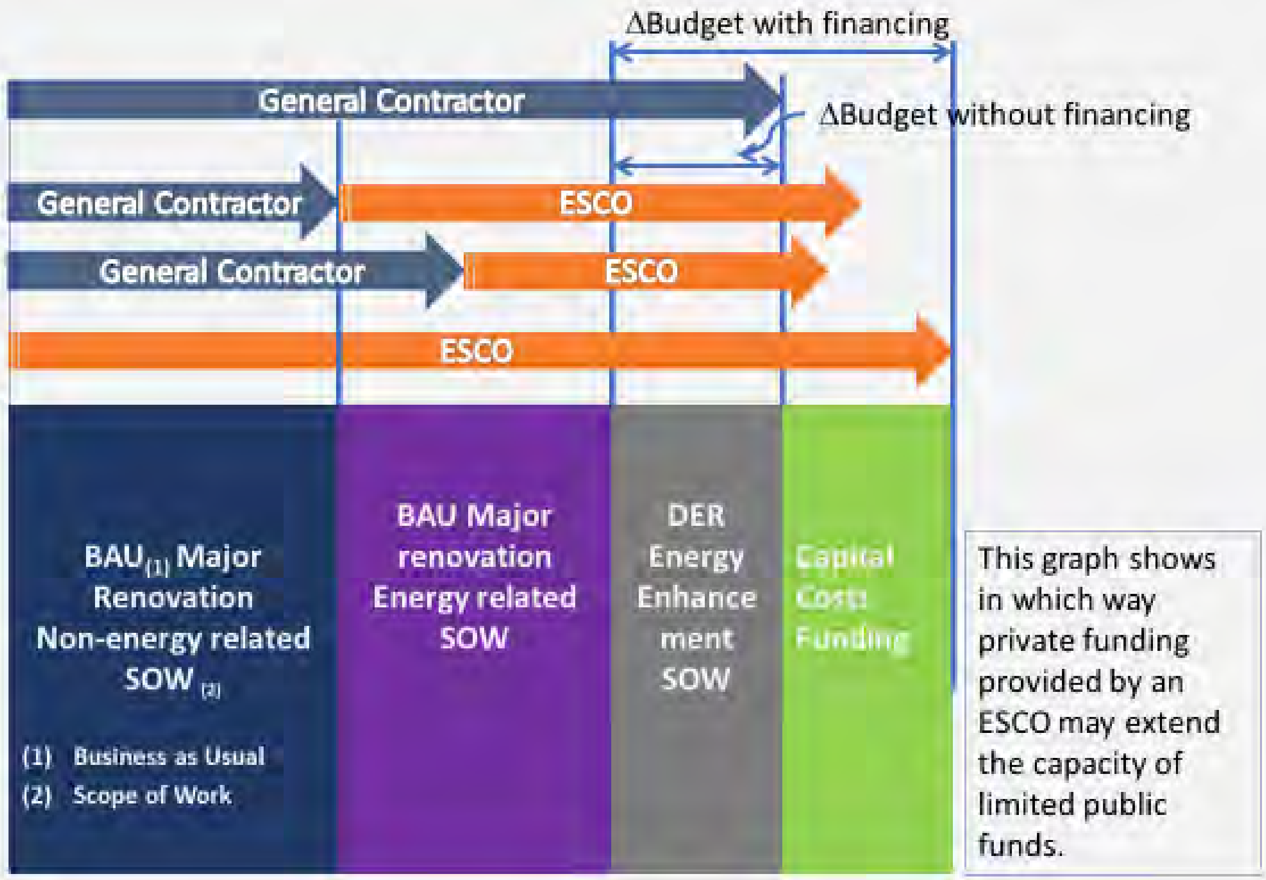
DER Implementation Strategies



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Conclusions

- Throughout the world much work has been done to improve energy efficiency and reduce energy costs with new construction projects.
- Today, significant energy cost reduction, improvement in communities' energy resiliency, and improvement in occupants' productivity and wellbeing can be achieved by focusing on major renovation projects of existing building stock (efficiency improvement in energy conversion, distribution and storage can be a topic for another presentation.)
- IEA Annex 61 showed, that 50% or more energy use reduction (DER) in renovated buildings is possible in a cost cost-effective
- DER can be achieved with a limited core technologies bundle readily available on the market
- In addition to reducing energy use and cost, better insulation, tighter buildings, and mass buildings significantly improve building resilience when the building loses heating energy and shaves peaks when the building requires cooling. This can be taken into consideration when requirements for the building are established
- Energy efficiency doesn't need to compete with the IAQ improvement. The book Healthy Buildings shows that ventilation improvement increases workers' productivity and improves overall business performance. These savings will justify at least a 5% increase in the overall building cost that can pay for additional energy efficiency measures.
- High levels of energy use reduction using core technology bundles along with improvements in indoor climate and thermal comfort can be only achieved when a Deep Energy Retrofit (DER) adopts a quality assurance process in addition to energy efficiency technologies.

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Annex 61 Publications

[Conference Papers || IEA EBC || Annex 61 (iea-ebc.org)](https://annex61.iea-ebc.org/publications)

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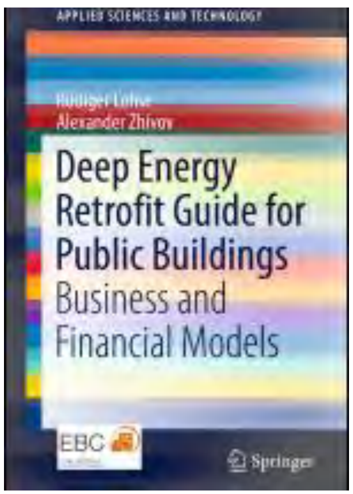

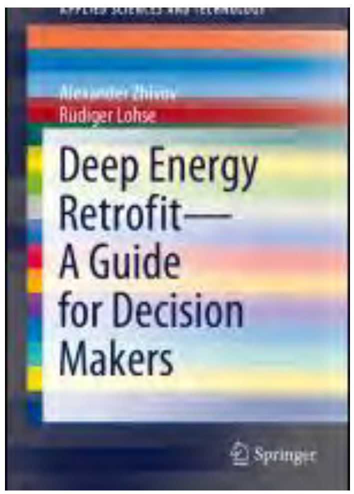

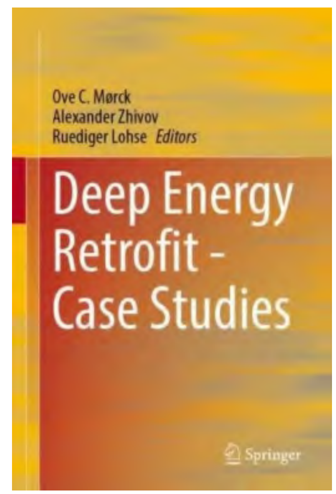

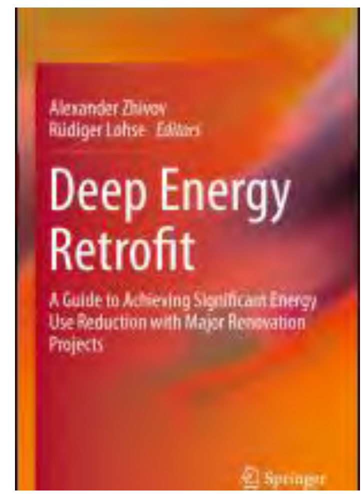

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Some Technologies Beyond the Core Bundle

1. Indirect evaporative cooling, which can be used in any climate (use of IDEC can be an interesting option for a few hot months in Alaska, Washington state,.. that never considered cooling before)

2. Heat recovery from chillers and DX condenser units (reduces corrosion in coastal areas, saves energy for reheat, domestic hot water, can be stored for future use)
DewPoint Control sensors (important in hot and humid climates to prevent condensation and mold)

3. Back to displacement ventilation and more use of localized ventilation in combination with workspace partitions to avoid cross-infection.

4. More use of seasonal storage – utilizes heat wastes that can be collected throughout the year and used for heating, DHW, and reheat

5. Humidity control in a cold climate during heating season: need more research on RH level, that will prevent damage to the building.

6. Improved building energy efficiency and IAQ (after the pandemic) and workers' productivity. Can be a major driver for getting to NZ emission society in a cost-effective way.

7. Airside and waterside heat pumps: their application (individual buildings or district systems) and cost-effectiveness in different climates

Thank you for your attention

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Results and challenges associated with the deep retrofit of residential buildings

IEA Future Buildings Forum Think Tank Workshop

October 19, 2022

Manuela Almeida | University of Minho - Portugal

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Decarbonisation of the Economy by 2050 | EU perspective

Buildings – crucial pathway to reach decarbonisation

Responsible for: 40% of Energy Consumption (of which heating, cooling and DHW correspond to 80%)
36% of Carbon Emissions

Building Sector
Intermediary goals (by 2030) - "Fit for 55" package and its REPowerEU suplement:

- ❑ **Reduce in 55% carbon emissions** (compared to 1990)
- ❑ **Increase renewable energy target from 40% to 45%**
- ❑ **Force the installation of solar rooftops**
- ❑ **Double the rate of deployment of heat pumps**
- ❑ **...**

Decarbonisation of the Building Sector| EU perspective

Current situation in the Building sector

>50% of buildings in EU do not meet any thermal requirements

Deep Renovation of the existing building stock is a key priority

Renovation Wave Program – triple the building renovation rates by 2030, prioritising the worst-performing buildings and public buildings

Current renovation rate – less than 1%

Renovation rate needed to meet the goals - ~3%

By 2030 - 70% of the renovations should be "Deep Renovations"

("Deep Renovation" should be the standard not the exception – BPIE, 2021)

Deep Renovation | EU perspective

Deep Renovation is a renovation that transforms a building into:

- ❑ **a nearly zero-energy building (until 2030)** **(EPBD 2018 recast)**
- ❑ **a zero-emission building (after 2030)** **(EPBD 2022 proposal)**

Deep renovations typically lead to over 60% energy savings and carbon emissions reductions

Deep renovation should include:

- ❑ **Passive measures on the envelope (to ensure a minimal level of performance)**
- ❑ **High-efficiency systems**
- ❑ **Integration of local renewable energy sources to supply the energy needs** (100% supply after 2030)

Passive measures on the envelope are crucial to:

- ❑ **Reduce building anomalies (e.g. mould)**
- ❑ **Increase thermal comfort**
- ❑ **Reduce the required power needs of the systems**

Co-benefits

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Deep Renovation | EU perspective

Energy Performance of Buildings (EPBD) - 2022 proposal

Additional requirements by 2030

- ❑ **Renovate the buildings in a life-cycle perspective considering the life-cycle global warming potential of the renovation process**
- ❑ **Prioritise the full decarbonisation of the buildings → take into account the materials embodied energy**
- ❑ **Eliminate local carbon emissions production (eliminate fossil-fuels-powered equipment)**
- ❑ **Renovate at least the 15% worst performing buildings**

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Deep Renovation | Challenges

- ❑ How to deep-renovate such a large number of buildings in a short period?
- ❑ How to implement RES locally in a large scale?
- ❑ How to find the cost-optimal balance between the renovation measures?

Hindering factors for deep renovation

- ❑ High upfront costs and long payback time
- ❑ Limited availability of:
    - ❑ easy-to-use and reliable tools for professionals and residents
    - ❑ building performance databases, technical guidance and support for the entire chain of professionals in the building sector, building owners and local authorities
- ❑ Lack of Stakeholders' engagement, persuasion and acceptance by residents and building owners
- ❑ Lack of exemplary and inspiring examples
- ❑ Lack of political will

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Deep Renovation| Opportunities and Research Findings

- ❑ **There are no ready-made or one-fits-all solutions. The best solutions depend on the starting situation (existing insulation level, installed heating/cooling systems, available ES and RES)**
- ❑ **High-quality renovations need:**
  - ❑ **holistic approach through an integrated design**
  - ❑ **comprehensive renovation (high level EE measures on the building envelope, high-efficiency HVAC and DHW systems, integration of RES)**
- ❑ **Regular maintenance of building elements is an opportunity to improve the energy performance of the building envelope**
- ❑ **Renewable energies must be mandatory whenever a heating system is replaced and conditions allow it**
- ❑ **Co-benefits should be considered when deciding on the best solution to be implemented**
- ❑ **Renovation at district level as an accelerator of the renovation rate**
- ❑ **Not just the technical and economic aspects matter in an energy renovation**
- ❑ **Social, legal and planning issues are equally important, and communication with different stakeholders is crucial**
- ❑ **Policy measures are essential to implement and accelerate energy renovations**

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Deep Renovation| Recommendations

- ❑ Adapt laws and regulations to stimulate deep building energy renovation and ZCRB targets
- ❑ Create energy certification schemes at buildings, clusters and district levels
- ❑ Make the implementation of RES mandatory whenever heating systems or district grids are replaced and when there are adequate conditions for the integration of renewables
- ❑ Promote a holistic approach linking buildings renovation to urban planning, energy grid development and carbon reduction goals
- ❑ Facilitate easy-to-use and reliable tools and transparent databases to assure quality in procurement, design and execution
- ❑ Offer integrated solutions and services by providing a single point of contact
- ❑ Deploy financial measures and business models for the entire renovation process, unburdening and guaranteeing the final performance of the renovation project
- ❑ Deploy financial schemes for different target groups, especially low-income households, which should be supported and unburdened of the upfront costs
- ❑ Create financial incentives to make RES and energy storage systems more accessible
- ❑ Facilitate specialised training for the whole chain of the building sector professionals, building owners and local administration staff
- ❑ Provide transparent communication and promote awareness raising and stakeholders engagement

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Deep Renovation| Further Research Issues

- Development of integrated solutions aiming for high-quality design:

  energy-efficient strategies + architecture + urban planning + energy planning

- Development of tools to identify and define cost-effective renovation packages combining energy efficiency and renewable energy supply for different archetypes and climates
- Advance research on the integration of renewable energies at the building and district levels, targeting positive energy districts and energy communities
- Integration and further development of energy storage systems
- Further improve technical solutions for renovating buildings and energy distribution grids for the transition to low-temperature district energy systems
- Further investigate heat pumps as a building technology to achieve ZCRB
- Advance research on cooling strategies (hot climates and climate change scenarios)
- Solutions that preserve cultural heritage when renovating historic/protected buildings
- Test new financial and policy instruments and new business models that create the basis for a massive renovation of buildings in their different typologies and climates

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Deep Renovation| Discussion Topics

- Accelerate Deep Renovation
  - Renovation at district level
    - Upscaling renovation to the district level can lead to cost reduction and address housing affordability, energy grid integration, and urban planning
    - Upscaling renovation to the district level increase complexity
  - Integrated and comprehensive renovation solutions
- Residents Role/involvement
  - Upfront costs, building ownership, temporary relocation during renovation
  - awareness campaigns, funding, affordability and better quality of life
- Massive Electrification
  - Increase in electricity production (renewable energy sources)
  - Improvement of infrastructure (grid) at the urban and building levels
- Circular economy: at the end of their service life, what is the destination of PV panels, heat pumps, wind turbine blades, lithium batteries, etc?

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Thank you for your attention

Manuela Almeida | University of Minho – Portugal

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Implications of energy retrofits on IEQ

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Bjarne W. Olesen
Intl. Centre for Indoor Environment and Energy
Technical University of Denmark

October 19, 2022

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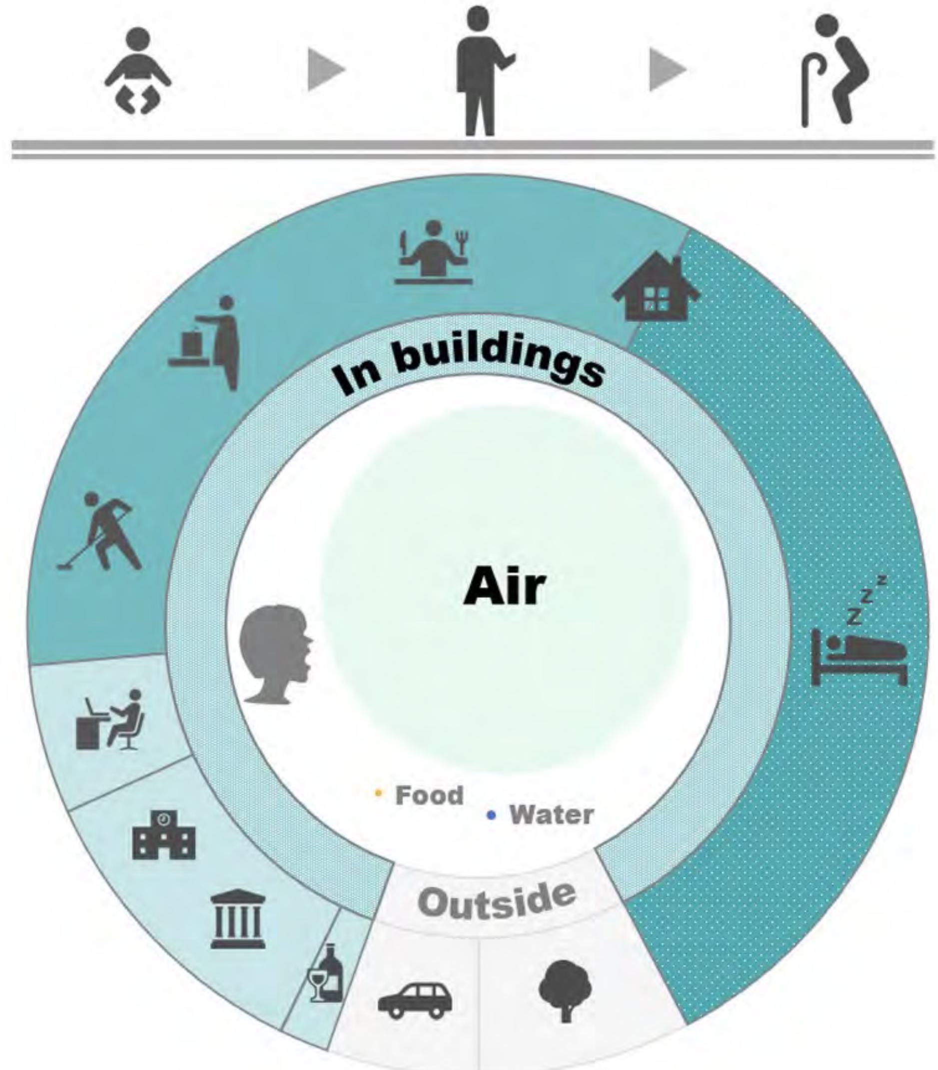
Buildings (built environment) are main exposure pathway



Source: Klepeis et al. (2011)

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Constitution of WHO (1946), health

Health is a state of complete physical, mental and social well-being (wellness) and not merely the absence of disease or infirmity

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What is Indoor Environmental Quality(IEQ)

- Thermal Comfort
- Indoor Air Quality
- Lighting
- Acoustic
- IEQ has an impact on
  - Comfort
  - Well being
  - Productivity
  - Health

What is Indoor Environmental Quality(IEQ)

- Thermal Comfort
  - Air temperature, mean radiant temperature, humidity, air velocity
  - Clothing and activity level
- Indoor Air Quality
  - Ventilation rate (CO_2 tracer, VOC's, particles, humidity)
- Lighting
  - Illumination, daylight factor, glare
- Acoustic
  - Noise (outside, inside), masking,

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Energy Renovation of Envelope

- Higher insulation of envelope will:
  - In winter increase surface temperatures →
  - Higher Mean radiant temperature →
  - Air Temperature can be decreased → Lower ventilation losses
  - Decrease risk of radiant asymmetry
  - More uniform temperature conditions
  - Decrease risk of down draught from cold surfaces
  - Decrease risk of condensation and mould growth
  - Decrease impact from outside noise
  - **Increase risk of overheating**

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Energy Renovation of Envelope

- A tighter envelope will:
  - Decrease infiltration ➡ decrease noise from outside
- Controlled ventilation must be guarantied.
- Increased window area will:
  - Increase daylight
  - Increase view outside
  - Increase use of passive solar heating
  - Risk of overheating in summer
  - Risk of glare

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Renovation of HVAC system

- Design for both winter and summer conditions
  - Focusing only on heating season may result in overheating in summer.
- Use of heat recovery on ventilation (bypass for ventilative cooling)
  - Reduce risk for draught
- Improved control of IEQ
  - Include feed-back from and till occupants in the control loop

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Evaluation of the impact of renovation

- KPI's for energy
  - Primary energy use kWh/m^2 per year
  - CO^2 emission in kg/m^2 per year
- KPI's for IEQ????
  - Thermal
  - IAQ
  - Lighting
  - Acoustic
  - Combined
- Monitoring of IEQ data

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International Standards for Indoor Environmental Quality(IEQ)

- EN16798-1 and ISO 17772-1
- EN TR 16798-2 and ISO TR 17772

EUROPEAN STANDARD
NORME EUROPÉENNE
EUROPÄISCHE NORM

EN 16798-1

May 2019

ICS 91.120.10; 91.140.01

Supersedes EN 15251:2007

English Version

Tekst

Energy performance of buildings - Ventilation for buildings - Part 1: Indoor environmental input parameters for design and assessment of energy performance of buildings addressing indoor air quality, thermal environment, lighting and acoustics - Module M1-6

DS/CEN/TR 16798-2:2019

TECHNICAL REPORT
RAPPORT TECHNIQUE
TECHNISCHER BERICHT

CEN/TR 16798-2

May 2019

ICS 91.120.10; 91.140.01

English Version

Energy performance of buildings - Ventilation for buildings - Part 2: Interpretation of the requirements in EN 16798-1 - Indoor environmental input parameters for design and assessment of energy performance of buildings addressing indoor air quality, thermal environment, lighting and acoustics (Module M1-6)

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Temperature ranges for hourly calculation of cooling and heating energy in four categories of indoor environment ISO17772-1/2

Type of building/ space	Category	Operative Temperature for Energy Calculations °C	
Offices and spaces with similar activity (single offices, open plan offices, conference rooms, auditorium, cafeteria, restaurants, class rooms, Sedentary activity ~1,2 met		Heating (winter season), ~ 1,0 clo	Cooling (summer season), ~ 0,5 clo
	I	21,0 – 23,0	23,5 - 25,5
	II	20,0 – 24,0	23,0 - 26,0
	III	19,0 – 25,0	22,0 - 27,0
	IV	17,0 – 26,0	21,0 - 28,0

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ASHRAE Standards dealing with Indoor Environmental Quality(IEQ)

- ASHRAE 55
  - Thermal environment conditions for human occupancy
- ASHRAE 62.1 and 62.2
  - Ventilation and indoor air quality

Recent work in Europe: Deep Retrofit and IEQ

- EPB-directive:
  - Monitoring of IEQ in zero carbon buildings
  - Smart-Building-Readiness (SRI)
  - Renovation passport

Building Renovation Passport

- A Building Renovation Passport is an evolution of the Energy Performance Certificate (EPC), as it supports building owners with personalised suggestions on their renovation options.
- These result from an on-site energy audit fulfilling specific quality criteria and indicators established in dialogue with the owner.
- Via BRPs, building owners receive a ready-to-use, personalised renovation plan, presenting all the measures to be taken and the related **expected benefits, including energy savings and comfort improvement.**

Recent work in Europe: Deep Retrofit and IEQ

- ALDREN EC Horizon 2020 project (Alliance for Deep Renovation in Buildings)
- TAIL, the new index for rating indoor environmental quality in offices and hotels undergoing deep energy renovation (EU ALDREN project)
- Renovation passport
- https://aldren.eu/building-renovation-passport/

THERMAL COMFORT SCORES

- In an EU project “ALDREN”, a yearly KPI for the thermal environment was proposed and used to evaluate a deep renovation.
- This value was calculated based on the percentage of occupied hours inside the categories of indoor environmental quality defined in EN 16798-1.
- The score assigned weighted values for % time spent in each category, and provides a single value from 1 (Best) to 5 (Worst) equation (2)

$$TCS = \%Cat.I * 1 + (\%Cat.II - \%Cat.I) * 2 + (\%Cat.III - \%Cat.II) * 3 + (\%Cat.IV - \%Cat.III) * 4 + \%outside * 5 \quad (2)$$

Yearly thermal comfort score (TCS)
Yearly Energy Use

Location	Copenhagen						Palermo					
Case	A	B	C	D	E	F	A	B	C	D	E	F
TCS	1.93	1.27	1.49	1.71	1.28	2.31	2.37	1.21	1.79	1.10	1.30	2.06
Energy use kWh/m² year	37	41	39	38	39	39	36	40	39	6	40	39
IEQ category	II	II	II	II	II	III	III	II	II	I	II	II

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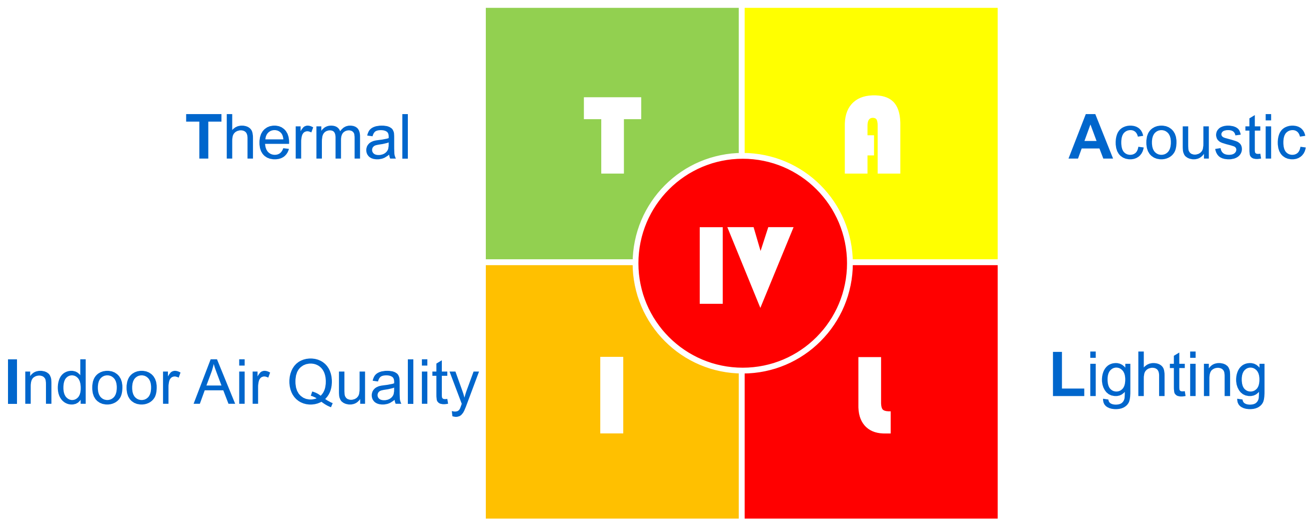
Recent work in Europe: Deep Retrofit and IEQ



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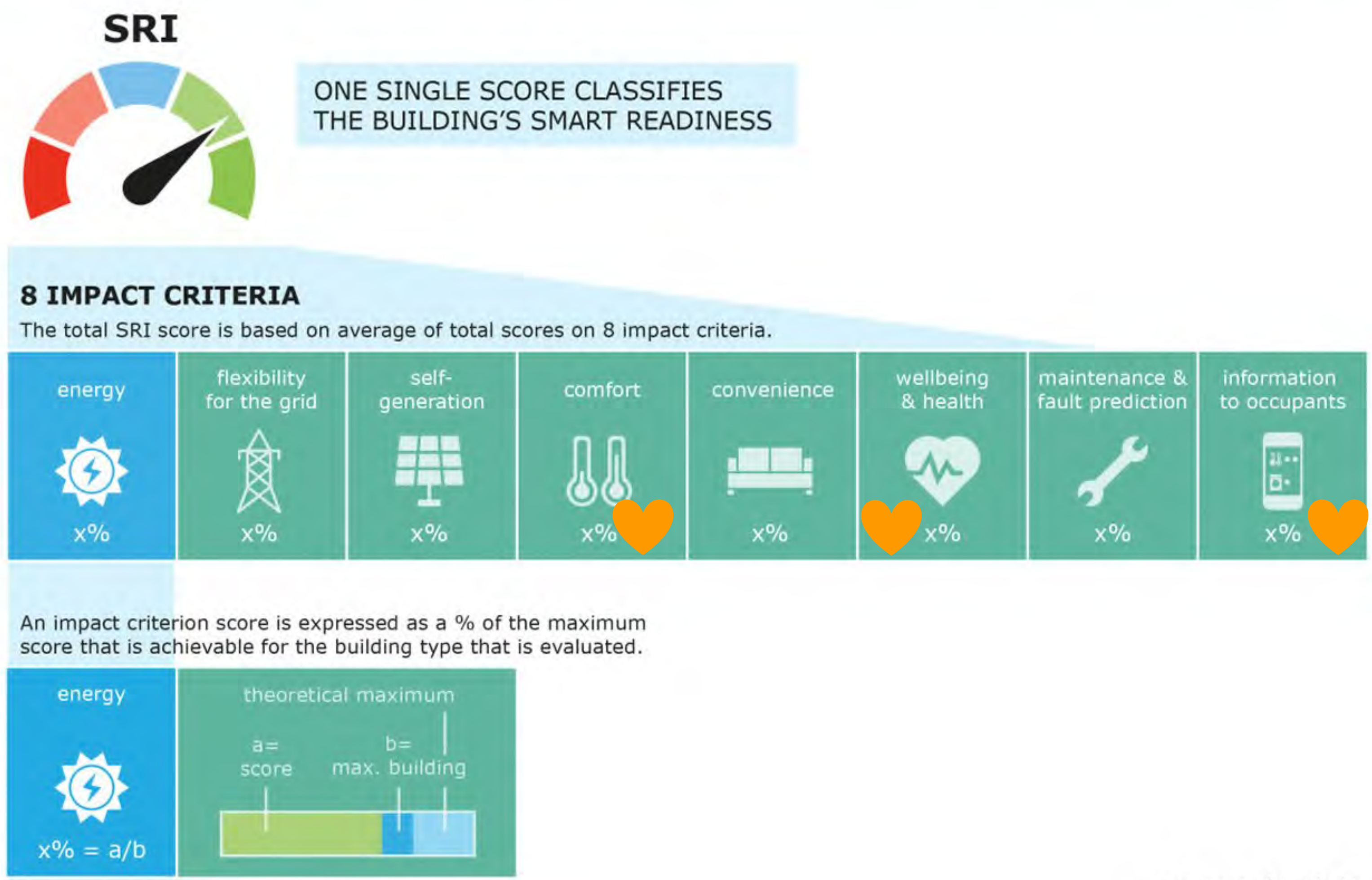
SRI - CALCULATION METHODOLOGY



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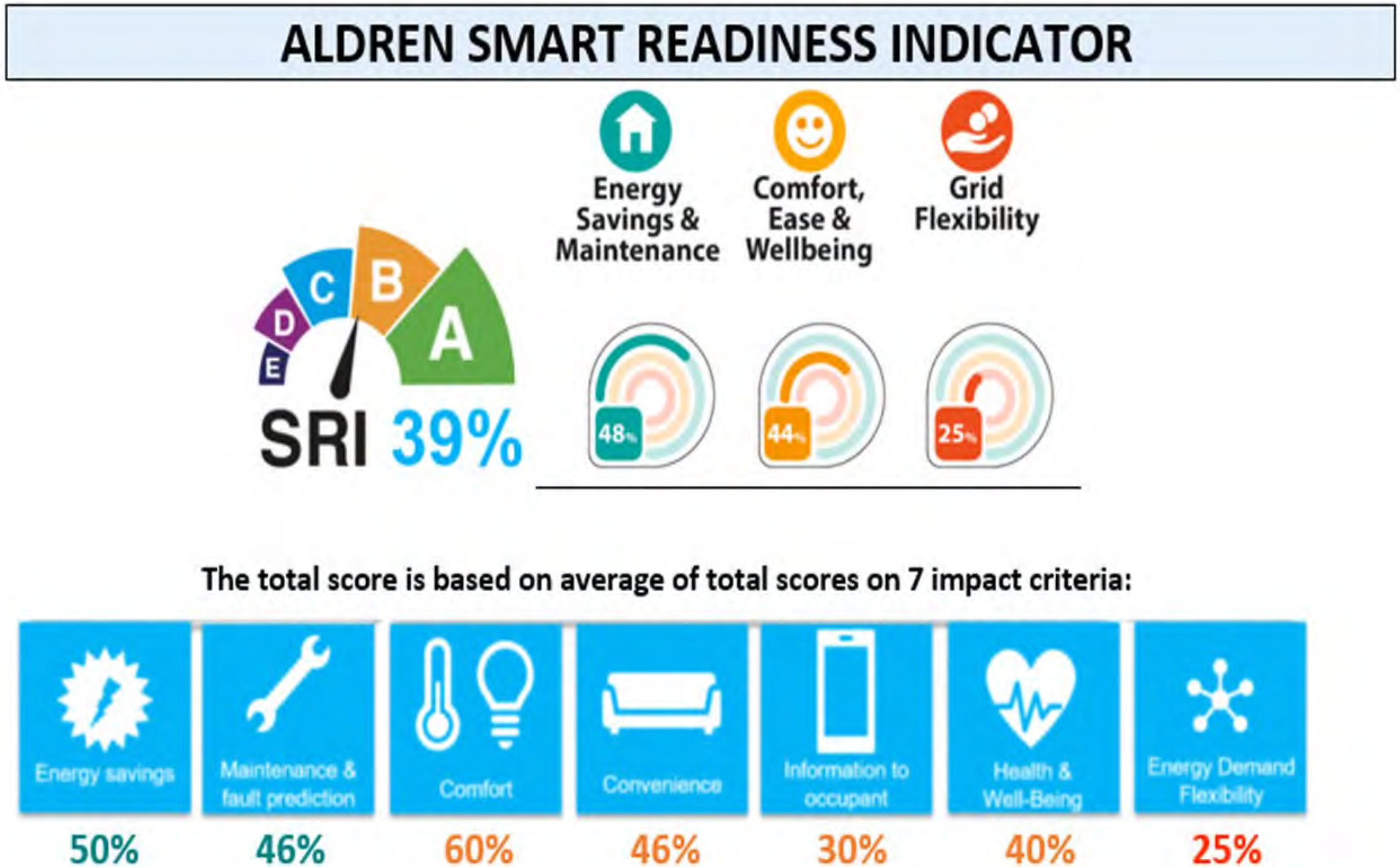
Recent work in Europe: Deep Retrofit and IEQ



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IEQ/wellness still are not satisfactory

Green buildings

Traditional buildings

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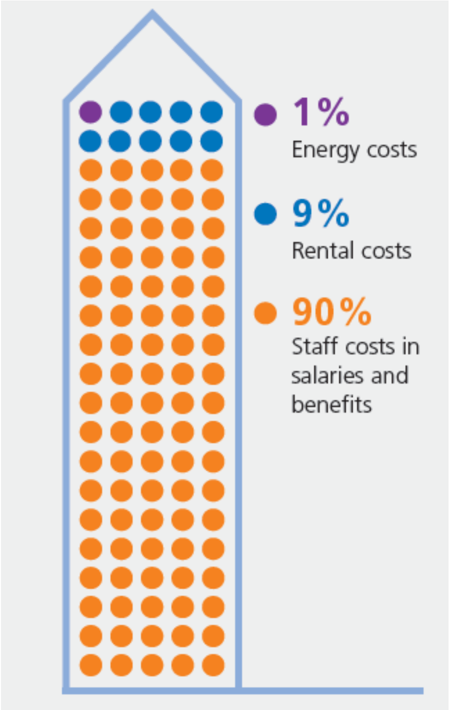
COMFORT-PRODUCTIVITY

Building costs

People	100
Maintenance	10
Financing	10
Energy	1



If an energy renovation improves IEQ and increase productivity, the pay-back period will be very short

Thank You

IT IS A MUCH CLEVERER THING
TO TALK NONSENSE THAN TO LISTEN TO IT
OSCAR WILDE

bwol@dtu.dk

Session 3

October 20th, 2022, AM

Systems as Transformational Process

Session Coordinators

Teun Bokhoven

Chair, ExCo, Energy Storage TCP / Chair, TKI Urban Energy

Robin Wiltshire

Chair, ExCo, District Heating and Cooling TCP / BRE Building Research Establishment

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Deployment of renewable/recycled energy and flexible sector coupling in buildings

IEA Future Buildings Forum Think Tank Workshop- session 3

Teun Bokhoven, chair Energy Storage TCP
teunbokhoven@consolair.nl

October 19th – 21st , 2022

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Or: how to decarbonise the energy for the existing building stock

Ingredients dealing with decarbonization

How to balance them through flexible sector coupling

Options for integration

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Transforming energy system

The entire energy system is in transformation, not only the built environment.

- Electricity moves to the hart of the energy system and provide multiple challenges: electrical vehicles, electrification industrial processes, electrical heating, etc
- Renewable energy- mostly volatile / variable
- Electricity grid reaches will reach its limits

- Need for flexible sector coupling at all levels (industry, mobility, built environment)

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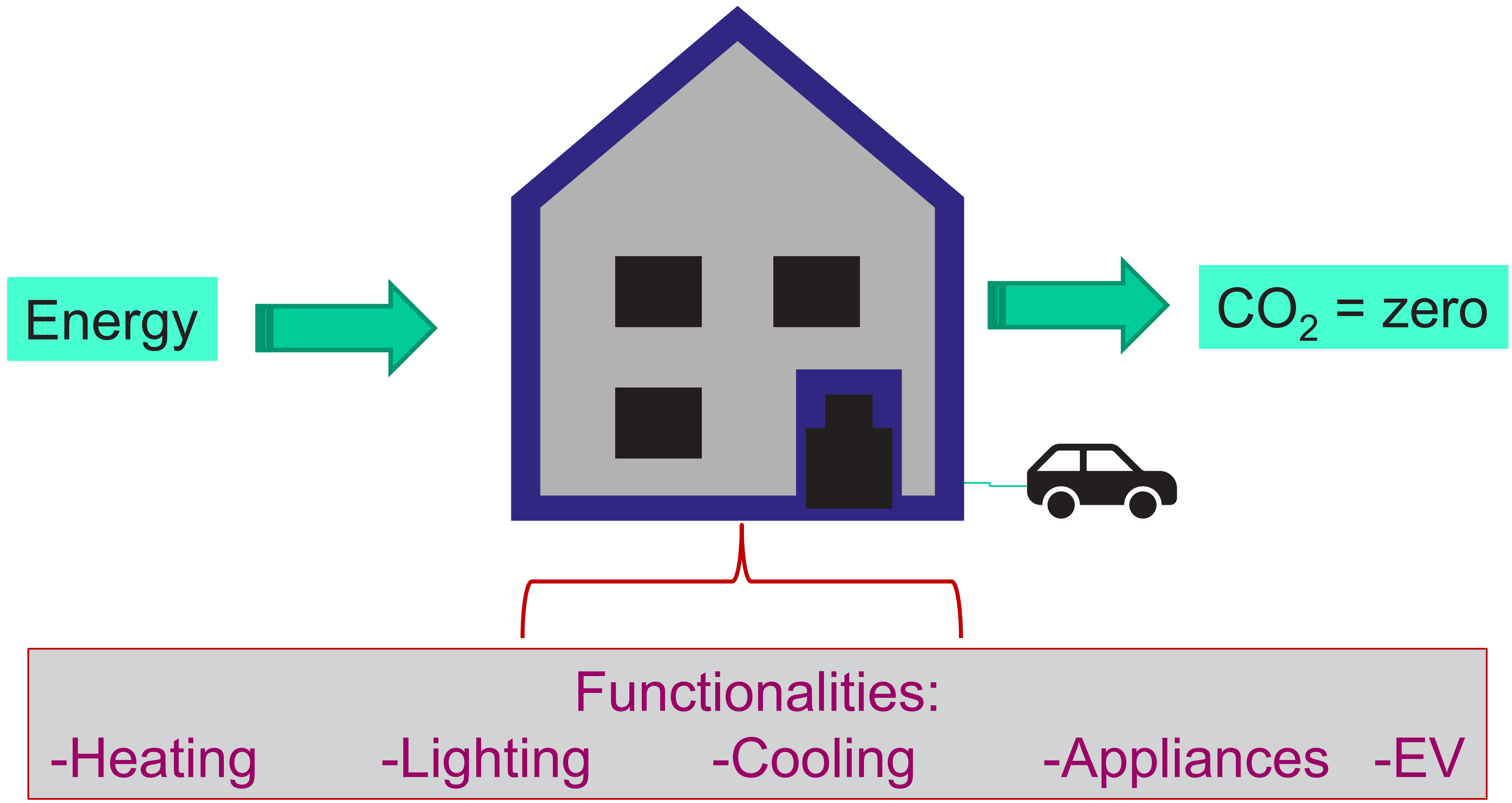
Desired energy flow at building level



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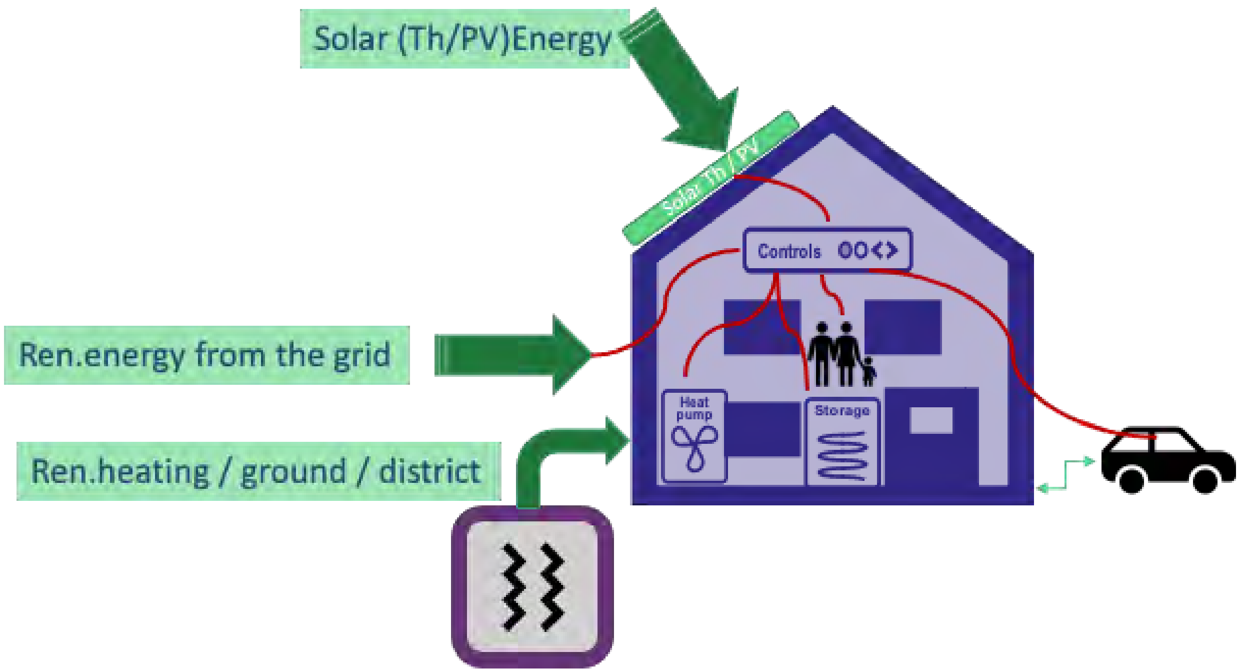
Input of renewable energy (sources)



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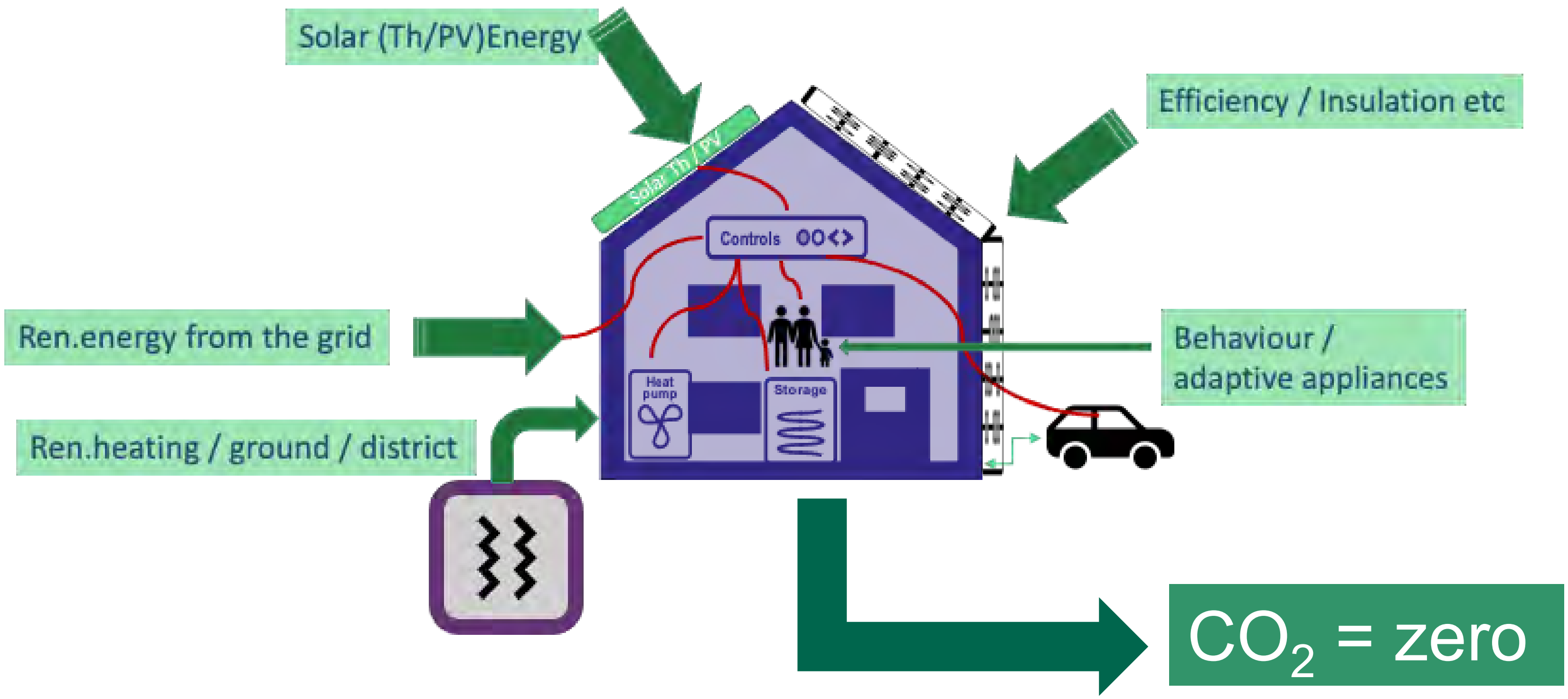
Input of renewable energy + efficiency and adaptive behaviour and appliances



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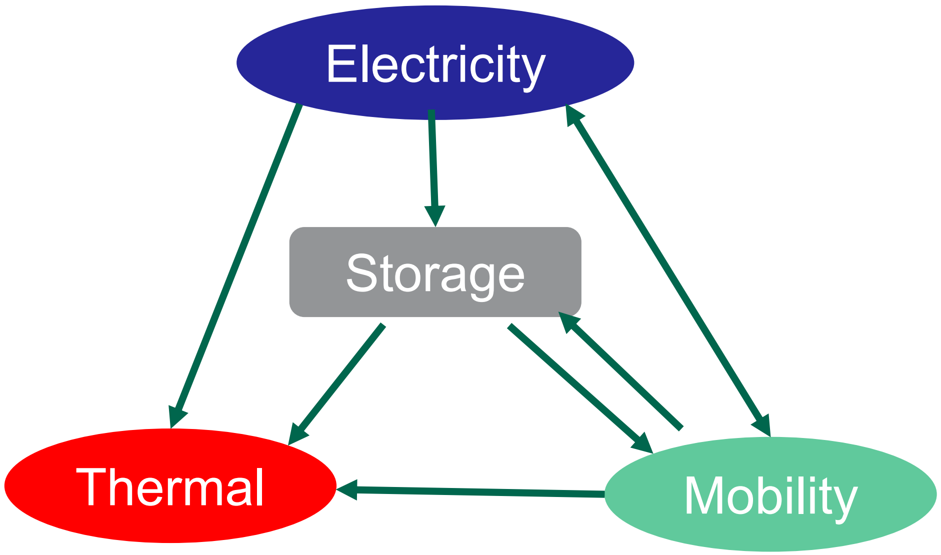
Concept of flexible sector coupling

Deploy (renewable) energy for multiple applications.

- Electricity to thermal and mobility applications
- EV's to support domestic appliances and thermal
- Storage as intermediate component



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Options for integration

Drivers for integration of components and installation in buildings (retrofit)

- Roofs /Walls & PV/ Solar Thermal
- Floors and storage / heating
- Heat pumps / storage
- …….

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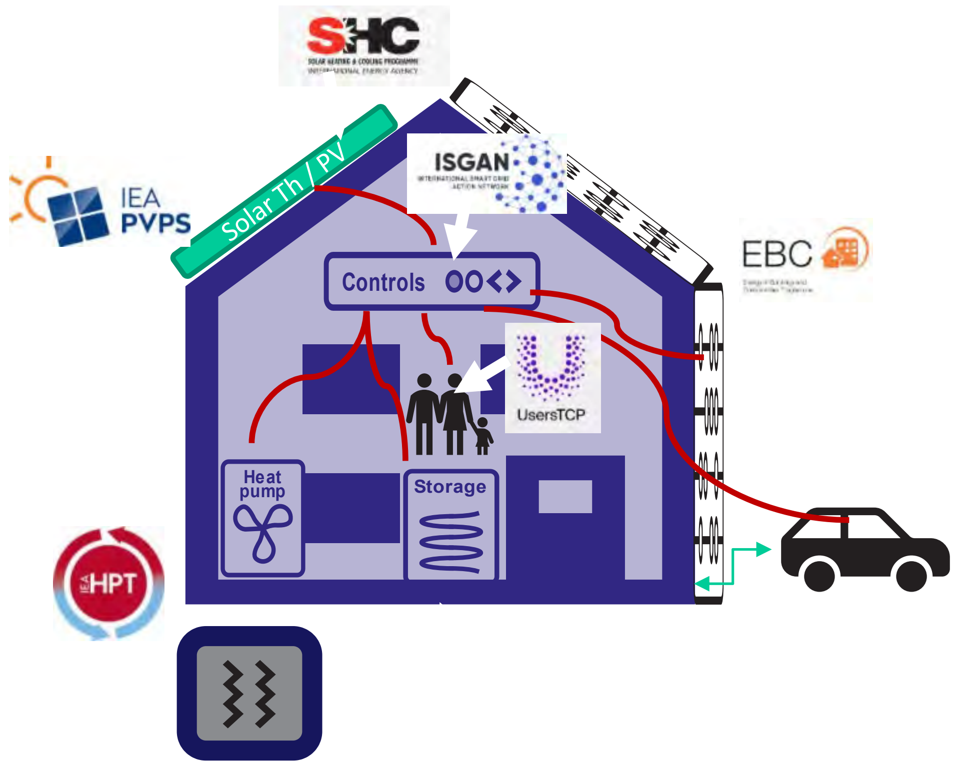
TCP's in/around the buildings

TCP's - for discussion

- What collaboration challenges do arise for further integration of functions and components
- Which functions require localised solutions, what can be standardised
- Interaction between the ZEB- and its energy environment (district / city)



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Optimisation and transition of district energy systems to lower temperatures

Future Buildings Forum

19 October 2022

Dr Robin Wiltshire

Chair, DHC TCP

IEA DHC

INTERNATIONAL ENERGY AGENCY TECHNOLOGY COLLABORATION PROGRAMME ON
DISTRICT HEATING AND COOLING

District energy…

- District energy, district heating, community heating, heat networks… many different names
- Many different systems, differing in size, age, typography, efficiency, ‘generation’
- This indicates the huge diversity of systems, but also the flexibility of the approach
- Like any technology there are examples of old systems performing poorly, and like any technology the solution is to modernise, technically and organizationally
- However, most district energy networks make better use of energy resources than individual systems, and most provide heat at a lower cost than the alternative
- Key concern now is the transition from fossil-based to zero-carbon networks
- This involves systems migrating to lower operating temperatures.

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INTERNATIONAL ENERGY AGENCY TECHNOLOGY COLLABORATION PROGRAMME ON
DISTRICT HEATING AND COOLING

Why transition?

- District energy networks are fuel flexible; the current transition to Low Temperature District Heating (LTDH) focuses on changing from fossil-fuel based systems to renewable and recycled energy, in pursuit of net-zero solutions
- District energy makes use of energy resources and technologies that would not work at an individual building level: eg industrial waste heat, heat from data centres, deep geothermal
- LTDH networks extend the potential use of solar thermal and waste heat sources by making use of them at a lower temperature, and thermal storage capacity is increased
- Opportunities for integrated district heating and cooling systems with heat pumps
- Heat losses are reduced and plastic pipe systems lower capital costs
- District energy networks are vital to integrated smart energy systems, providing balancing for the future electricity grid based on intermittent renewables.

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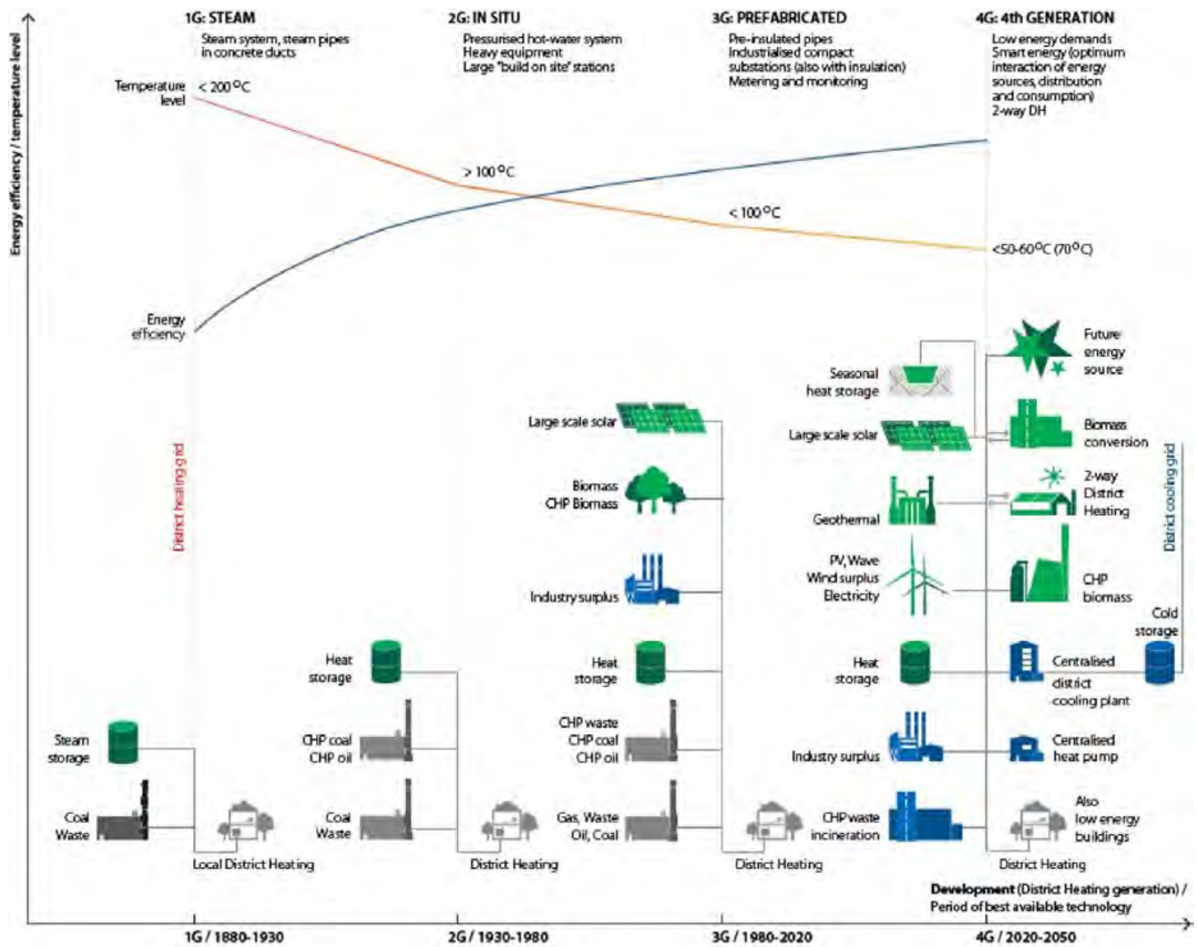
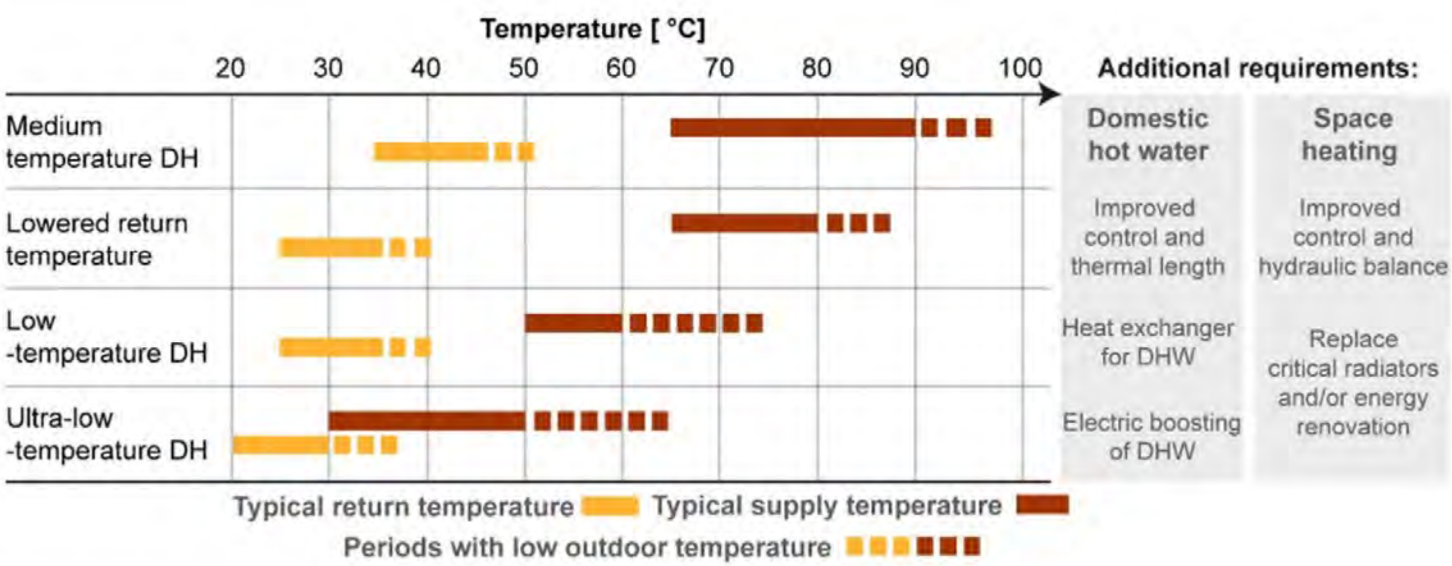
DISTRICT HEATING AND COOLING



1G: STEAM
Steam system, steam pipes in concrete ducts
2G: IN SITU
Pressurised hot-water system
Heavy equipment
Large "build on site" stations
3G: PREFABRICATED
Pre-insulated pipes
Industrialised compact substations (also with insulation)
Metering and monitoring
4G: 4th GENERATION
Low energy demands
Smart energy (optimum interaction of energy sources, distribution and consumption)
2-way DH
Energy efficiency / temperature level
Temperature level
< 200 °C
> 100 °C
< 100 °C
<50-60 °C (70 °C)
Energy efficiency
District heating grid
District cooling grid
Future energy source
Seasonal heat storage
Large scale solar
Biomass conversion
Biomass
CHP Biomass
Geothermal
2-way District Heating
Industry surplus
PV, Wave
Wind surplus
Electricity
CHP biomass
Cold storage
Heat storage
Centralised district cooling plant
Steam storage
CHP coal
CHP oil
CHP waste
Centralised heat pump
Coal
Waste
Gas, Waste
Oil, Coal
CHP waste incineration
Also low energy buildings
Local District Heating
District Heating
Development (District Heating generation) / Period of best available technology
1G / 1880-1930
2G / 1930-1980
3G / 1980-2020
4G / 2020-2050

Two-step implementation of Low Temperature District Heating



INTERNATIONAL ENERGY AGENCY TECHNOLOGY COLLABORATION PROGRAMME ON
DISTRICT HEATING AND COOLING

'4GDH systems should have the following abilities'

- To supply low-temperature district heating for space heating and domestic hot water
- To distribute heat with low grid losses
- To recycle heat from low-temperature sources
- To integrate thermal grids into a smart energy systems
- To ensure suitable planning, cost and motivation structures.

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DISTRICT HEATING AND COOLING

7

DHC TCP work on transition

Substantial work on this area already:

- Optimisation of DH operating temperatures and an appraisal of the benefits of low temperature district heating (Annex V, 1999)
- Optimisation of a DH system by maximising building system temperature differences (Annex VI, 2002)
- Towards fourth generation DH: experiences with, and potential of, low temperature DH (Annex X, 2014)
- Low temperature DH for future energy systems (Annex TS1, 2017)
- Transformation roadmap from high to low temperature DH systems (Annex XI, 2017)
- Stepwise transition strategy and impact assessment for future DH systems (Annex XII, 2020)
- Implementation of low temperature DH systems (Annex TS2, 2021)

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INTERNATIONAL ENERGY AGENCY TECHNOLOGY COLLABORATION PROGRAMME ON
DISTRICT HEATING AND COOLING

Current DHC TCP work on transition

Lots of focus on this area at present:

- Optimised transition towards low-temperature and low-carbon DH systems
- CASCADE: a comprehensive toolbox for integrating low-temperature sub-networks in existing DH systems
- Leave second generation behind: cost-effective solutions for small-to-large DH networks

And the following associated areas:

- Hybrid energy networks (Annex TS3)
- Digitalisation of DHC (Annex TS4)
- Integration of renewable energy sources into existing DHC systems (Annex TS5).

Optimising networks for low temperature operation

1. Eliminate temperature errors in existing distribution networks and substations.
2. Avoid these temperature errors in new network parts and in new substations.
3. Use heat exchangers with longer thermal lengths in substations – so substation designs need to be revised.
4. Reduce heat demands through energy efficiency measures.
5. *Install larger heating surfaces in radiator and ventilation systems (but note that for existing buildings radiators may have been oversized initially, and energy efficiency measures may have reduced the heat demand).*
6. Reduce return temperatures by correct commissioning of internals, including radiators/TRVs
7. New low-temperature networks may be connected as secondary networks to existing systems – cascading.

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INTERNATIONAL ENERGY AGENCY TECHNOLOGY COLLABORATION PROGRAMME ON
DISTRICT HEATING AND COOLING

Optimising networks for low temperature operation

- Not only about optimising and transitioning the heat distribution network.
- Also requires co-operation from inside the buildings – note these factors from the last slide:

4. Reduce heat demands through energy efficiency measures.
5. *Install larger heating surfaces in radiator and ventilation systems (but note that for existing buildings radiators may have been oversized initially, and energy efficiency measures may have reduced the heat demand).*
6. Reduce return temperatures by correct commissioning of internals, including radiators/TRVs

Hence the sequence of measures in the next slide.

11

Achieving low return temperatures

For 2-string systems with panel radiators:

- Evaluate performance
- Find and fix errors in system
- Optimise central control of supply temperature and pump pressure
- Optimise function of thermostatic radiator valves, TRV
- Implement operating improvements
- Monitor performance
- Continue to optimise operation.

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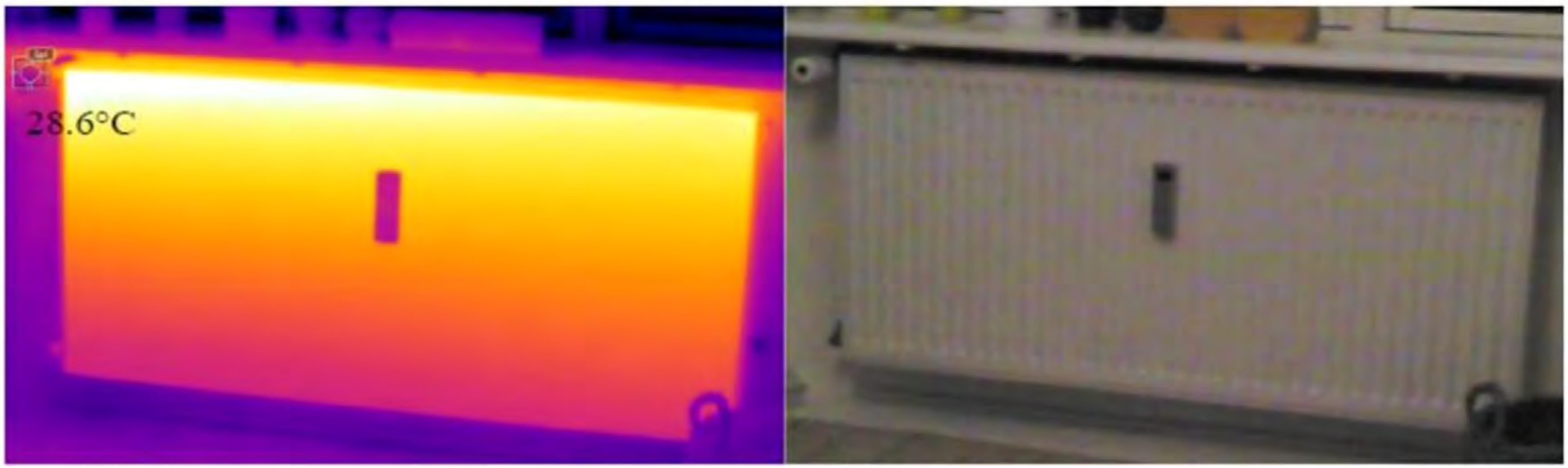
DISTRICT HEATING AND COOLING

Radiators can cool water close to room temperature if correctly commissioned



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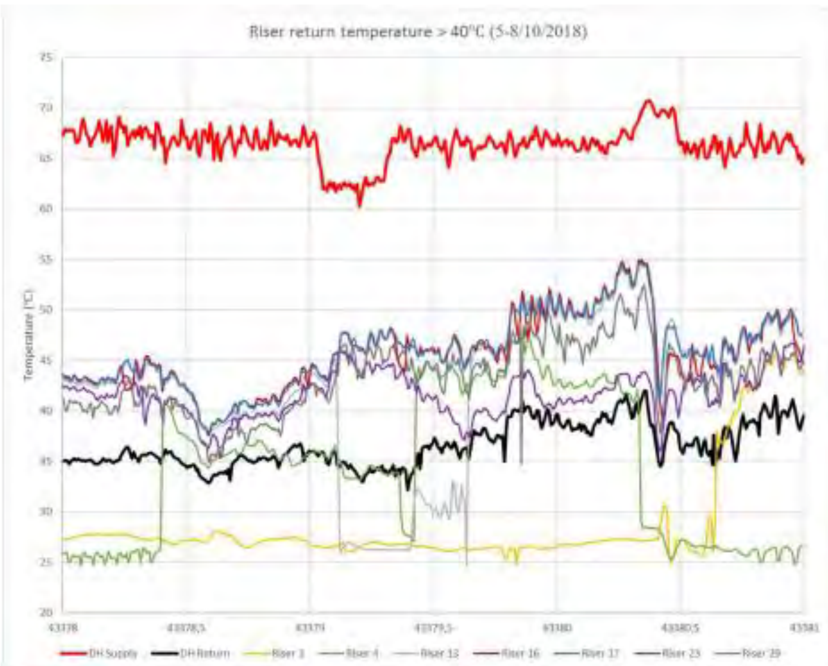
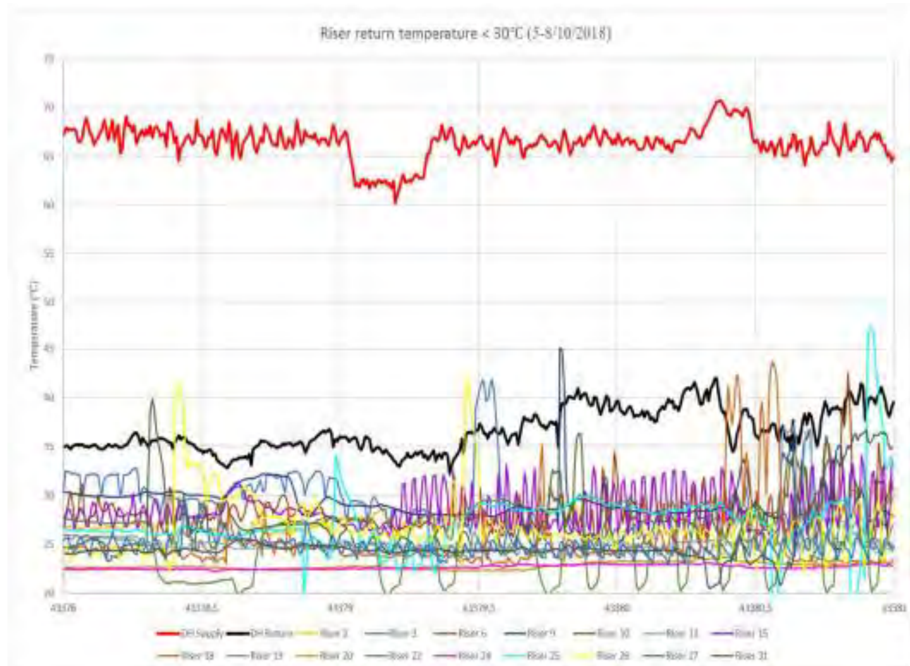
Lower return temperatures: optimising the TRVs





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DISTRICT HEATING AND COOLING

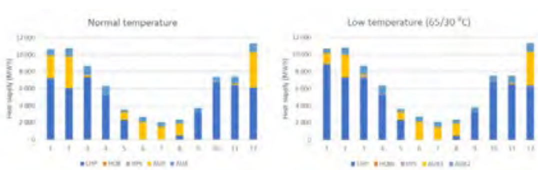
14

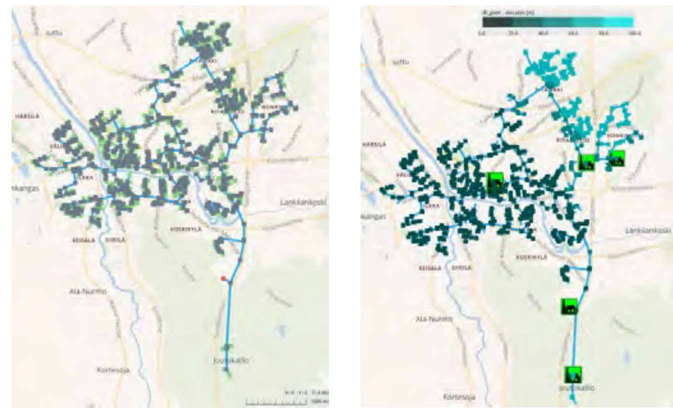
Current work: Combining heat supply optimisation & network simulation

Core idea: to combine heat supply optimization and network simulation. A DH system level case study on the impact of distribution temperatures and a more decentralized heat supply based on utilisation of excess and renewable heat sources in an urban area.

Both the optimisation model (left) and the network simulation model (right) have been defined. Work for final adjustments for the network model (especially concerning the control systems) is underway.

- System divided into 21 areas (preliminary division)
- Each area as a specified demand
- Transport capacity between areas limited (based on temperatures and pipe dimensions)
- Optimisation model testing carried out for year 2019 for two scenarios:
  - Existing system (normal temperatures)
  - Estimated low temp situation (65/30 °C)
- Assumed heat pump capacity for specific areas
- Efficiencies of CHP unit, flue gas condenser and heat pumps tied to distribution temperature levels (to be based on results of the network simulation model)





Apros District © model defined for the case system (Lapua, Finland). The heat supply will be run according to results of the optimization model, and temperatures and related constraints (e.g. required local production will be made available for the optimization.

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Current work: Digitalization of demand side and motivation tariffs

Main objective: to investigate new strategies to achieve low temperatures and improve the operation of space heating and domestic hot water systems in buildings connected to DH by using the capabilities of new digital smart meters and sub-meters

Project status

- Improved operation of residential and commercial buildings
- Digitalization of demand side: use of data from heat cost allocators, energy meters and temperature sensors
- It was documented that supply temperature below 55 °C at 0 °C are adequate to secure the expected comfort in several demo cases

Next Steps

- Motivation tariffs' role as the key economic incentive to prepare for the future fossil-fuel free energy market and stimulate the transition towards the 4GDH.

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Thank you for your attention!

For more about the IEA DHC TCP:

www.iea-dhc.org

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Andrej Jentsch, AGFW (Operating Agent)

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IEADHC

INTERNATIONAL ENERGY AGENCY TECHNOLOGY COLLABORATION PROGRAMME ON
DISTRICT HEATING AND COOLING

Reducing CO_2 emissions in cities – key measures and state of the art cases

IEA Future Buildings Forum Think Tank Workshop

Helmut Strasser, SIR
helmut.strasser@Salzburg.gv.at

October 2022

The target is clear

Net zero greenhouse gas emissions in the second half of this century

COP21 · CMP11
PARIS 2015
UN CLIMATE CHANGE CONFERENCE

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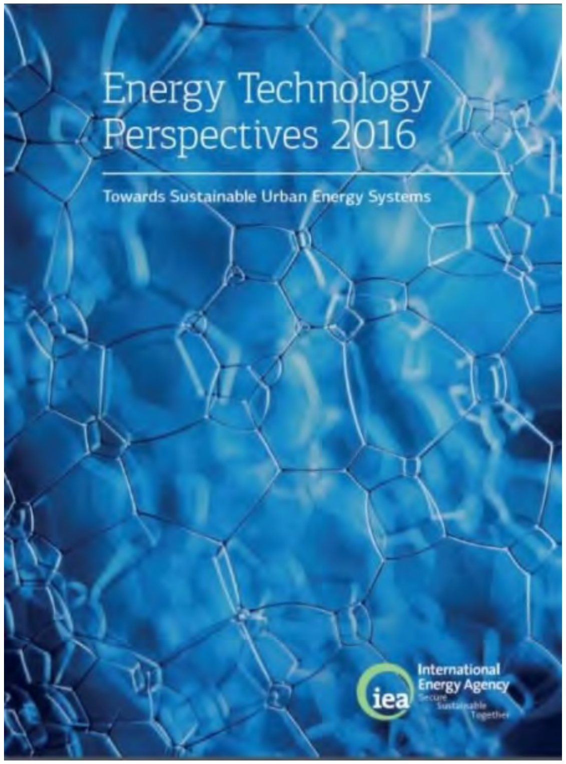
Towards sustainable urban energy systems

"Cities are at the heart of the decarbonisation effort"



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Facts and figures

- 2% of the earth's surface is occupied by cities
- 53% of the world's population lives in cities
- 70% of worldwide CO_2 emissions occur in cities

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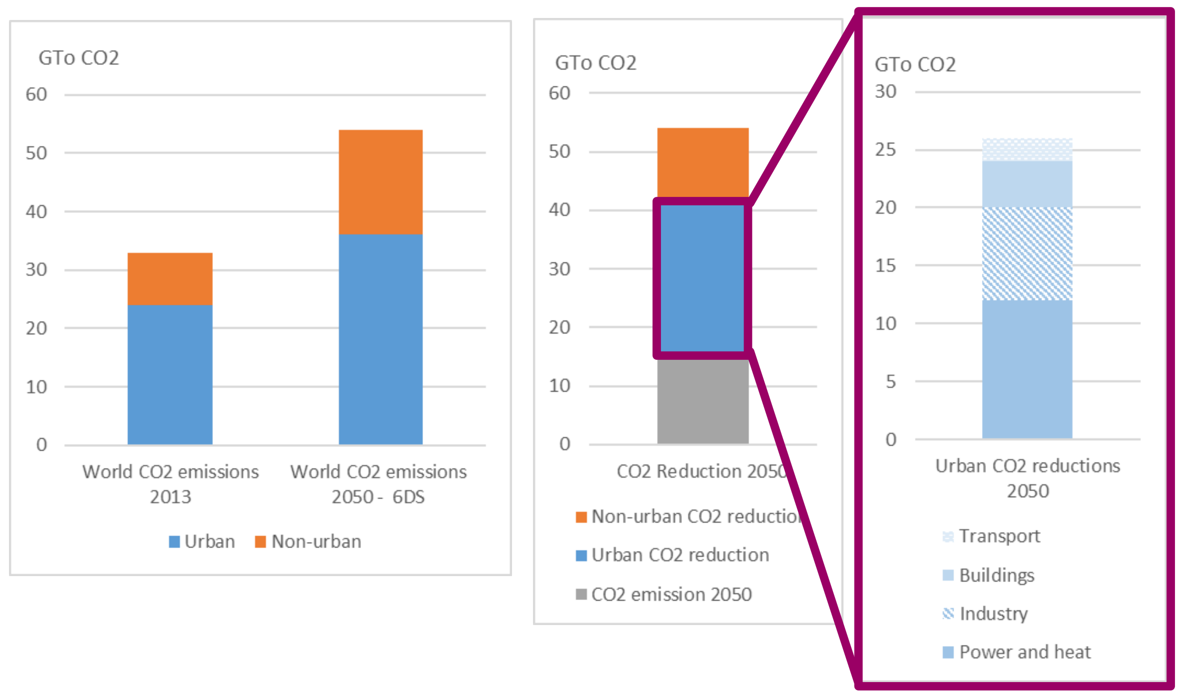
“Cities are at the heart of the decarbonisation effort”

2/3 are CO_2 emissions in cities

- **Buildings**
- **Power & heat**
- **Mobility**
- Industry



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Transformation requires investment

Costs for implementation of decarbonisation measures

10.000 € / person
(Austrian Environmental Agency, 2022)

e.g. City of Salzburg, Austria (pop. 160.000)
→ 1.6 billion €

→ Common strategies and investment decisions by city, investors, energy suppliers, mobility providers, …

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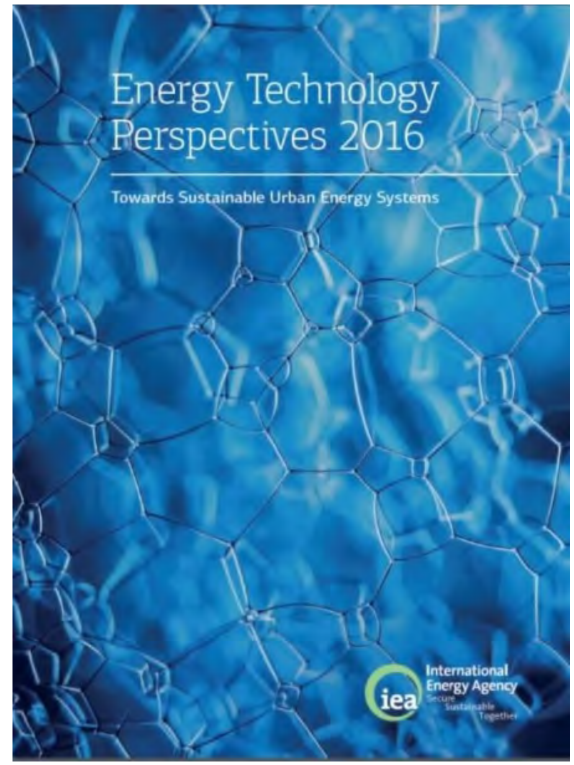
Towards sustainable urban energy systems

- Cities are at the heart of the decarbonisation effort"

- "Mobilizing the urban sustainable energy potential requires strong support from national governments to local policy makers"



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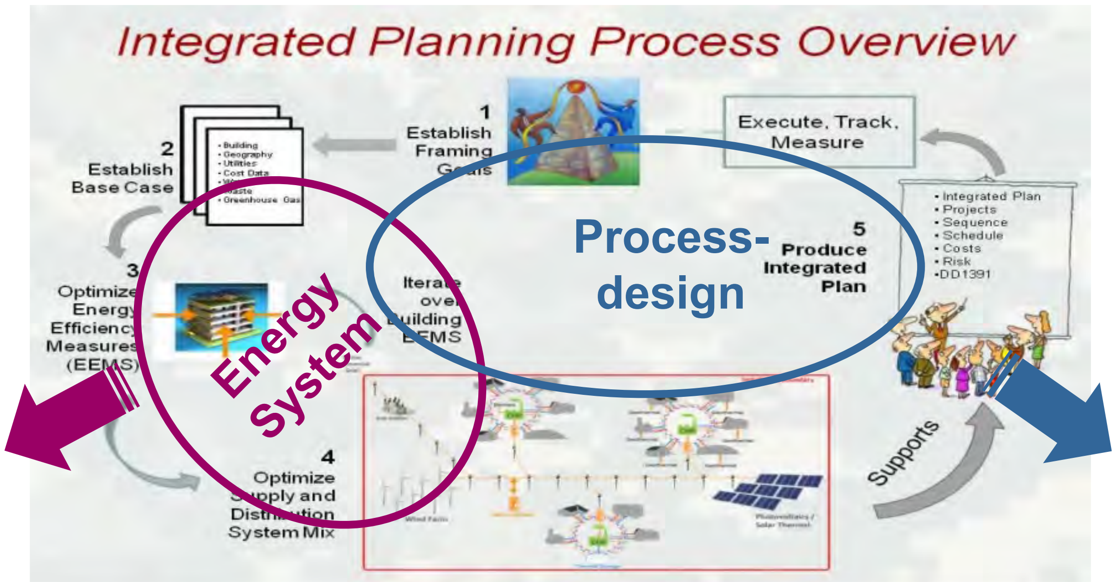
Integrated planning



Energy System

IEA-EBC Annex 51: Guidebook on Successful Urban Energy Planning

Process design

IEA-EBC Annex 63: Implementation of Energy Strategies in Communities

www.annex63.org

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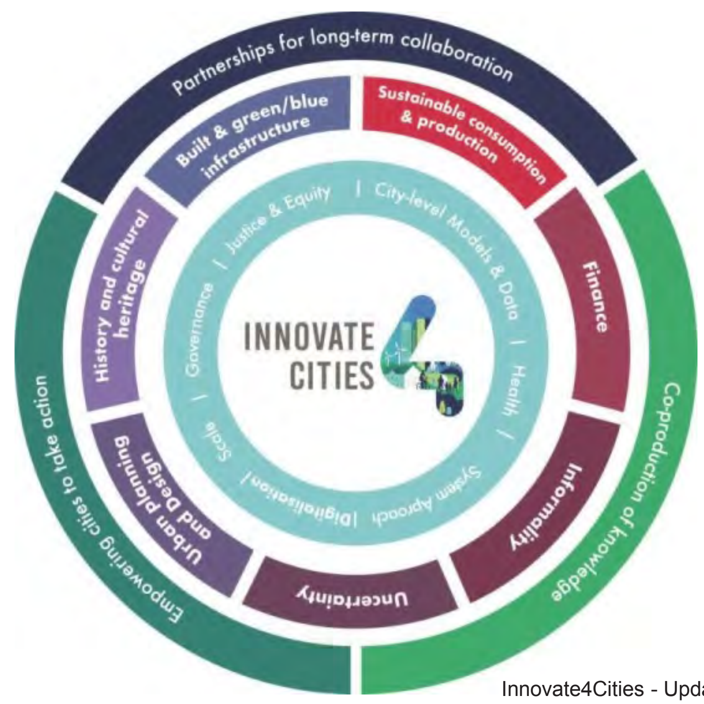
Research gap

Gaps by topic

- Informality
- Urban planning and design
- Built blue & green infrastructure
- Sustainable production and consumption
- Finance
- Uncertainty
- History and cultural heritage

Gaps by cross-cutting issue

- Systems approach
- Governance and institutions
- Scale
- Observation, data, modelling, scenarios - city scale
- Health and wellbeing
- Justice and equity
- Digitalisation and smart cities



Innovate4Cities - Update to the Global Research and Action Agenda, GCoM, 2022

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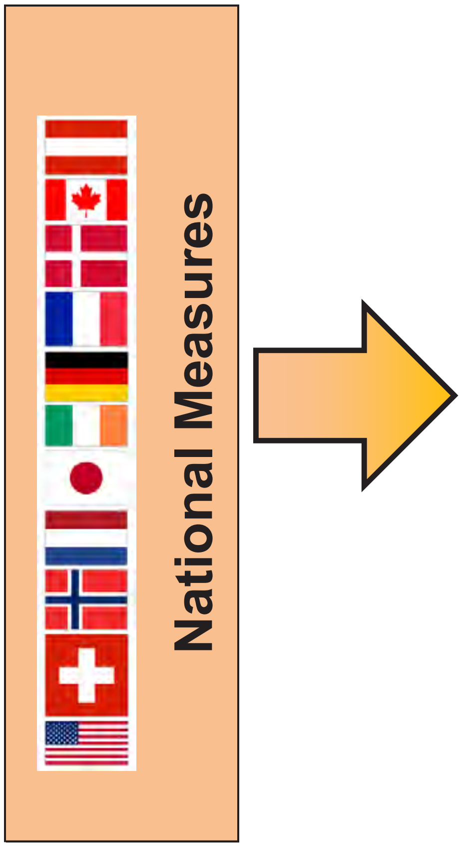
Integrating energy aspects in urban planning processes



Strategic Measures

- **Set Vision and Targets**
- **Develop Renewable Energy Strategies**
- **Make Full Use of Legal Frameworks**
- **Design of Urban Competition Processes**
- **Make Use of Tools Supporting the Decision Making Process**
- **Implement Monitoring of Energy Consumption and GHG Emissions**
- **Stakeholder Engagement & Involvement**
- **Include Socio Economic Criteria**
- **Implement Effective and Efficient Organisational Processes**

IEA EBC Annex 63, 2016

9 strategic measures:

- Entry point: tasks of urban planning
- Entry point: planning process
- Implementation at different scales

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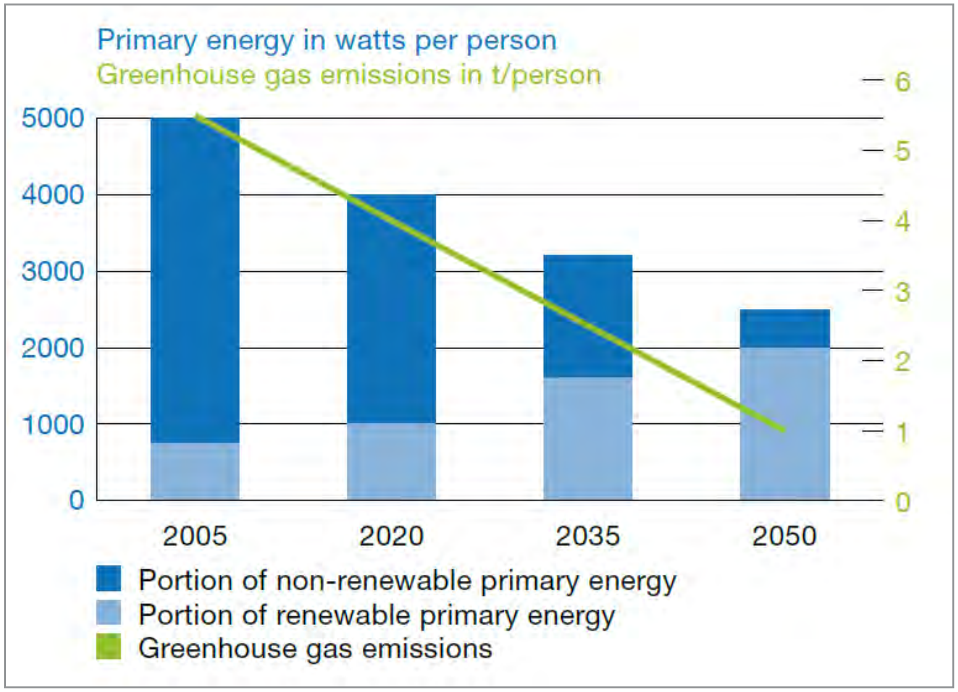
(1) Set vision and targets

Qualitative

Framework Strategy 2019-2050, 2018

Quantitative



Energy master plan of the city of Zurich, 2016

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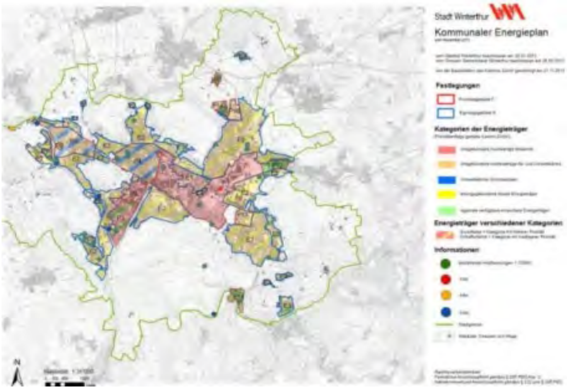
(2) Develop renewable energy strategies

Spatial Energy Planning, Vienna, 2016

Spatial information



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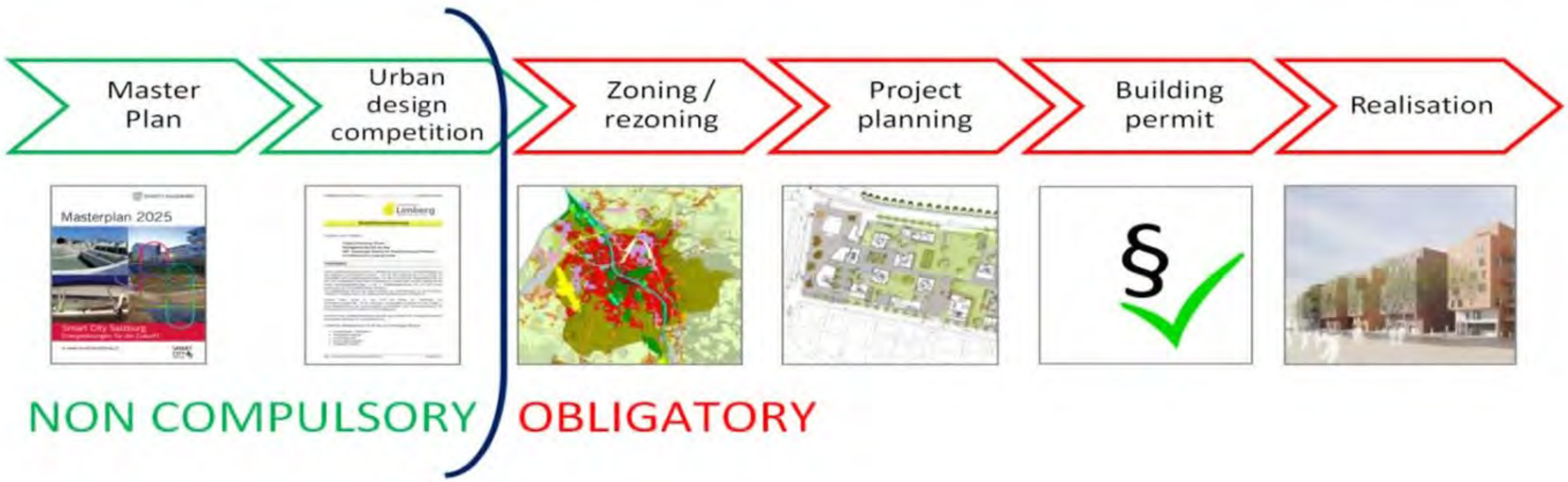
(3) Make full use of legal frameworks



- Consider energy / climate goals and energy planning in existing legal frameworks
- Make full use of the given options

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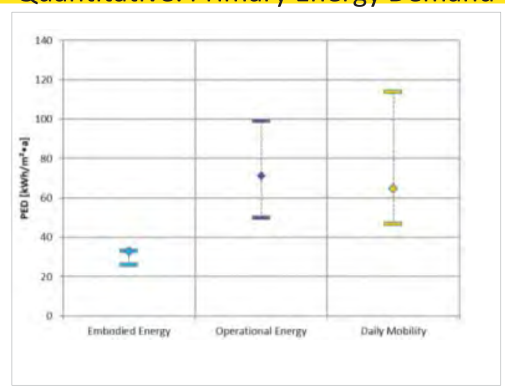
(5) Make use of tools supporting the urban decision making processes

City	Site	Building
		
QM for Cities	**Site certification**	**Building labels**

Qualitative: Management Assessment

Quantitative: Primary Energy Demand



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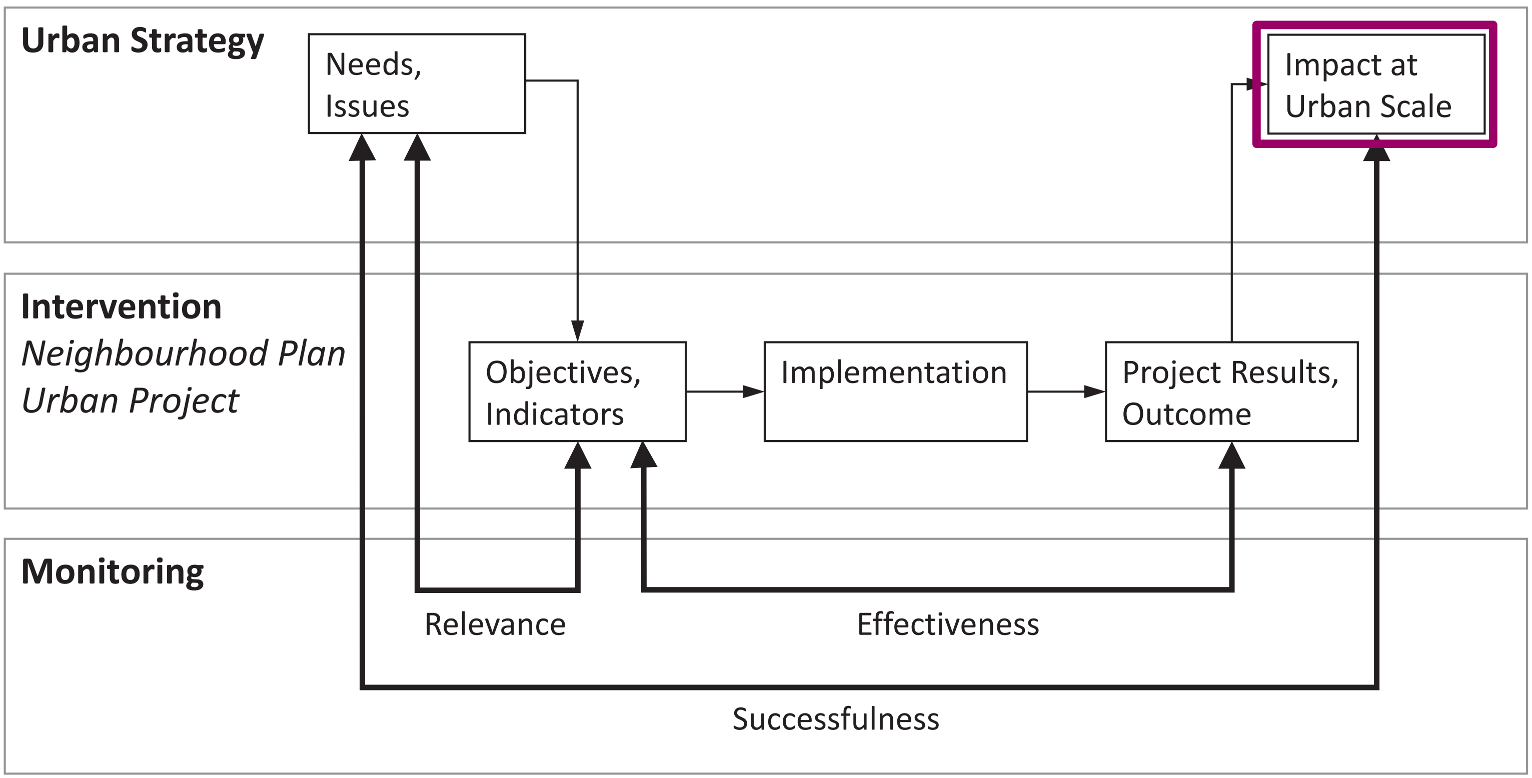
(6) Implement monitoring



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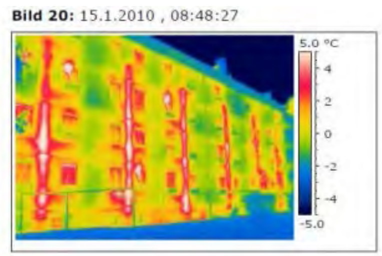
(7) Stakeholder engagement & involvement



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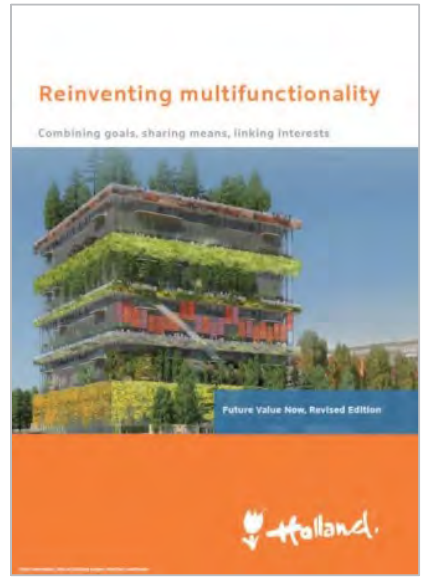
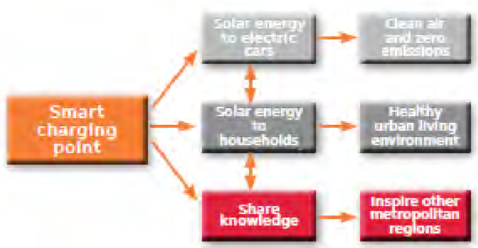
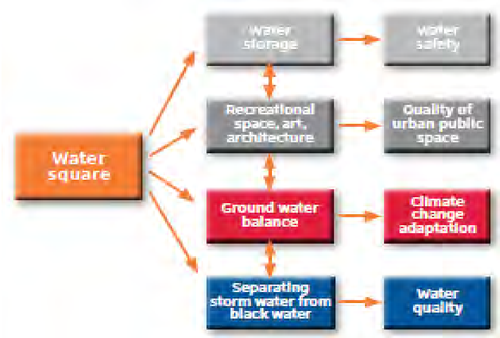
(8) Include socio-economic criteria

- Multifunctionality means crossing sectoral boundaries and making connections
- Challenges
  - Considering co-benefits in decision-making phase
  - What is the benefit – are there co-benefits? It depends on the perspective of the stakeholder!







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All criteria in practice

Renovation / modernization

Salzburg, Austria

1983

- 75 apartments
- Solid construction
- Natural gas for heat supply
- 75 parking lots

2021

- 99 apartments
- Solid construction + insulation + wood construction
- Waste heat from sewage system + pellets + PV
- 68 parking lots + mobility point

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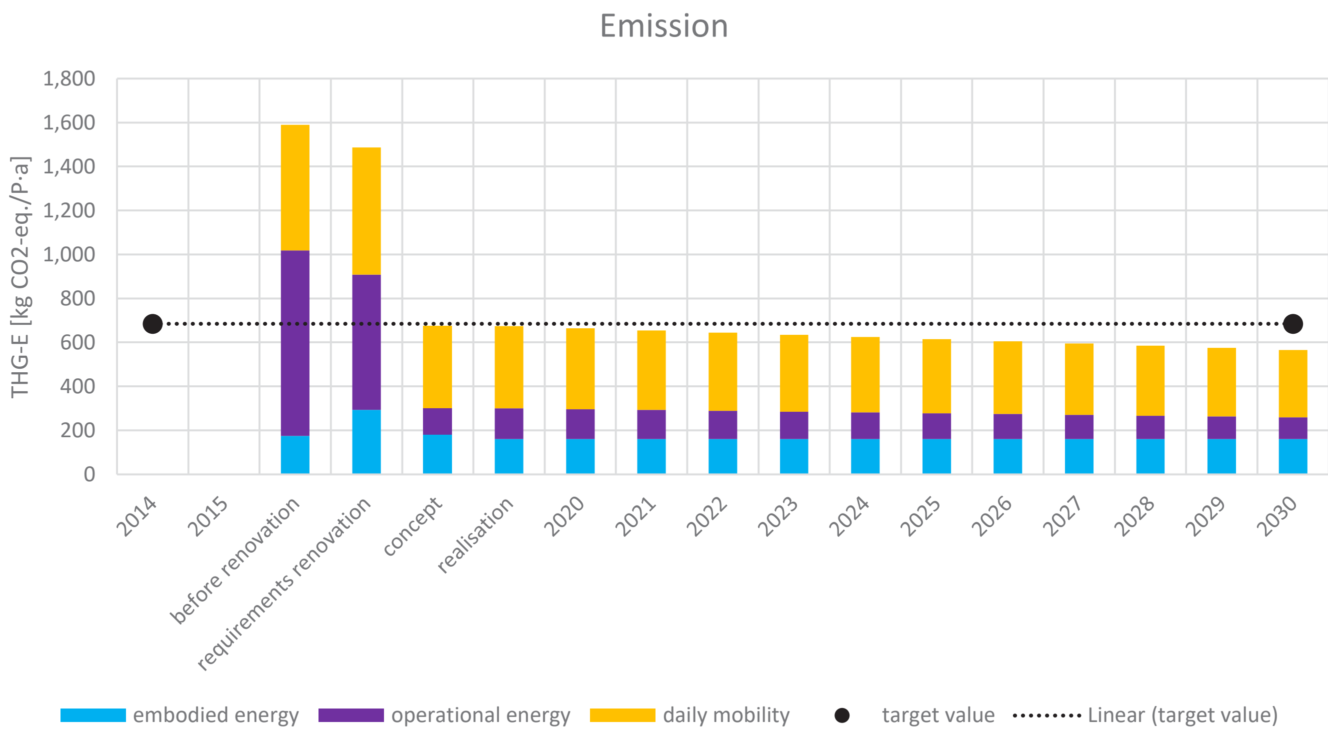
All criteria in practice



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All criteria in practice

Strategic Measures	
Set Vision and Targets	Masterplan 2025, City of Salzburg
Develop Renewable Energy Strategies	Heat map, City of Salzburg
Make Full Use of Legal Frameworks	Urban development plan: Exclusion of fossil fuels, reduction of parking lots
Design of Urban Competition Processes	klima**aktiv** performance standard "gold" for each building and the whole site
Make Use of Tools Supporting the Decision Making Process	klima**aktiv** tool for integral optimization
Implement Monitoring of Energy Consumption and GHG Emissions	Performance standard monitoring in the planning phase, after the construction phase and in the operation phase
Stakeholder Engagement & Involvement	Tenants, neighbourhood, …
Include Socio Economic Criteria	Stock increase, affordable housing, climate protection
Implement Effective and Efficient Organisational Processes	Quality agreement (housing association, city of Salzburg, SIR, …)

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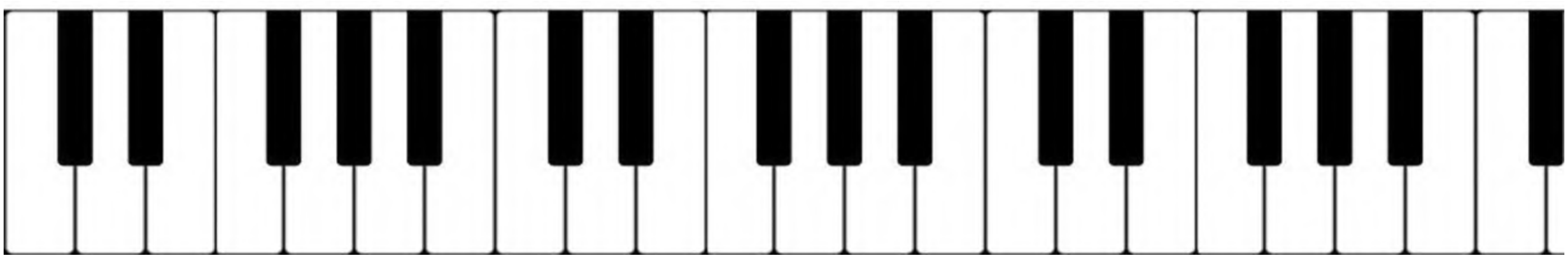
Conclusion

- Transformation of the energy system is a challenge: linking urban and energy planning
- Technologies are available – it´s about their implementation
- It is not just a technology issue - it is about the whole range of municipal policy
- A wide range of skills and knowledge is needed, as well as a "common language" for better mutual understanding



“Mobilizing the urban sustainable energy potential requires strong support from national governments to local policy makers”

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Discussion

Decarbonization of urban energy and mobility systems requires the simultaneous **coordination and consideration** of a multitude of **technological** as well as **non-technological aspects**

→ We need **dissemination and integration of existing knowledge** of the different facets of future urban energy systems and the implications of their implementation

- System integration (and sector coupling)
- Mobility (integrated transport systems)
- Scenario development for strategic planning
- Data, tools, and methods
- Spatial (energy) planning: procedures, instruments, tools
- Implementation at district scale (PED / Net Zero Districts), focus building stock
- Financing, consideration of co-benefits
- Social aspects of (energy) planning, stakeholder-involvement

Transforming buildings into great citizens of the electric power system

Steven Wong, Natural Resources Canada

IEA Future Buildings Forum Think Tank Workshop

October 2022

Natural Resources Canada   Ressources naturelles Canada

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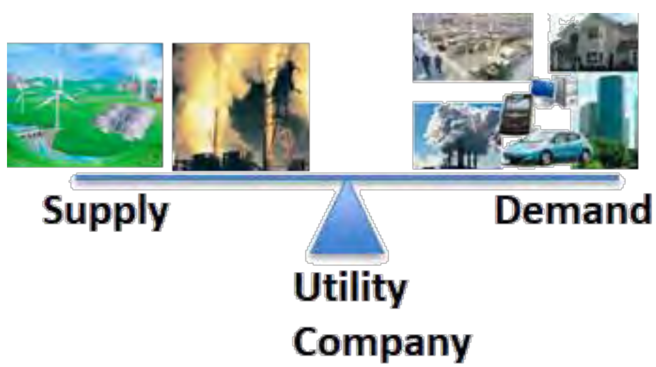
Outline

- Power System Refresher
- Challenges Facing the Power Sector
- The Grid of Tomorrow
- Flexibility and the Role of Buildings
- Illustration
- ISGAN WG 6 and 9 Activities

Power System Refresher

- Utilities **sell energy**, but are **built for power** (the lowest the utilization factor, the worst the bottom line)
- **Supply** and **demand** are instantaneously **balanced**
- Beyond being produced, the power needs to be delivered to the client and as in a chain, the **strength** of the network is **limited** by its **weakest link**
- The electricity sector is **highly regulated**



Power System Refresher

The power system now: mostly unidirectional

Challenges Facing the Power Sector

Prosumer adoption
Electrification speed and intensity
Technological progress

Lower system inertia
Distributed energy resources
Variability

Uncertainty Complexity

VUCA

Volatility Ambiguity

Variable renewable energy
Climate
Electrification

Net-zero pathways
Prosumer roles

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The Grid of Tomorrow

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Flexibility and the Role of Buildings

"The ability of a power system to reliably and cost-effectively manage the variability and uncertainty of demand and supply across all relevant timescales."

– Status of Power System Transformation: Advanced Power Plant Flexibility, International Energy Agency, Paris

Variability and uncertainty examples:

- Planned and unplanned equipment outages
- End-user demands
- Mid to long-term load growth
- Distributed energy resources/prosumers
- Variable renewable generation

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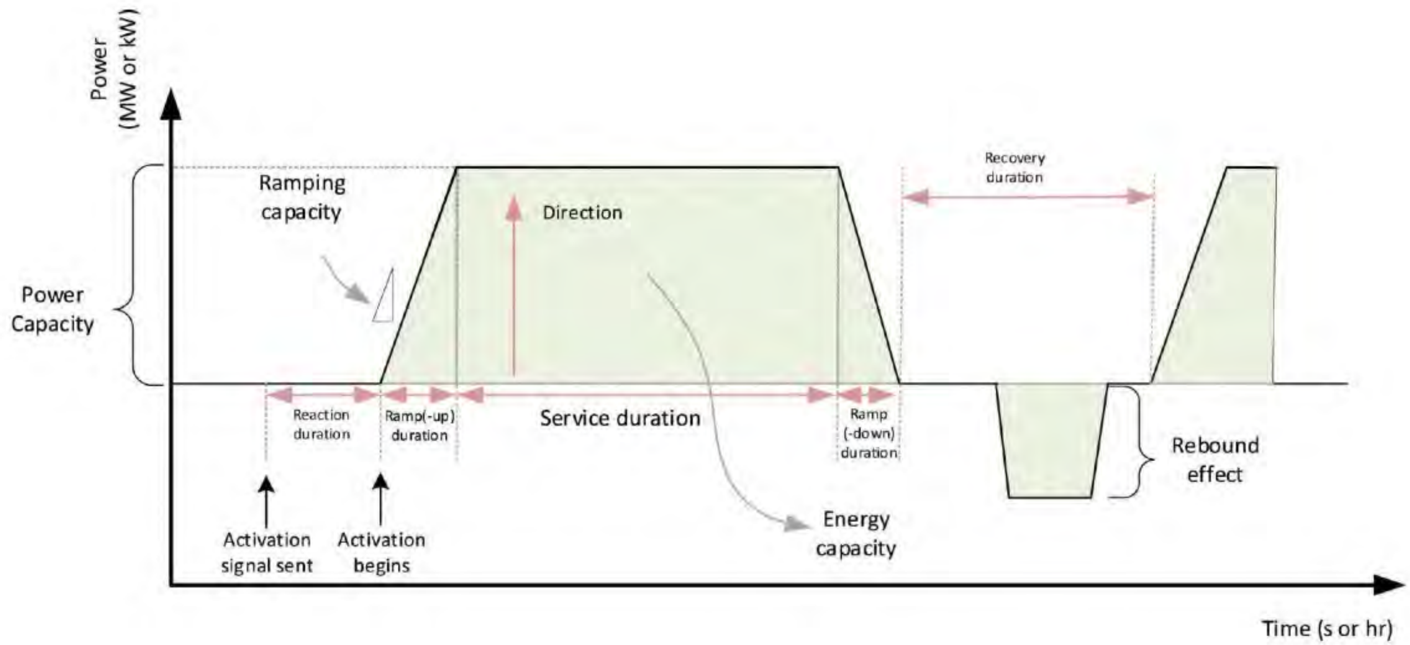
Flexibility and the Role of Buildings

- **<u>Flexibility is more than peak shaving</u>**



Degefa, Iver Bakken Sperstad, Hanne Sæle, Comprehensive classifications and characterizations of power system flexibility resources, Electric Power Systems Research, Volume 194, 2021, 107022, ISSN 0378-7796, https://doi.org/10.1016/j.epsr.2021.107022.

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Flexibility and the Role of Buildings

Benefits of Increased Flexibility

- Technical
  - Facilitates adoption of renewable energy
  - Contributes to grid reliability and resilience
  - Enables new electrification options
- Economic
  - Allows more efficient operation of grid assets
  - Provides new opportunities for prosumer/consumer engagement
  - Defers capital investments | provides non-wires alternatives

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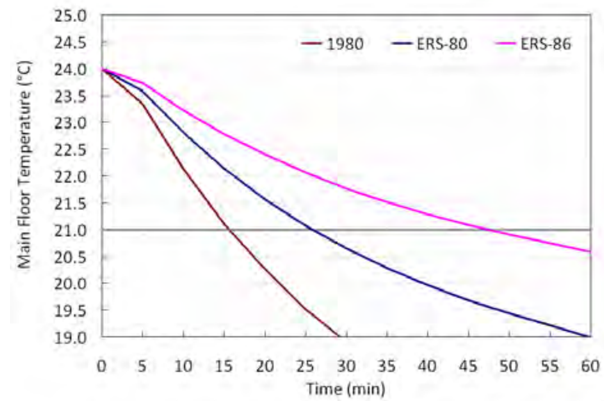
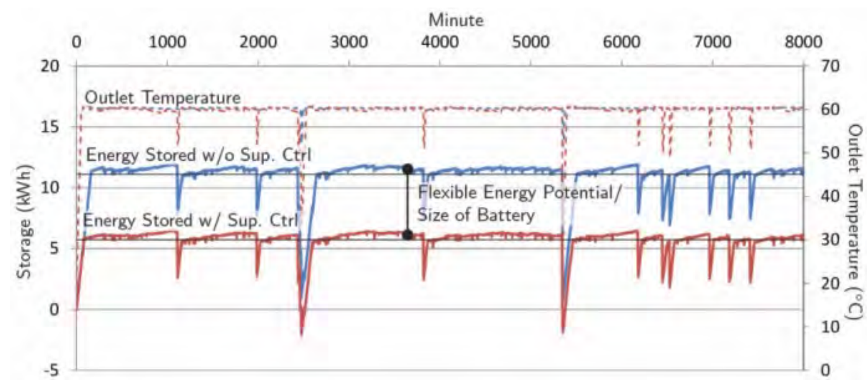
Flexibility and the Role of Buildings

Low hanging fruit

- Thermal loads with "built-in" storage
  - Electric water heaters
  - Electric thermal storage devices
- Thermal loads with some storage
  - Housing
- Other
  - Refrigerators (defrost cycle)
  - Electric vehicles



Temperature decay in various households (winter, Montreal)



Energy stored in EWH throughout the day at 60°C (blue) and 40°C (red) setpoints

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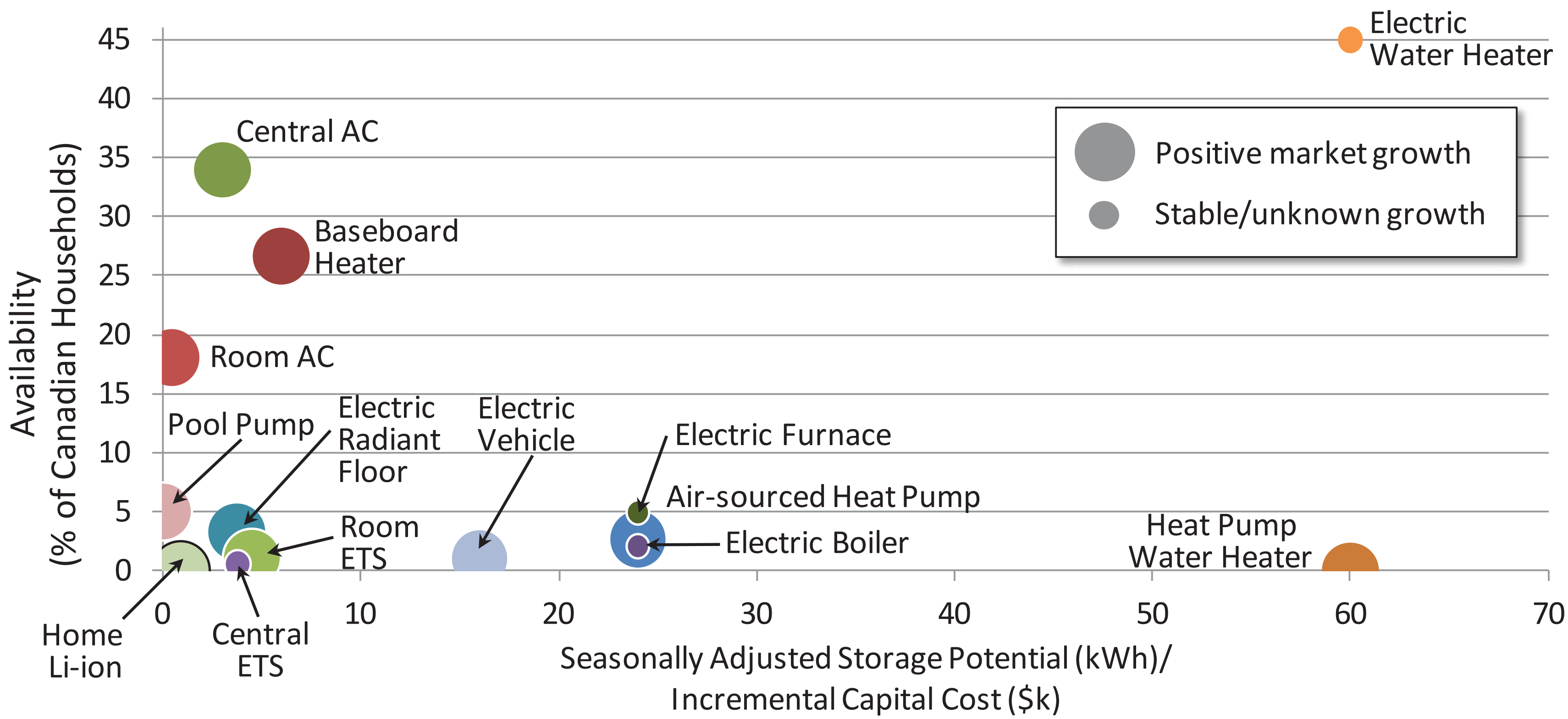
Flexibility and the Role of Buildings



Residential Load Flexibility

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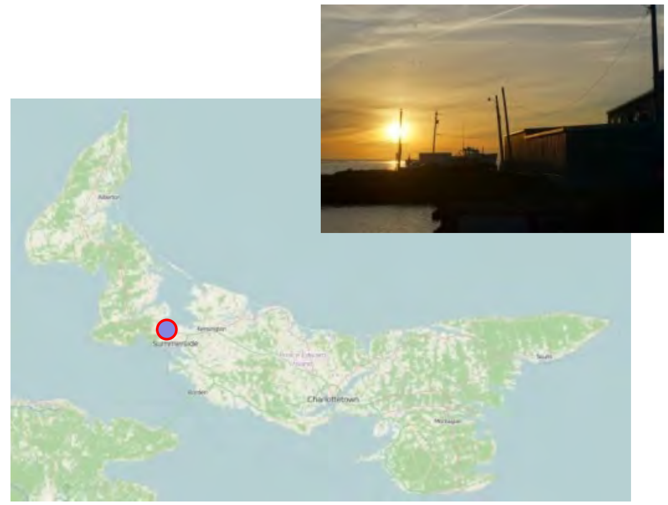
Illustration: Summerside, PE

City of 15,000 people, with city owned electric distribution utility

- Energy demographics
  - 80% residential, 15% commercial
  - Winter space heating demand
    - Two options: oil or electricity
- Power system (2018)
  - 27 MW peak, 130 GWh annual load
  - 21 MW wind (40 to 50% energy needs)
  - Interconnected with neighbouring system



City of Summerside

Prince Edward Island

Background:
S. Wong, G. Gaudet and L. P. Proulx, "Capturing Wind with Thermal Energy Storage – Summerside's Smart Grid Approach," in *IEEE Power and Energy Technology Systems Journal*, doi: 10.1109/JPETS.2017.2754139

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Illustration: Summerside, PE

- Goals
  - Reduce GHGs (increase renewables use)
  - Increase value of existing assets to community
- Method
  - Use storage to increase community *self-consumption* of renewables
    - Charge devices when excess of wind
  - Encourage fuel switching from oil to electric heating

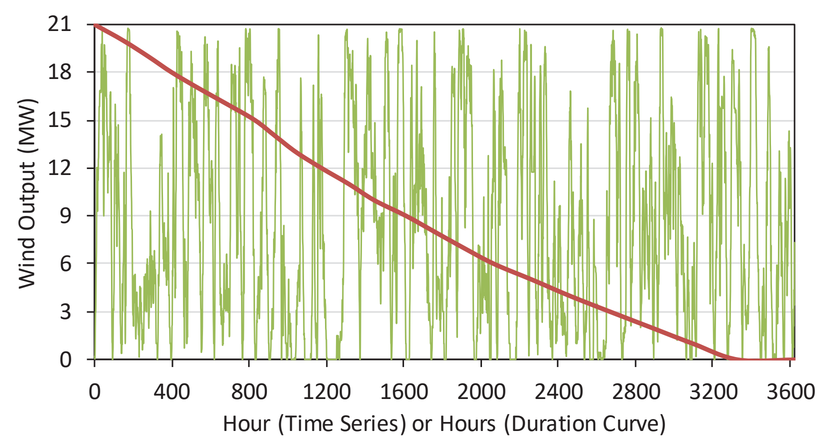

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Illustration: Summerside

Utility-side Program

- MyPowerNet
  - Communications network
    - Multipurpose fibre-optic backbone
    - Open protocol (OpenADR) for high speed control and security
  - Smart metering (AMI/R)
  - Utility SCADA system integration

Consumer-side Program

- Encourage replacement of oil-fired appliances with electric equivalent
  - Electric thermal storage (ETS) space heating units
  - High capacity/temperature electric water heaters
  - by offering discounted rates
  - Offsetting customer-borne capital costs
  - Bucket at 8¢ vs 12¢ per kWh for appliance energy demand
- Appliance load management options
  - Smart (dynamically)
  - Time-of-use

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Illustration: Summerside

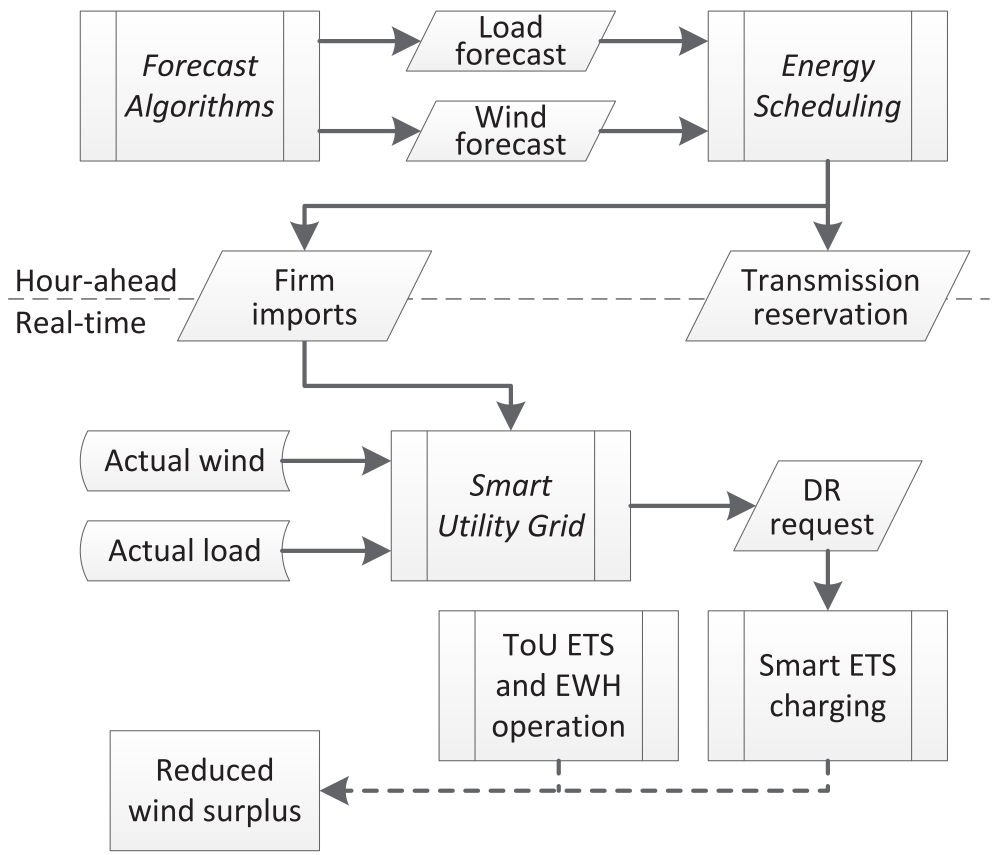

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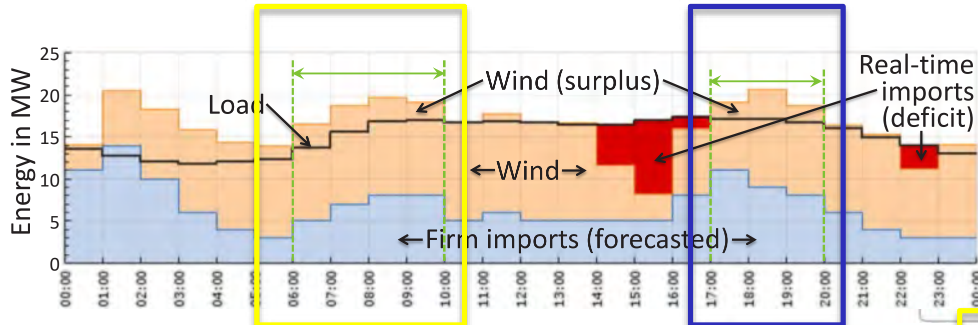
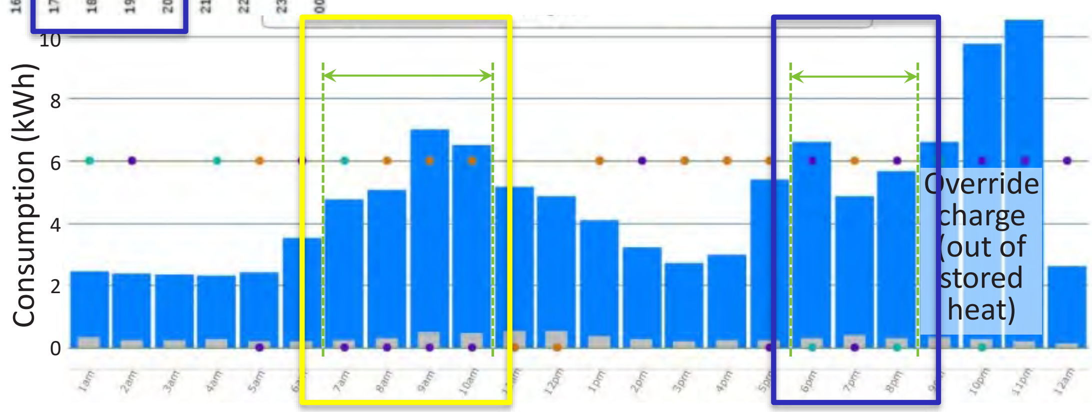
Illustration: Summerside



SSE 24 Hour Load Curve and Supply

Utility-managed thermal storage operations



Corresponding ETS charging

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A good grid citizen...

- is predictable,
- is visible,
- has flexibility over many time horizons,
- can respond to changing grid needs,
- uses grid assets to maximum potential.

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International Smart Grid Action Network

WG6: Power Transmission & Distribution Systems

- Flexibility harvesting and its impact on TSO-DSO interaction
- Network planning procedures under uncertainty
- Local energy communities

WG9: Flexibility Markets

- Flexibility Characteristics
- Consumer Focussed Flexibility
- Interoperable Markets
- Operational Planning

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Session 4

October 20th, 2022, PM

Technological Systems as Catalysts for Future Proofing Buildings

Lessons learned and future readiness

Session Coordinators

Stephan Renz

Chair, ExCo, Heat Pump Technologies TCP / Beratung Renz Consulting

Georges Zissis

4E TCP / Professor Université de Toulouse

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- Who is VEKS?
- Ongoing need to adapt 35-year-old design to today's requirements
  - Increased production capacity
  - Heat exchangers – with and without gaskets
  - Liberalization of the power market – need for Load dispatching
- VEKS Strategy 2025
- Questions

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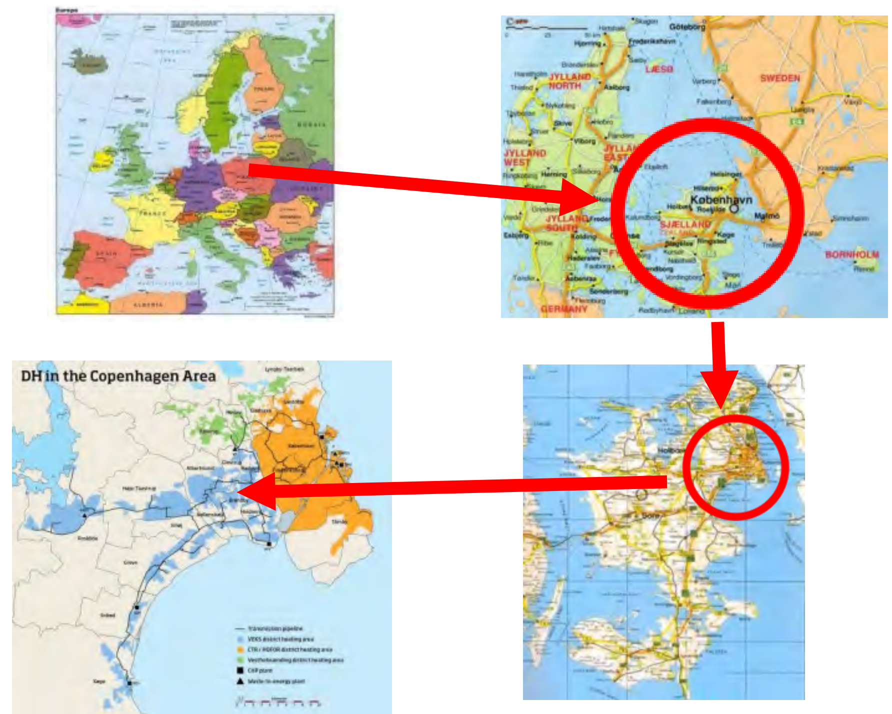
Where are we – and who is VEKS?

Vestegnens Kraftvarmeselskab I/S

- Established in 1984.
- District heating (DH) company with the purpose to utilize and distribute surplus heat from CHP plants and waste-to-energy plants.
- From 2012 involved in production, transmission and distribution of DH.
- Annual turnover: $ 200 mill.
- Round 100 employees.



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DH in Greater Copenhagen

VEKS, CTR and HOFOR

40 km

VEKS

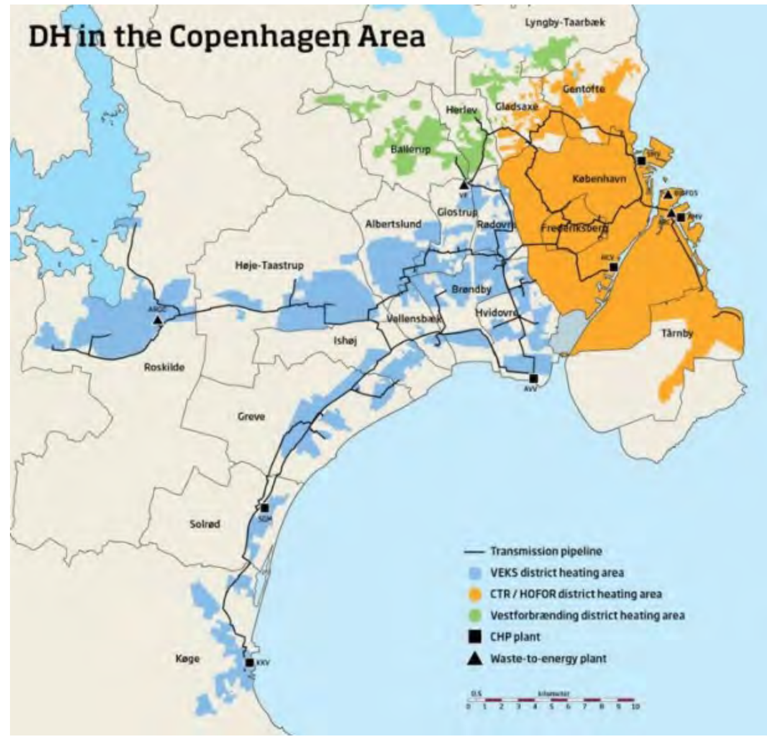
- Partnership between 12 municipalities
- 350,000 tax-payers
- 170,000 end – users
- 9,000 TJ (2,500 GWh)

DH in Greater Copenhagen

- 19 municipalities
- 4 integrated systems
- 500,000 end – users
- 34,500 TJ (9,600 GWh)

History of VEKS

1979-1982-1984-1986-1987-1990-2012-2022



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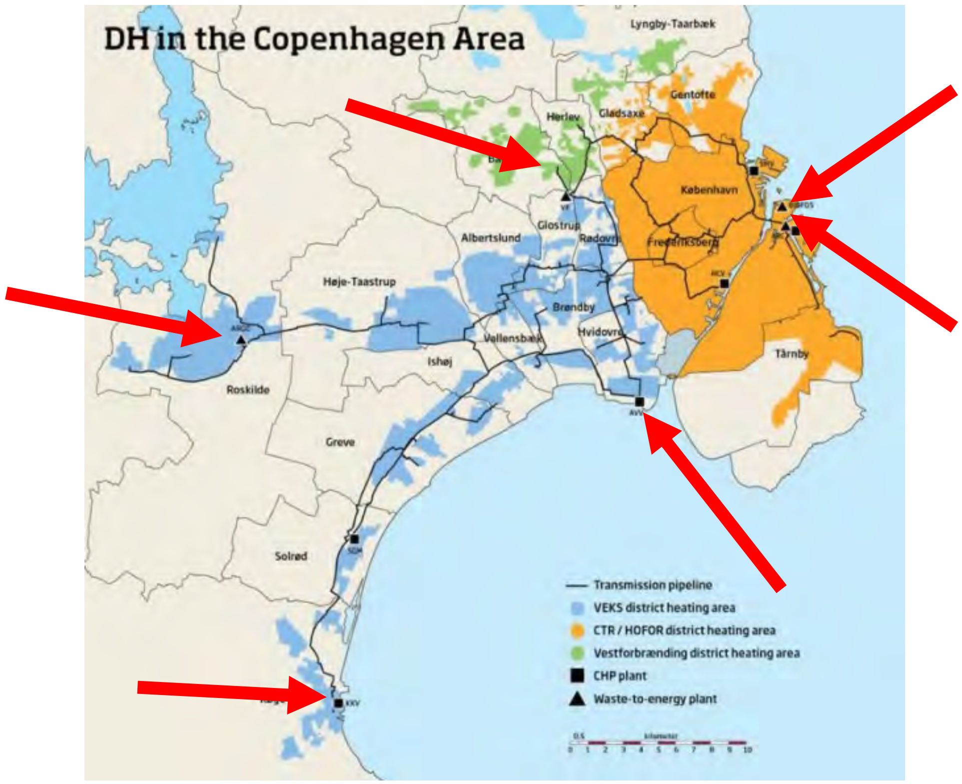
VEKS – Heat production



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Avedøre CHP Plant

Unit 1 (1990/2016) and unit 2 (2001/2014)

Unit 2 from natural gas to wood pellets

Unit 1 from coal to wood pellets

100% wood pellets - 797 MW electricity and 932 MJ/s heat

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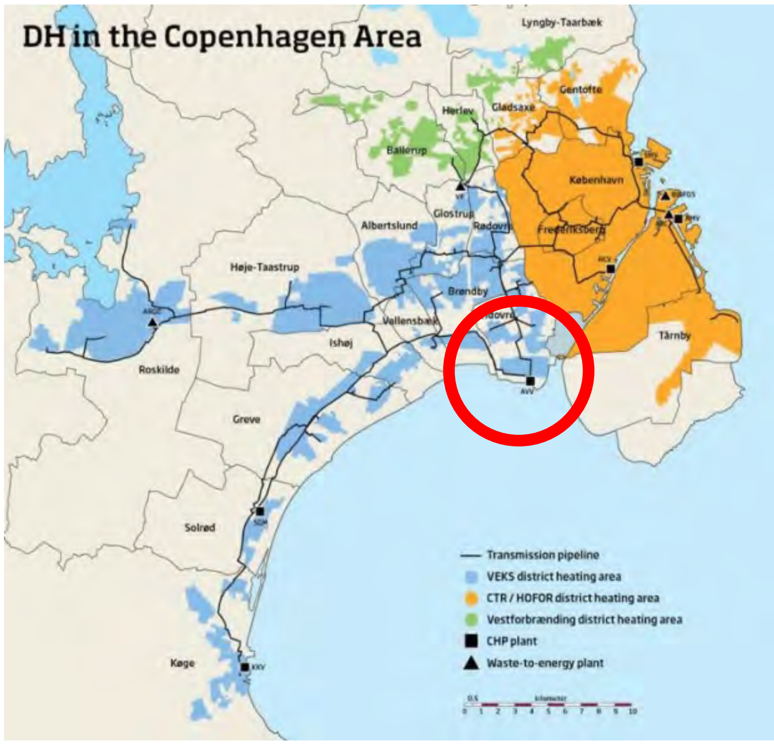
Changes in production capacity at AVV CHP



- Original capacity (1990)
  - Unit 1 - 330 MJ/s
  - Unit 2 - 330 MJ/s

660 MJ/s

- Capacity to day (2022)
  - Unit 1 - 350 MJ/s
  - Unit 2 - 480 MJ/s

830 MJ/s

- North and South pipeline each dimensioned for 330 MJ/s.

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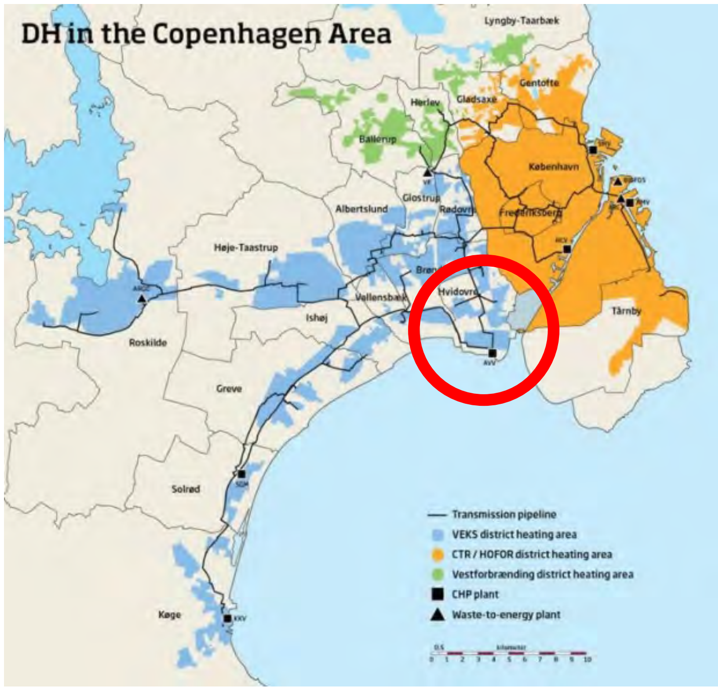
Changes in production capacity at AVV CHP



- What to do?
  - Increase the flow (m^3/s)
  - Increase T_F
  - Increase dT

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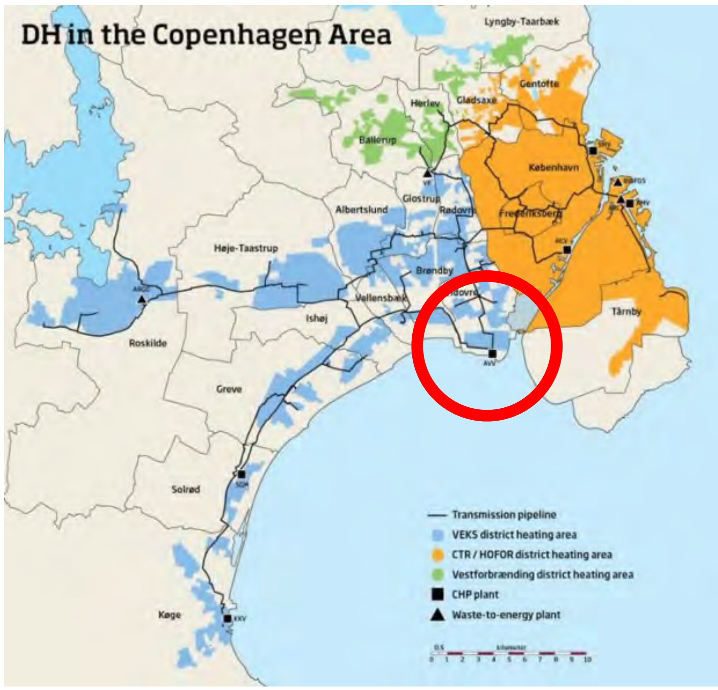
Changes in production capacity at AVV CHP



- What to do?
  - **Increase the flow (m^3/s)**
  - Increase T_F
  - Increase dT

- Increase the flow
  - Larger pumps – but…
  - Modify closing speed of valves (waterhammer) – measuring dP over valves.
  - Modify sensor pockets for temperature sensors - fatigue failures.
  - Turbulent flow at the backside of the sensor pockets led to erosions corrosion.

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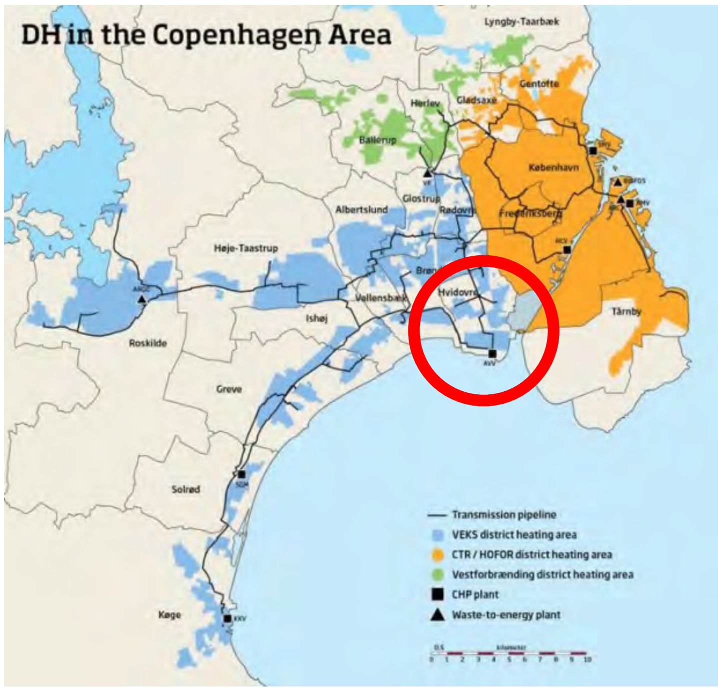
Changes in production capacity at AVV CHP



- What to do?
  - Increase the flow (m^3/s)
  - **Increase T_F**
  - Increase dT

- Increase T_F
  - Decrease the power production at CHP plants.
  - Increase the production costs as heat price is linked to T_F and T_R.
  - Increase heat losses in the pipe network.

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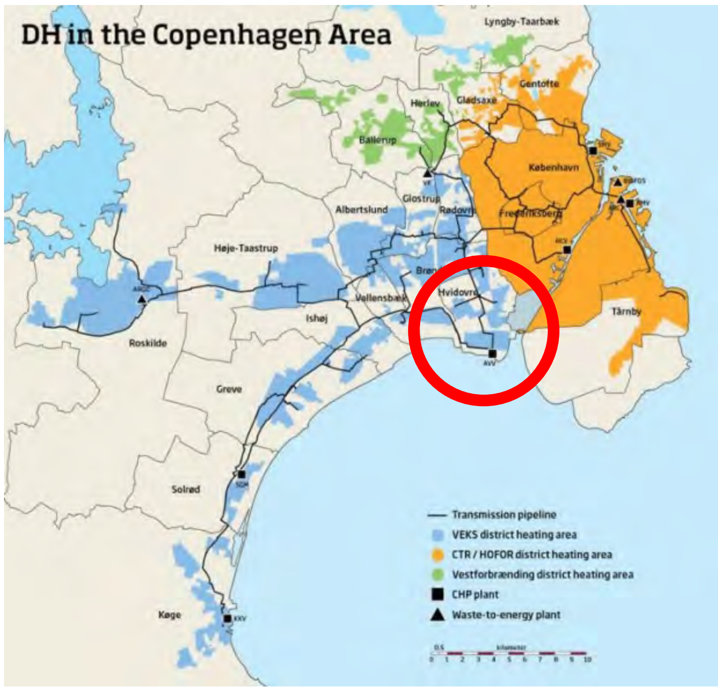
Changes in production capacity at AVV CHP



- What to do?
  - Increase the flow (m^3/s)
  - Increase T_F
  - **Increase dT**

- Increase dT
  - dT is a consequence of the cooling of the DH water done by the individual end-users in the local distribution companies and therefore in principle out of VEKS' control.
  - Introduction of incentive tariffs - T_R and dT - towards the local distribution companies.

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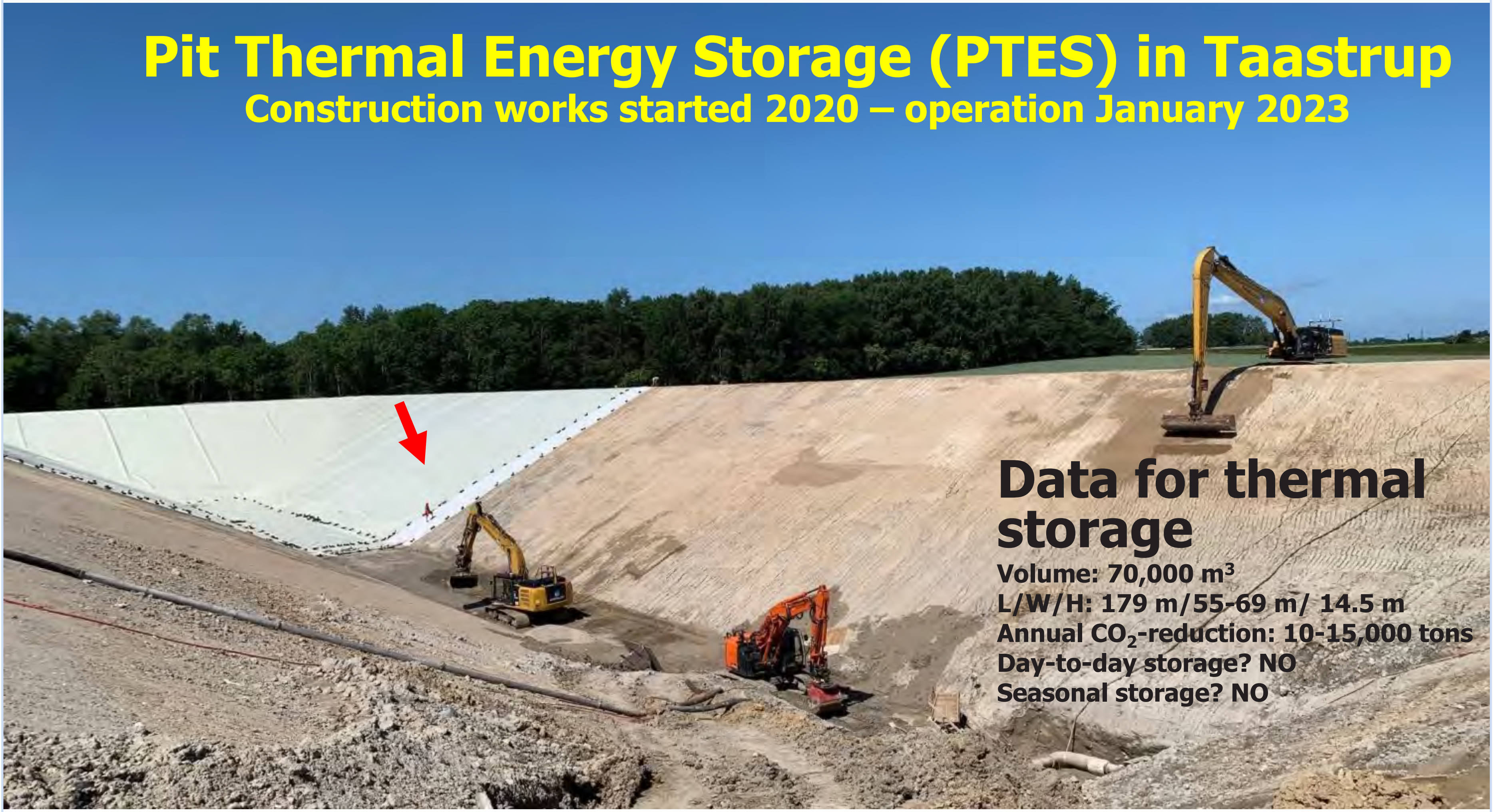
Pit Thermal Energy Storage (PTES) in Taastrup

Construction works started 2020 – operation January 2023



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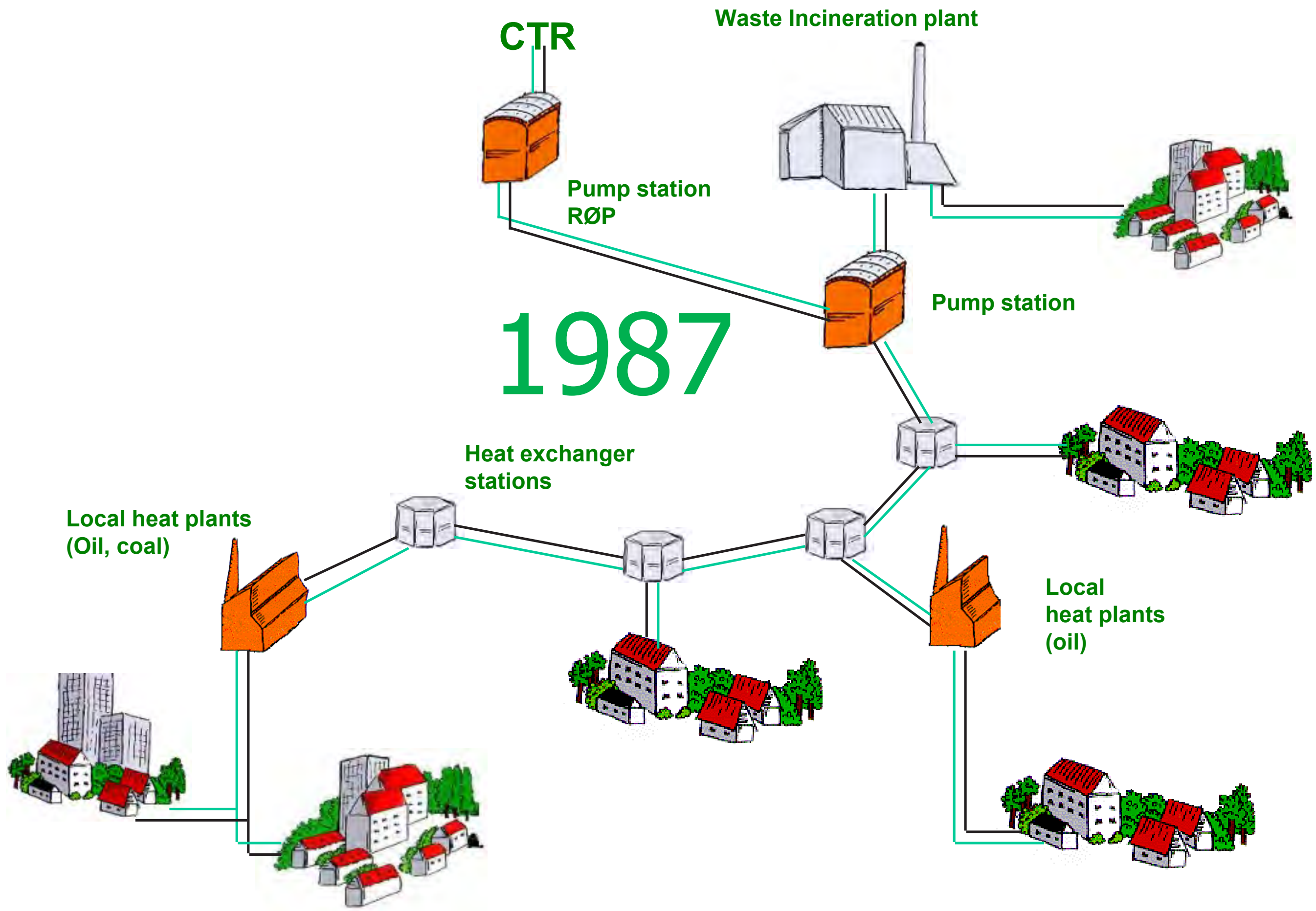
CTR
Waste Incineration plant
Pump station
RØP
Pump station
1987
Heat exchanger
stations
Local heat plants
(Oil, coal)
Local
heat plants
(oil)

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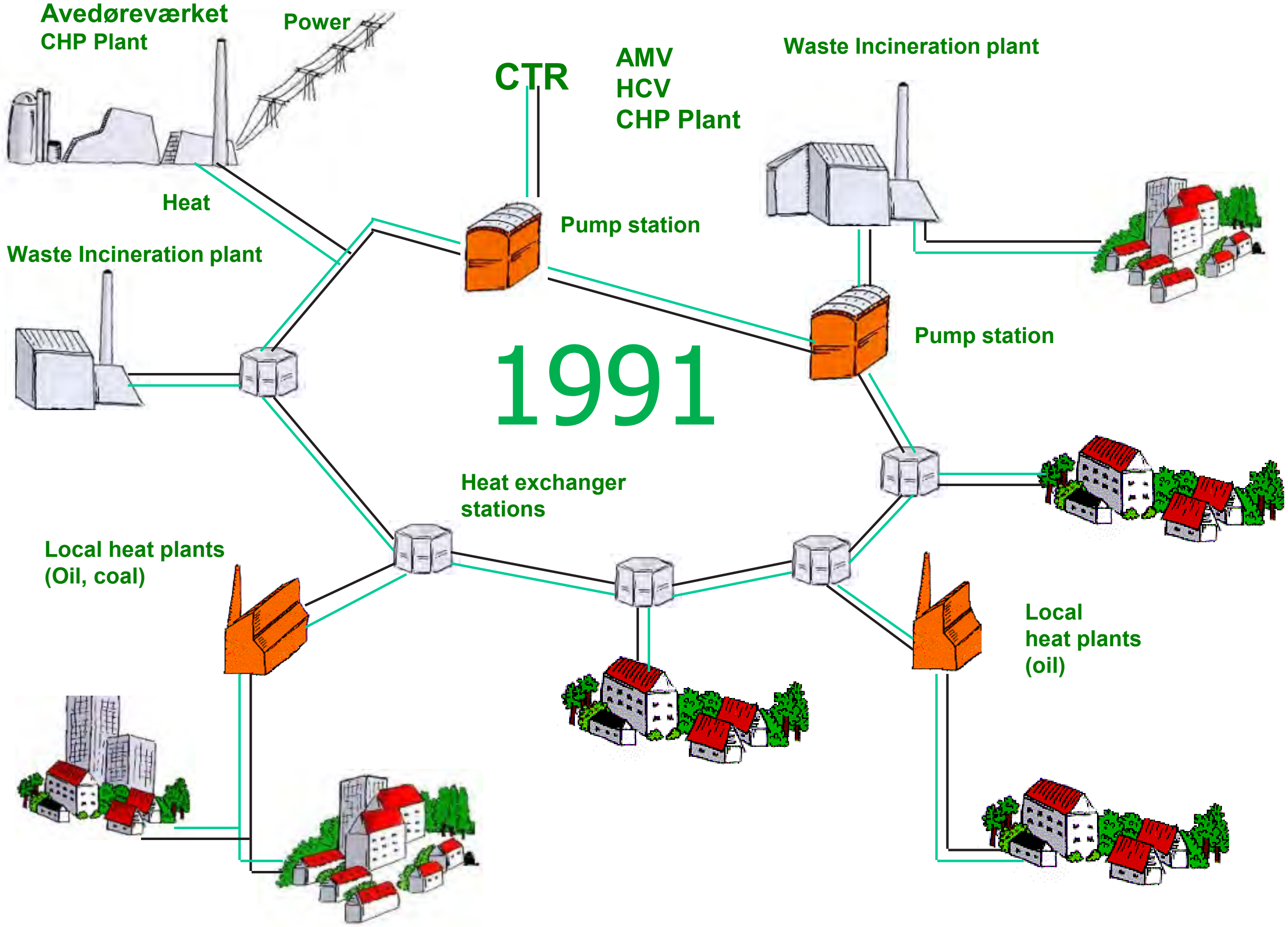

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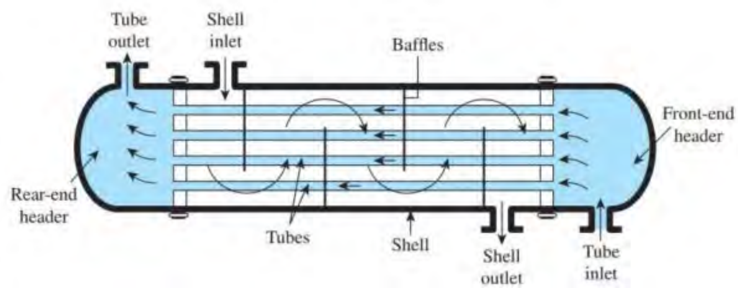
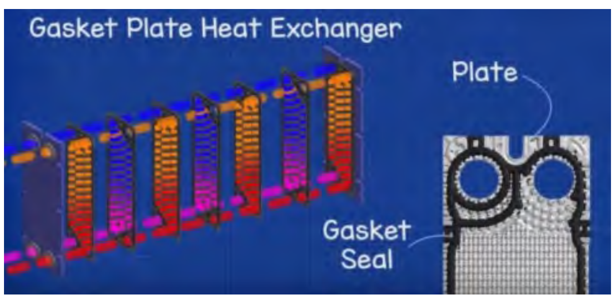
Heat exchangers

CHP Plant





Transmission/Distribution

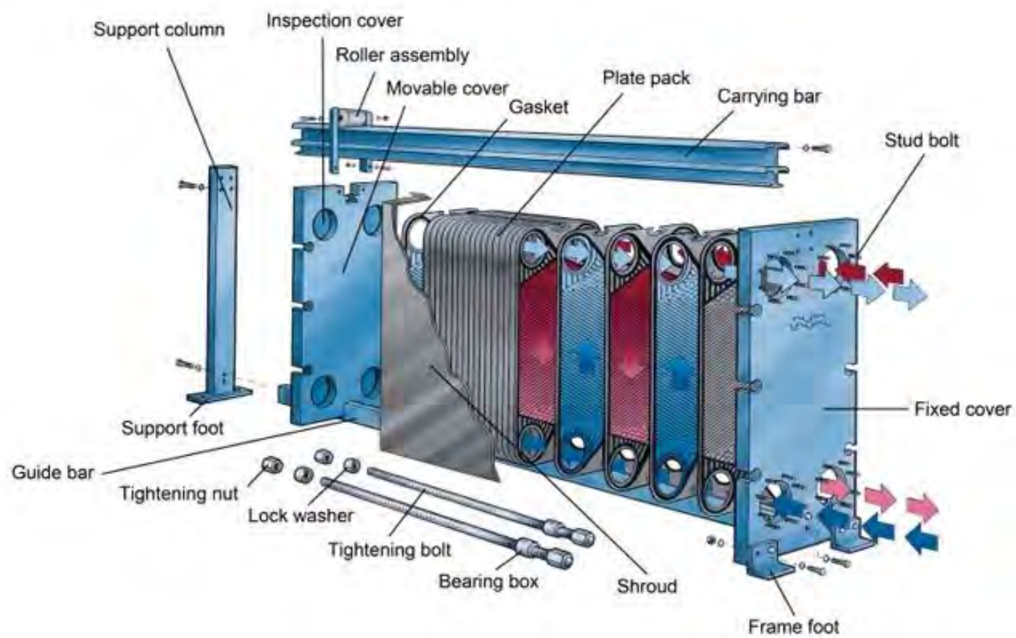


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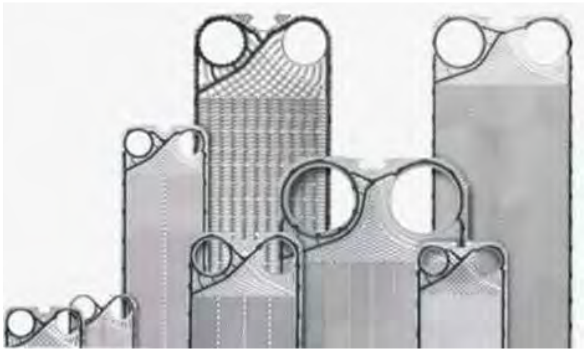
Plate Heat exchangers

Challenges of heat exchangers with gaskets

- Lifetime of rubber gasket max. 6-7 years.
- Lifetime depends on pressure and temperature gradients.



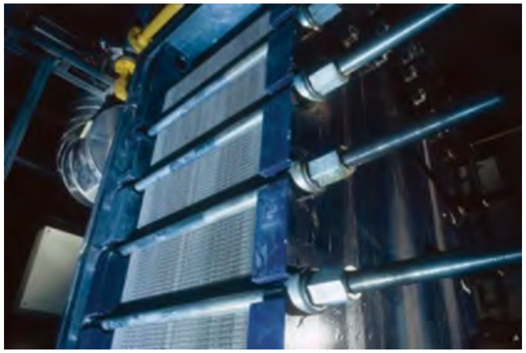


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Plate Heat Exchangers

Without gaskets (brazed)

- Absolute biggest advantages of brazed exchangers - they can't leak as a result of temperature variation. Simply because they don't contain gaskets.
- Plates are brazed together and therefore can't be opened.
- Cheaper, have a longer life-time and require no maintenance (LCC).

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Plate Heat Exchangers

Without gaskets (brazed)

- The installation itself is relatively expensive, because they are still only available as small units of a maximum of 6.5 MW.
- Properly treated water is a precondition for stable operation of the heat exchangers.
- First brazed heat exchanger introduced in VEKS system in 1993 – no problems. Actual measurements of temperature and flow on both sides of the heat exchanger compared with "virgin values" unit ensures an online picture of potential calcification – Cleaning In Place (CIP).

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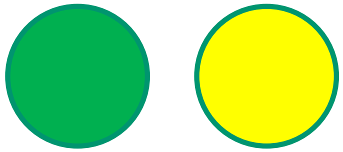
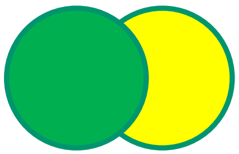
Varmelast ("Load Dispatching")

Background

- Prior to the liberalization of the power market in Denmark, there were two large producers of District Heating (DH) in the Copenhagen metropolitan area.



- The production companies had a joint load dispatching center. Back then, no confidential data were involved as they didn't need to take the liberalized power market into consideration.
- With the liberalization of the power market in the year 2000, the producers merged so that there was only one big producer of DH in the Copenhagen metropolitan area which handled the load dispatching of all the plants itself.



Varmelast ("Load Dispatching")

Background

- In 2006, Amager CHP Plant was sold off to the Swedish Vattenfall. Out of consideration for the competitive situation of the power market between Ørsted (formerly named DONG) and Vattenfall, the producers could no longer themselves perform the load dispatching for the heating and power production in the Copenhagen metropolitan area.

- Consequently, it was necessary to find a new solution to ensure the economic optimization of the production across the plants with different owners – "Varmelast".

Varmelast (Load Dispatching)

Background

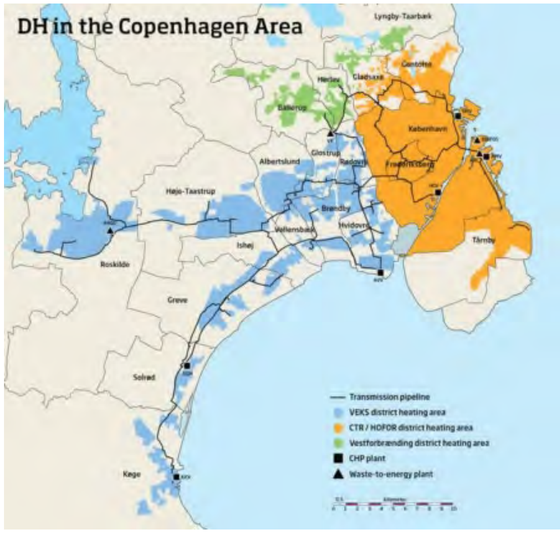
- Since 7 January 2008, Varmelast has handled the total load dispatching of the Copenhagen metropolitan area. In brief, the load dispatching is an economic optimization of heat production on an hourly basis in proportion to the production costs and prices on the power market.

Varmelast (Load Dispatching)

Background

- Heat Supply to 500,000 households.

- Varmelast schedules the heat production in the connected DH systems of the total Copenhagen metropolitan area. The DH system constitutes the largest connected DH system of Northern Europe.



- Varmelast is a cooperation between the three DH companies CTR, VEKS and HOFOR.

- Overall, Varmelast orders 32-34 PJ heat annually at a value of DKK 4.5 billion ($600 million).

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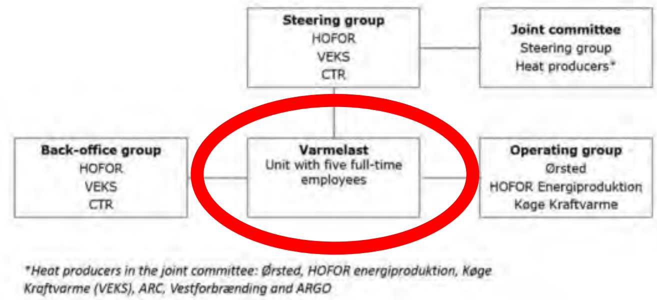
Varmelast (Load Dispatching)

Daily work

- Varmelast is manned by a total of five employees from the three DH companies CTR, HOFOR and VEKS.

- Varmelast unit always make the day-ahead planning, whereas the intraday heat plans in the evening and at night are usually made by the heating companies' control room (manned 24 hours) based on the modelling tools of the Varmelast unit.

- The control rooms of VEKS and CTR have the final responsibility for the reliability of heat supply to all customers and can turn on the peak load units in critical situations.



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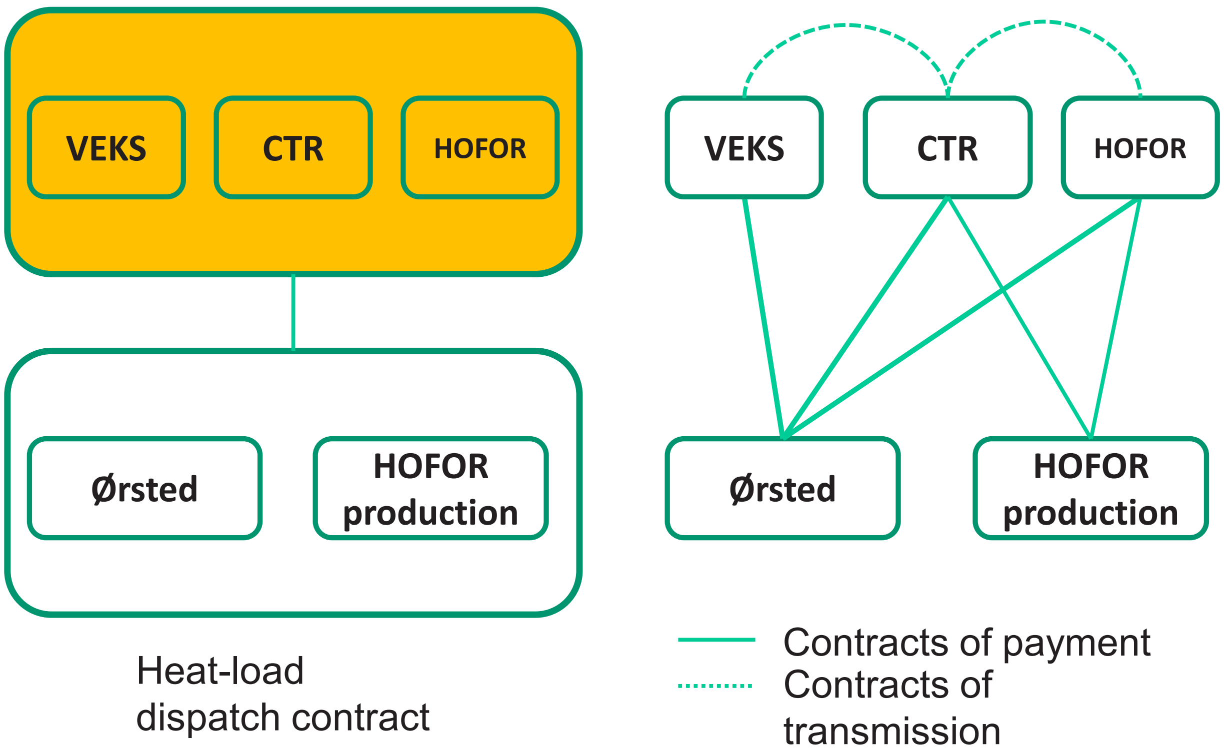
Contractual structure



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Varmelast (Load Dispatching)

Daily heat production plans

- Central assignments is to prepare the heat production plan (heat plan) for the coming 59 hours based on prognoses for heat demand from the DH companies.

- The producers offer heat production to Varmelast - cost of heat is dependent on:
  - Fuel prices
  - Capacities and efficiency of the plants
  - Variable operating and servicing expenditures
  - Energy and CO_2 taxes on the heat production
  - CO_2 quota costs
  - Forecasts for incomes from the power market
  - The production subsidy for biomass-based power production

- In most hours, heat from CHP plants is less expensive than the heat from heat only boilers – except in case of very low power prices.

- The production of DH based on sustainable biomass receives a subsidy for biomass-based power production and is exempt from energy and CO_2 taxes and does not involve use of CO_2 quotas, lowering the cost of the heat.

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Example of preliminary heat plan - one producer

Warm spring day

	AVV1 Water	AVV2 Water	HCV7 Water	HCV7 Steam	HCV8 Steam	HCV21 Steam	SMV7 Water	SMV7 Steam	SMV21 Steam
	MJS	MJS	MJS	MJS	MJS	MJS	MJS	MJS	MJS
09-05-2012 01:00	60	122,8	0	0	36,4	0	0	0	25
09-05-2012 02:00	60	122,9	0	0	36,1	0	0	0	25
09-05-2012 03:00	60	122,8	0	0	35,7	0	0	0	25
09-05-2012 04:00	60	122,9	0	0	36,1	0	0	0	25
09-05-2012 05:00	60	139,1	0	0	36,9	0	0	0	25
09-05-2012 06:00	60	229,1	0	0	38	0	0	0	25
09-05-2012 07:00	60	274,4	0	0	38,6	0	0	0	25
09-05-2012 08:00	60	274,4	0	0	38,7	0	0	0	25
09-05-2012 09:00	60	274,4	0	0	37,3	0	0	0	25
09-05-2012 10:00	60	274,4	0	0	35,3	0	0	0	25
09-05-2012 11:00	60	274,4	0	0	32,6	0	0	0	25
09-05-2012 12:00	60	274,4	0	0	32	0	0	0	25
09-05-2012 13:00	60	274,4	0	0	31,9	0	0	0	25
09-05-2012 14:00	60	274,4	0	0	30,7	0	0	0	25
09-05-2012 15:00	60	274,4	0	0	31	0	0	0	25
09-05-2012 16:00	60	274,4	0	0	30,9	0	0	0	25
09-05-2012 17:00	60	274,4	0	0	30,8	0	0	0	25
09-05-2012 18:00	60	274,4	0	0	31	0	0	0	25
09-05-2012 19:00	60	274,4	0	0	31,7	0	0	0	25
09-05-2012 20:00	60	220,4	0	0	33	0	0	0	25
09-05-2012 21:00	60	130,4	0	0	34,1	0	0	0	25
09-05-2012 22:00	60	130,4	0	0	27,8	0	0	0	31,8
09-05-2012 23:00	60	80	0	0	27,8	0	0	0	32,4
10-05-2012 00:00	60	80	0	0	27,8	0	0	0	31,2

Not actual data

The heat plan to the left shows how the producer would have liked to produce the required amount of heat, this day.

In another file would be marginal costs for making changes to this plan in the event that hydraulic bottlenecks would require us to change something.

In yet another file would be maximum capacities, telling us how much we can increase production on each unit.

The heat planning procedure, including scheduled intraday adjustments, requires 75 different files to be sent between participants - every day.

Contents of the files include prices, capacities, forecasts and more exotic stuff like options for buying out of required deliveries in case of negative power prices.

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Varmelast (Load Dispatching)

Day ahead Plan and Intra-day planning

Day ahead plan

Which units are going to produce during which hours of the coming day

VARMELAST
PRODUCERS

7.45am Heat demand forecast
8.30 Heat bid curve
9.00 Heat order
9.30 Preliminary heatplan
10.00 Final heatplan

Intraday-plan

Which adjustments are needed during the day

VARMELAST
PRODUCERS

3.00am Updated data
3.45 Updated plan
7.00 Updated data
7.45 Updated plan
3.00pm Updated data
3.45pm Updated plan
7.00pm Updated data
7.45pm Updated plan
11.00pm Updated data
11.45pm Updated plan

The supply round for heat production of the next 48 hours starts before 8:30 am, where the heat demand forecasts for the next 48 hours is sent to Ørsted and HOFOR Energy Production. At the same time, the waste-to-energy companies report their expected heat production for the next 48 hours.

After this, Varmelast receives the supply curves for the heat production for the next 48 hours from respectively Ørsted and HOFOR Energy Production. Varmelast will then calculate the least costly way to get the heat demand covered after which the optimum quantity of heat production is ordered from each of the large producers.

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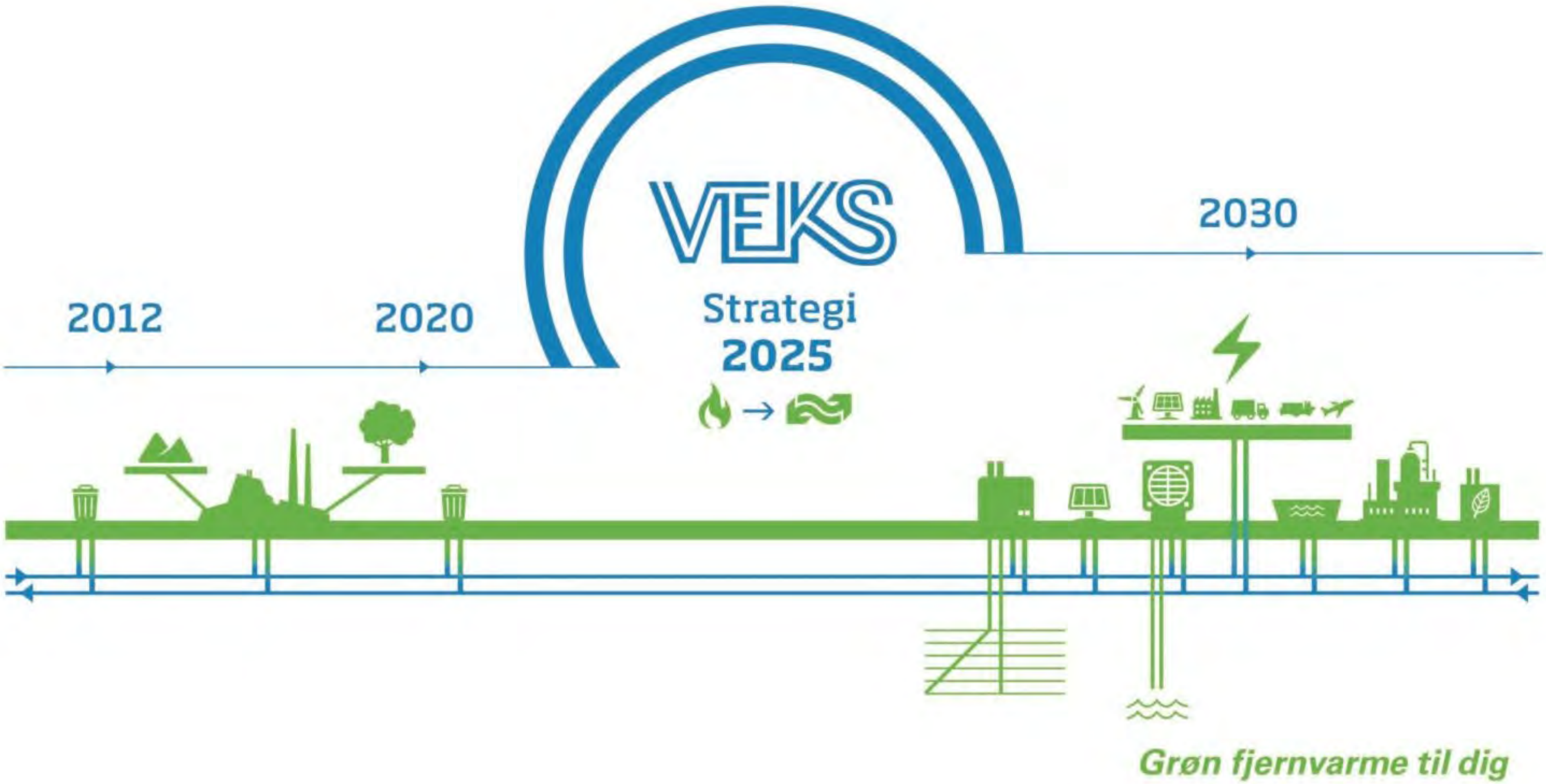

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Thank you

Further information:

www.veks.dk

lg@veks.dk

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Data and its use in performance monitoring and operation of buildings

IEA Future Buildings Forum Think Tank Workshop - October 2022

Dr Stephen White, CSIRO, Australia

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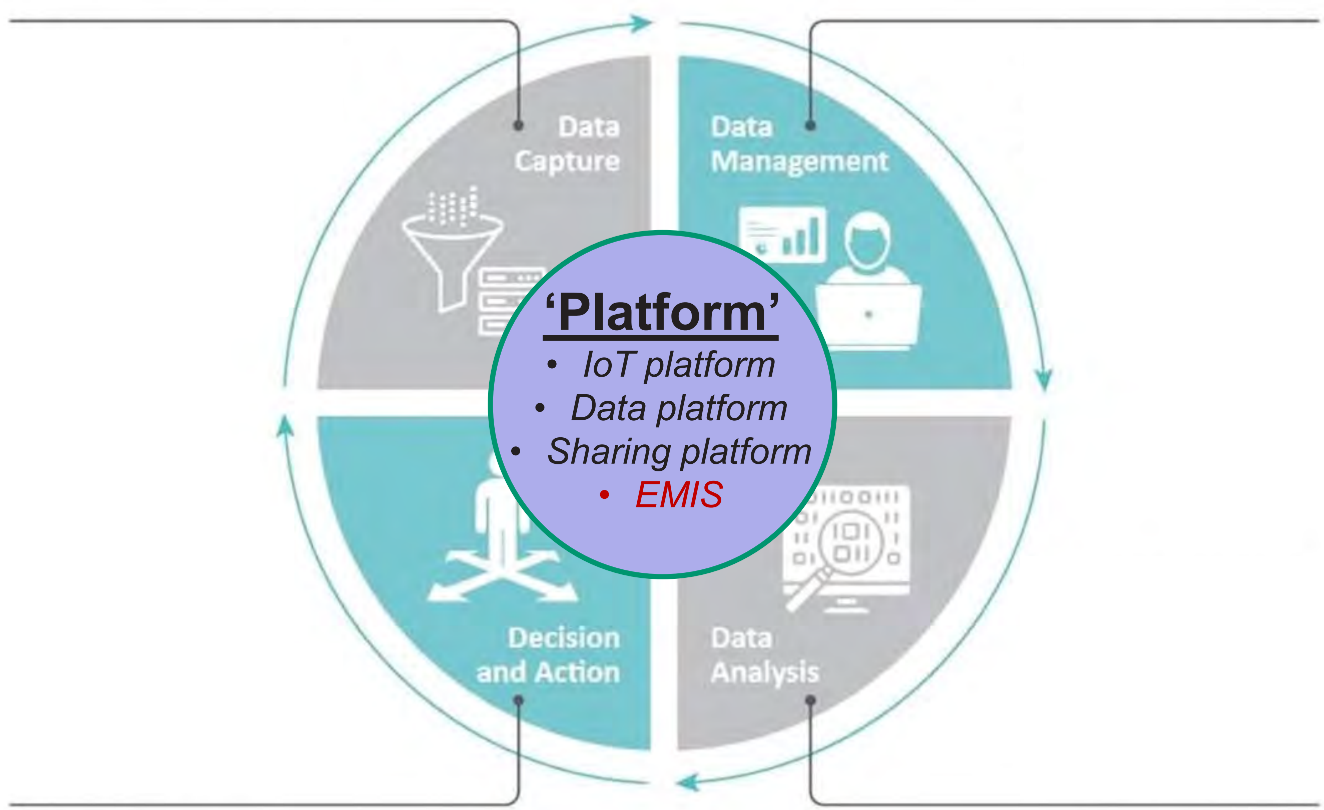
Data to Decisions:
Digitalization Technology



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Indicative platform functions

(Example of a DER flexibility management platform (DSO))

Coordination	Coordinating platform tasks Facilitating data flows Harmonisation of standards and principles Alignment with external platforms and markets Conflict avoidance
Flexibility Procurement	Attracting flexibility providers and purchasers to the market Communicating requirements and availability Matching providers and purchasers
Dispatch and Control	Sending signals to dispatch assets Notification of asset dispatch Verification of asset dispatch
Platform Transaction Settlement	Verification of service against transaction Settlement of transactions
Platforms Market Services	Credit checking Asset pre-qualification
Analytics and Feedback	Network analytics, response times etc. Counterparty scoring and review Identification of market faults

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Source: Ofgem, 2019

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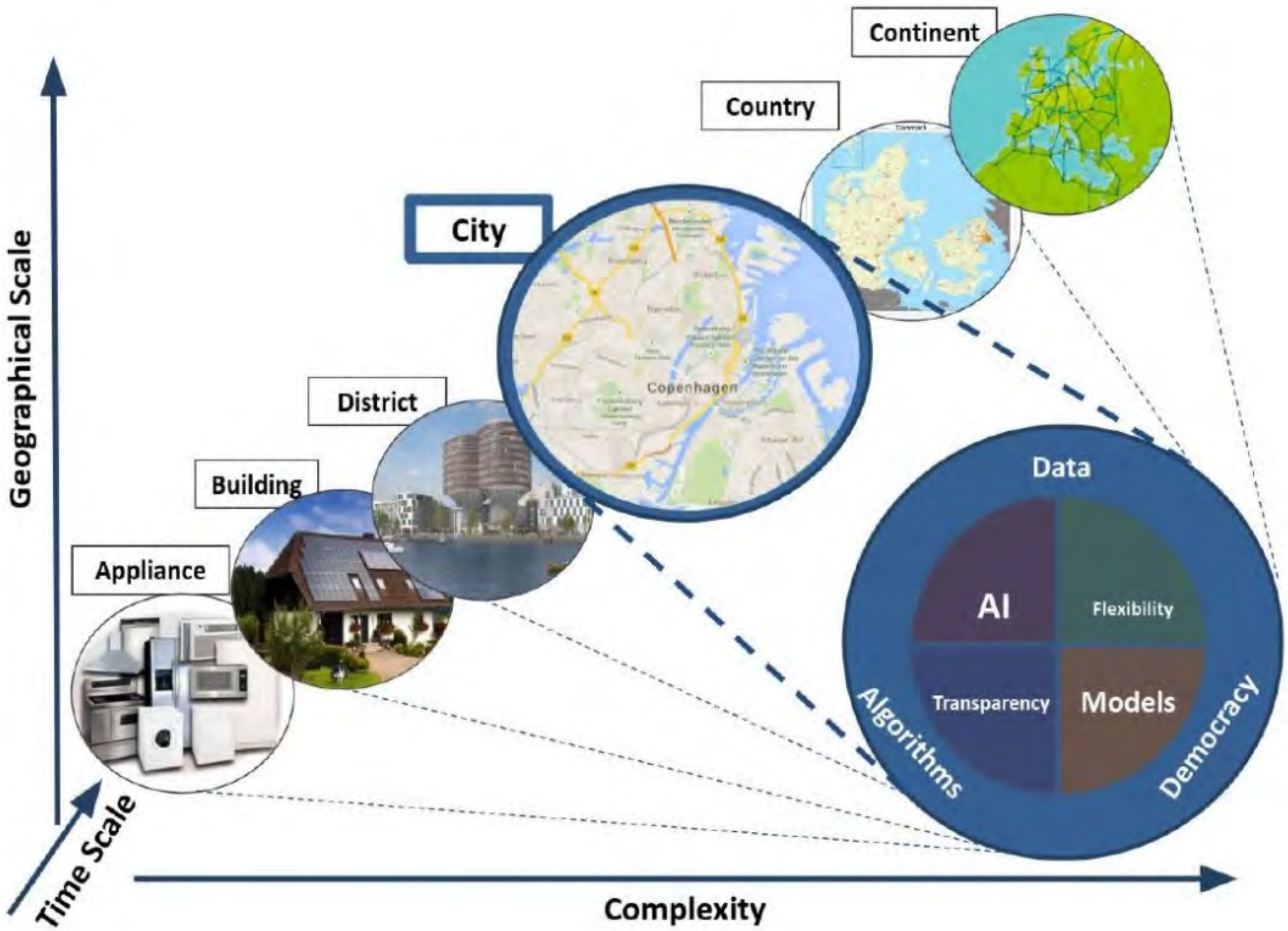
Digital key to integration



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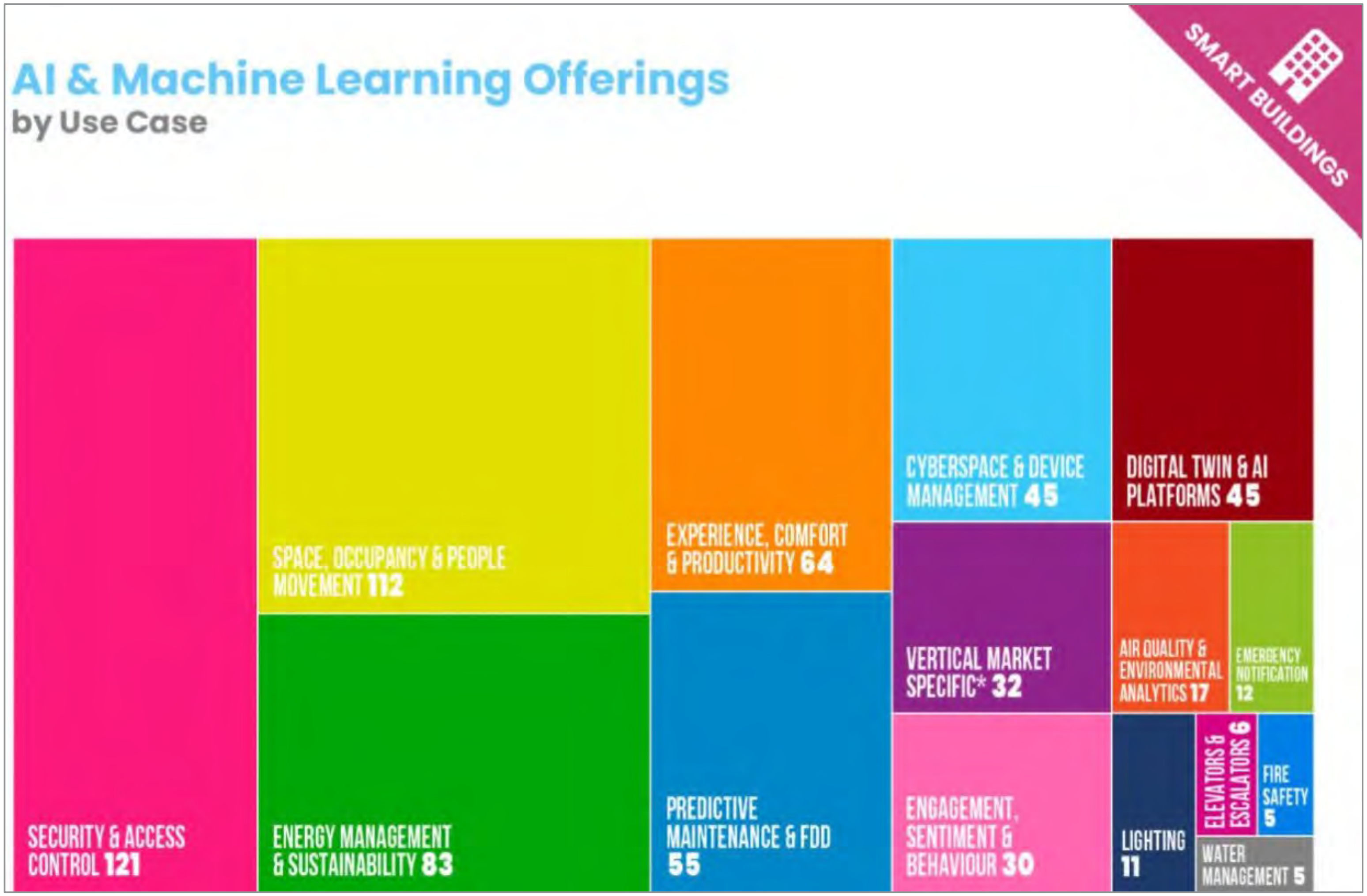
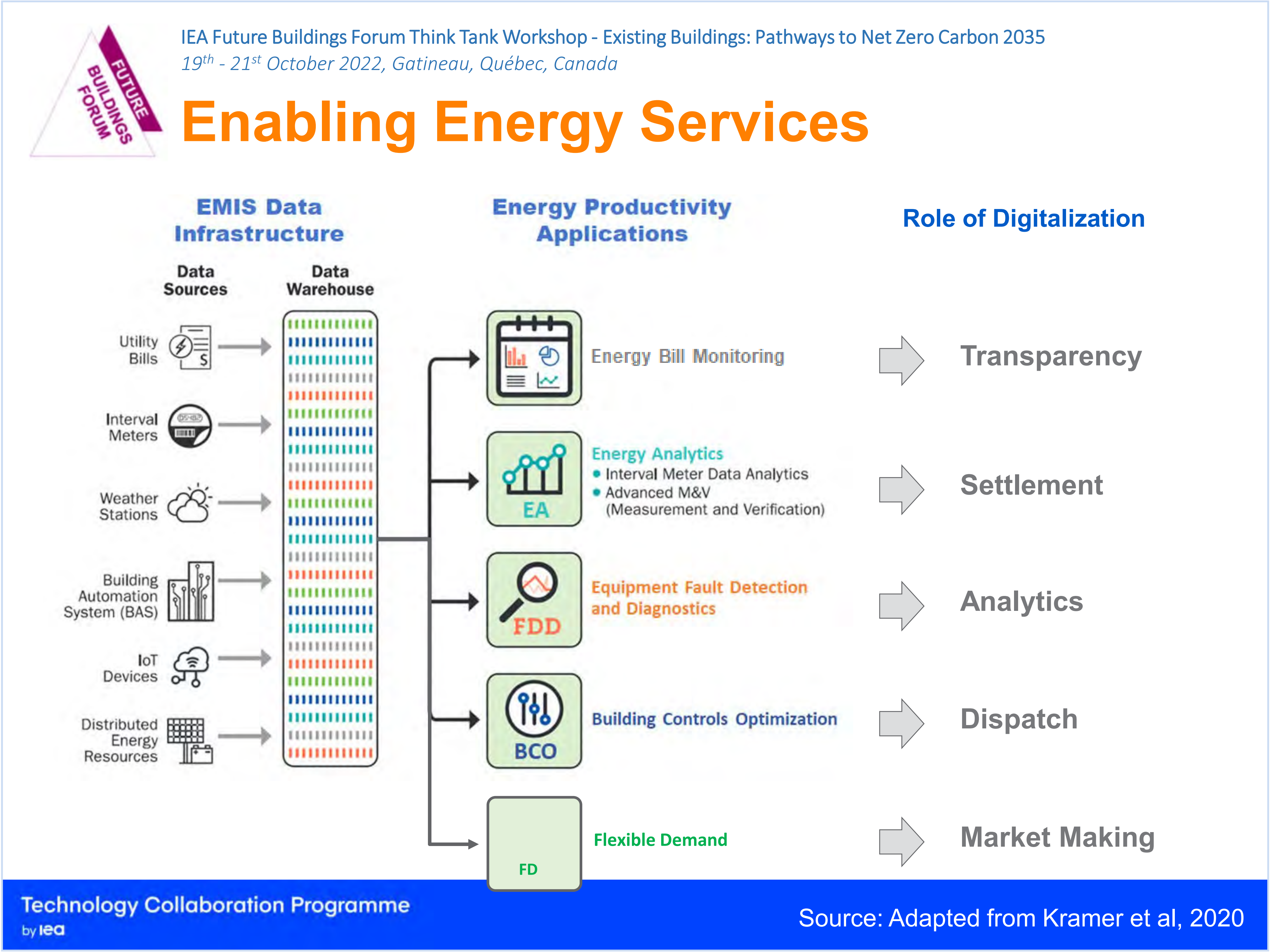
Lots of smart "Apps" are possible



Technology Collaboration Programme by iea

Source: Memoori, 2021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Enabling Energy Services
EMIS Data Infrastructure
Energy Productivity Applications
Role of Digitalization
Data Sources
Data Warehouse
Utility Bills
Interval Meters
Weather Stations
Building Automation System (BAS)
IoT Devices
Distributed Energy Resources
Energy Bill Monitoring
EA
Energy Analytics
• Interval Meter Data Analytics
• Advanced M&V (Measurement and Verification)
FDD
Equipment Fault Detection and Diagnostics
BCO
Building Controls Optimization
FD
Flexible Demand
Transparency
Settlement
Analytics
Dispatch
Market Making
Technology Collaboration Programme by iea
Source: Adapted from Kramer et al, 2020

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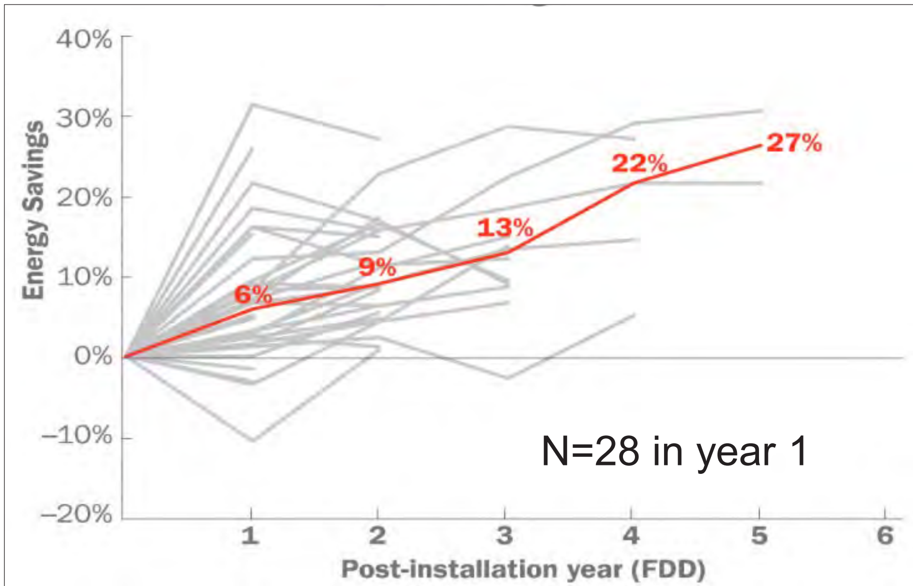
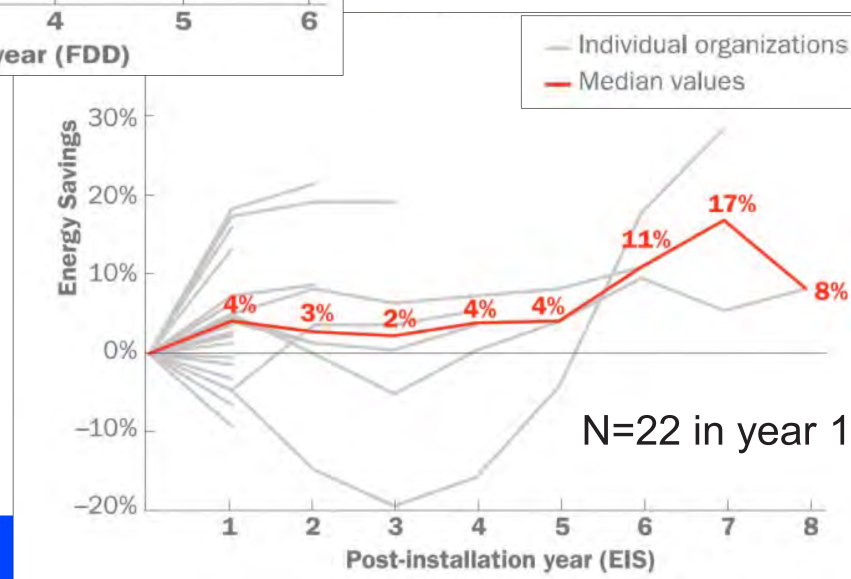
Data Analytics Outcomes

Equipment Fault Detection & Diagnosis



Source: Kramer et al, 2020



Energy Metering Analytics

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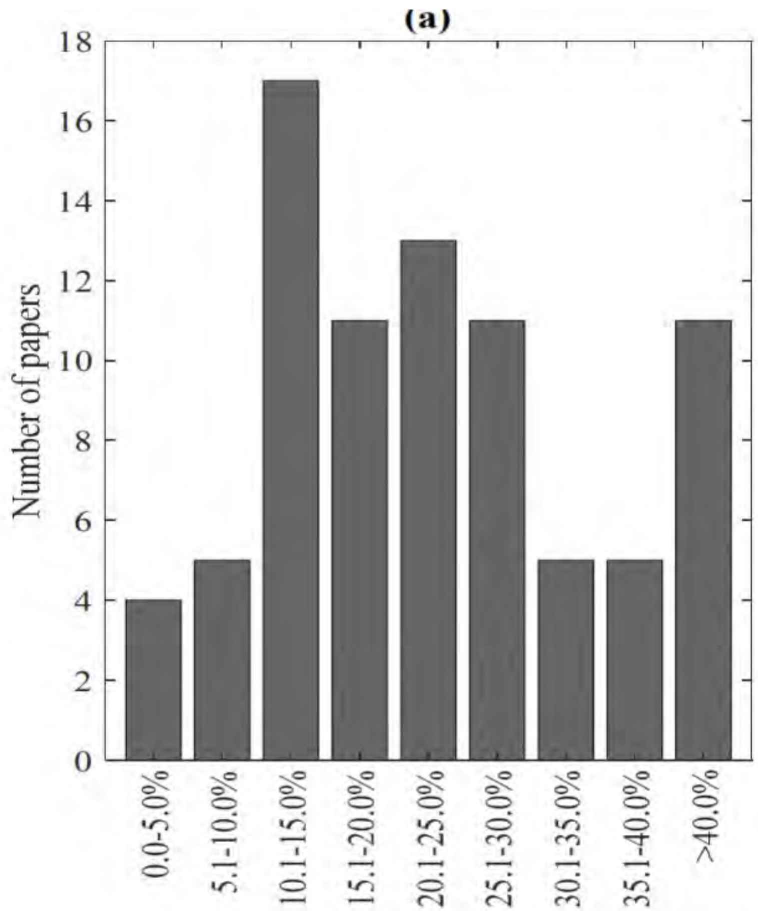
Advanced Control Outcomes



Source: Serale et. al., 2018

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Scalability of Data-Driven Approaches

Physical rules based control and analytics

In real time

Unconstrained machine-reasoning based control and analytics

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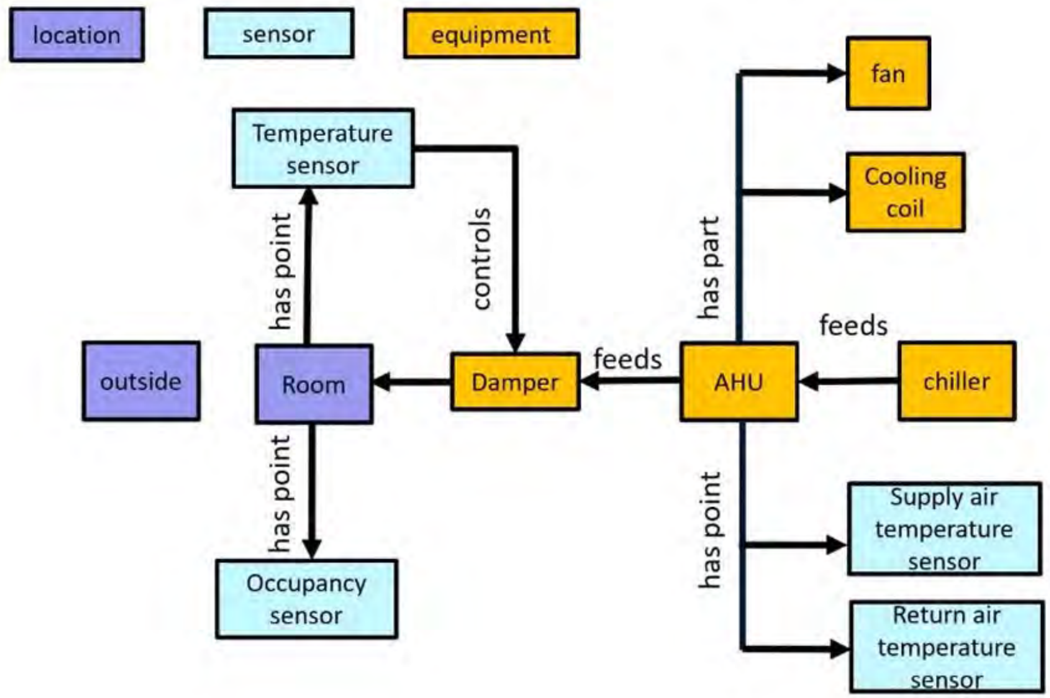
FAIR Data Infrastructure



✓ **Data re-use**

- Multiple Apps from single data collection/ management infrastructure

✓ **Low/no customisation software**

- Self service (low/no human intervention)

✓ **Interface to the web**

- New data sources/ novel Apps

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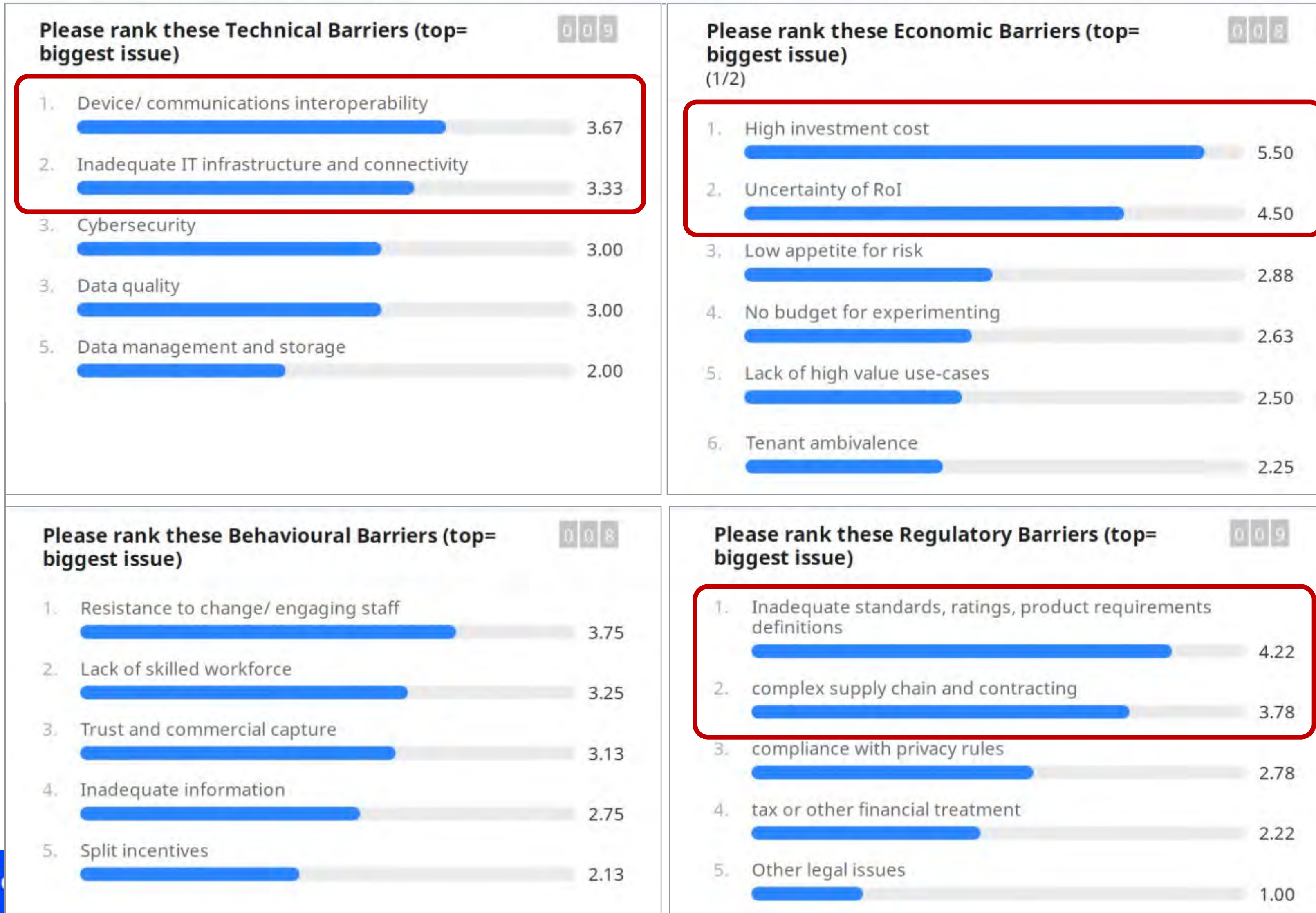
Barriers



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Two Step Implementation

Step 1

IT Infrastructure & Connectivity

Digital and M&V Ready

Step 2

Analytics, Advanced Controls, Flexible Demand

Barriers

- ? Cost (or cost uncertainty)
- ? Interoperability
- ? Cybersecurity
- ? Data quality
- ? Product confusion
- ? Complexity/ risk
- ? Trust/ commercial capture

Opportunities

- ✓ Payback <2 years

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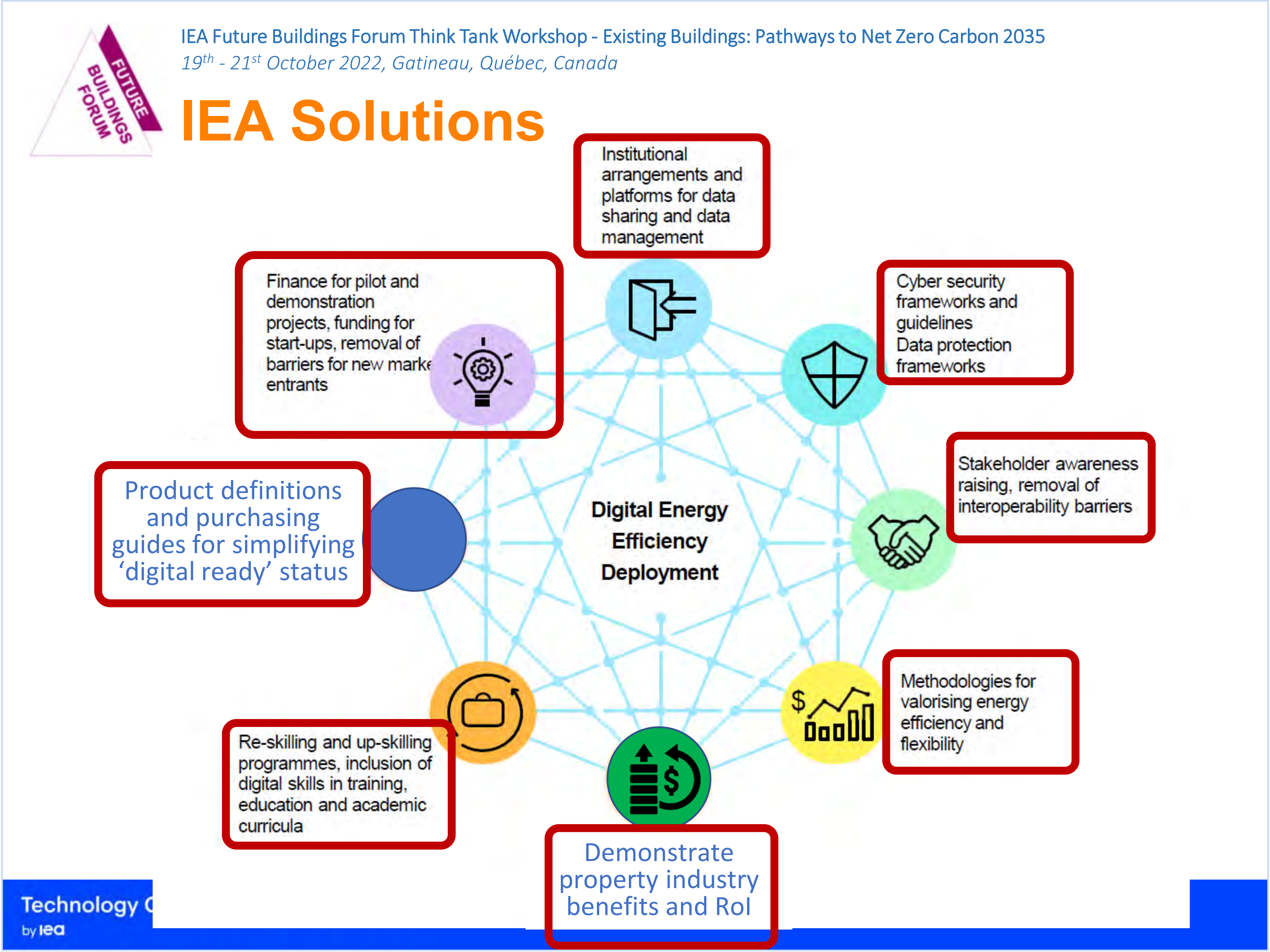
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IEA Solutions
Institutional arrangements and platforms for data sharing and data management
Finance for pilot and demonstration projects, funding for start-ups, removal of barriers for new marke entrants
Cyber security frameworks and guidelines
Data protection frameworks
Product definitions and purchasing guides for simplifying 'digital ready' status
Digital Energy Efficiency Deployment
Stakeholder awareness raising, removal of interoperability barriers
Methodologies for valorising energy efficiency and flexibility
Re-skilling and up-skilling programmes, inclusion of digital skills in training, education and academic curricula
Demonstrate property industry benefits and RoI
Technology
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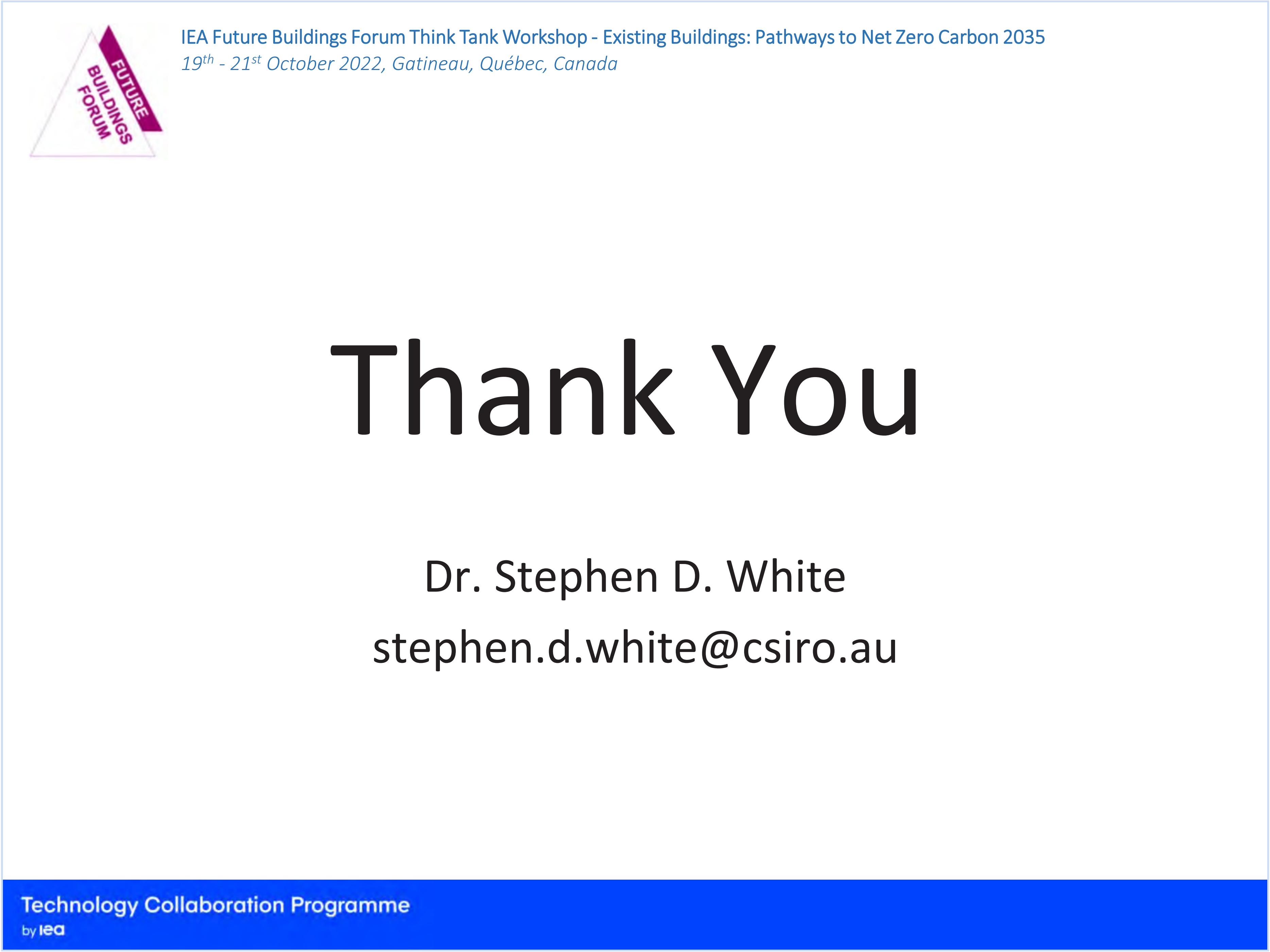
Some Thoughts/Questions

- Is digitalization on the net-zero pathway?
- How can we define, promote, incentivise and/or regulate digitalisation for the net zero pathway?
- What does the future workforce look like?
- How do we scale digital solutions (Annex 81)
  - How do we drive interoperability (communications and semantic) ?
  - How do we enable self-service deployment (M&V and smart Apps)?
    - How does equipment recognise itself in a system of parts?
  - Where/how do we get tagged data to train models?
  - What processing do we do at the edge vs the cloud?
  - How do we get the energy industry and the property industry to conduct business on common platforms?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Thank You
Dr. Stephen D. White
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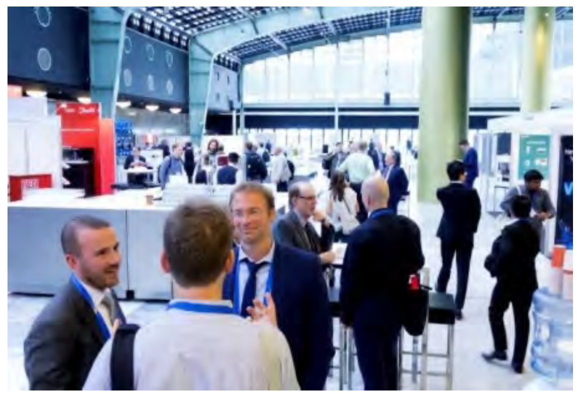
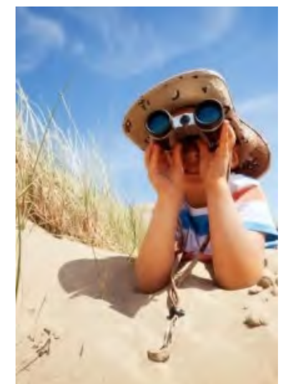
IEA Technology Collaboration Programme on Heat Pumping Technologies (HPT TCP)

Caroline Haglund Stignor, Heat Pump Centre, c/o RISE Research Institutes of Sweden

RI. SE



Research, Development, Demonstration, and Deployment of Heat Pumping Technology

www.heatpumpingtechnologies.org

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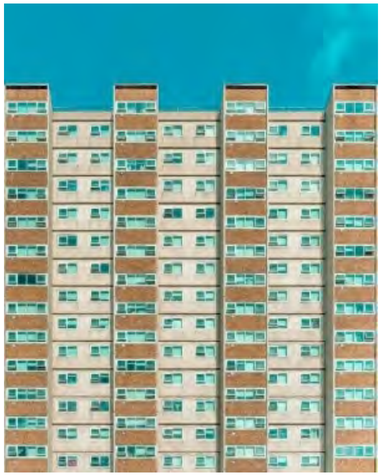
Heat Pumping Technologies in existing buildings

POSSIBILITIES AND CHALLENGES IN THE DESIGN, INSTALLATION AND OPERATION OF HEAT PUMPS



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Heat Pumping Technologies

Existing and available, here and now, – keeps millions of homes warm

- Energy Security
- Energy efficiency
- Renewable energy
- Clean – no local emissions
- Reduced dependence on fossil fuels
- Decarbonization
- Suitable to combine with other clean energy technologies

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Heat Pumps

Different types

- Air-to-air
- Air-to-water
- Water/brine-to-water
- Ground-to-water
- Etc., etc.

Different climates

- Cold (and humid) climates
- Climates with heating and cooling demand

Different applications

- Single-family buildings
- Multi-family buildings
- Commercial and institutional buildings
- New and existing buildings
- Waste heat recovery (e.g., supermarkets, data centers, industries, exhaust air, etc.)
- Industrial applications
- Thermal grids in cities and communities
- Other applications

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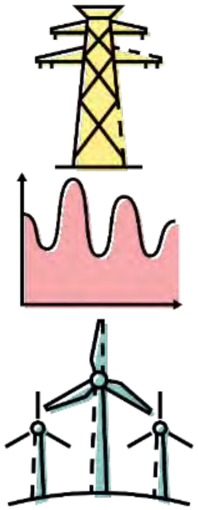
Heat Pumps – a flexibility provider for the grid

Many possibilities

- **Peak shaving** within the building (HP, PV, EV)
- Increased **self-consumption** of on-site-produced electricity
- Cluster controlled
  - for **peak shaving** within a district
  - to **increase the share of renewable energy** within the region or district
- **Flexible** operation of **large heat pumps** in thermal grids in cities and communities
- **Can respond to**
  - Price signals
  - Availability of on-site produced electricity
  - Electric loads
- Most heat pumps are connected to **energy storage,** more can be added



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Lack of awareness and skills in the whole value chain

Challenges today

- Heat pumps are still ”science fiction”
- Lack of **skill and knowledge** - installers, building system designers, etc.

Challenges tomorrow

- Awareness and skill will **increase**
- Continued need for **capacity building**
- **Expectations** to follow performance IRL

Solutions

- **Information** campaigns
- Home energy advisers, **one-stop-shops**
- Increased knowledge on **end-user perceptions**
- **Comfort** and Climate Box solutions
- Self-commissioning **plug-and-play** heat pumps
- A strong focus on **capacity building**

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ANNEX 50 — HEAT PUMPS IN MULTI-FAMILY BUILDINGS FOR SPACE HEATING AND DHW

ANNEX 60 — RETROFIT HEAT PUMP SYSTEMS IN LARGE NON-DOMESTIC BUILDINGS

ANNEX 6Y — HEAT PUMPS IN RESIDENTIAL MULTIFAMILY BUILDINGS IN CITIES

High temperature of heating system

Challenges today

- Many buildings ”heat pump ready” **– awareness low**
- Fossil fuel heating systems, require **high temperatures** > 55C

Challenges tomorrow

- Better **insulated** buildings, heating systems can operate at a **lower** temperature

Solutions

- Check the **”real” temperature need** on the coldest day
- **Insulate** buildings to lower heating need
- Complement heating system with **fan coils**
- Develop heat pumps with high efficiency at **higher** temperatures – further **R&D**

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ANNEX 50 HEAT PUMPS IN MULTI-FAMILY BUILDINGS FOR SPACE HEATING AND DHW

ANNEX 6Y HEAT PUMPS IN RESIDENTIAL MULTIFAMILY BUILDINGS IN CITIES

ANNEX 55 COMFORT AND CLIMATE BOX

Limited space for indoor units

Challenges today

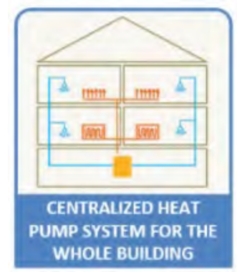
- The gas boiler to be replaced require **less space** – no water tank, no compressor

Challenges tomorrow

- This challenge will remain – the buildings **most challenging to retrofit**, will be the ones that **remain**

Solutions

- **”Boxified”** system design should be used, avoid oversized tanks
- The whole indoor unit (HP, tank, ventilation) placed in a **”box” outdoor**
- In **multifamily buildings central** - or decentralized - units could be applied



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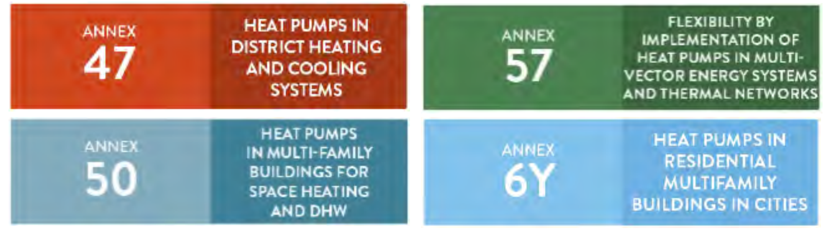
Limited space for outdoor units



Challenges today

- Dense areas - not sufficient space for **outdoor units** (ASHP)

- Dense areas - no access to land for **drilling** (GSHP)

Challenges tomorrow

- If cities get **denser**, this challenge will **remain** and **grow**

Solutions

- Thermal grids
  - To recover waste heat
  - To be used as a heat source and sink
  - To transport heating and cooling produced by **large-scale heat pumps**

Source: eon.se

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Acoustic signatures of heat pumps (and aesthetics)

ANNEX 51 ACOUSTIC SIGNATURE OF HEAT PUMPS

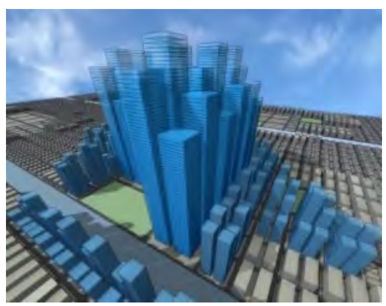
ANNEX 6X PLACEMENT IMPACT ON HEAT PUMP ACOUSTICS

Challenges today

- Outdoor units in dense areas could **disturb** the owner and neighbors
- If you see it – you hear it

Challenges tomorrow

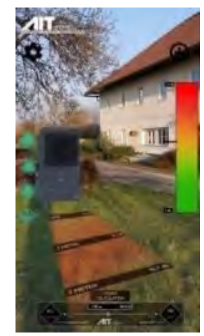
- More **dense cities** - this challenge will **remain** and **grow**
- More **silent** and **visually appealing** heat pumps will mitigate this challenge



Solutions

- **Research and developmen** of more **silent** heat pumps
- Better awareness and knowledge about the **placement impact** of heat pumps
- Tools for calculation and **visualization**
- **Thermal grids**, with a large heat pump placed far from buildings

Acoustic Signatures of Heat Pumps
IEA HPT Annex 51



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High running cost

ANNEX 55 COMFORT AND CLIMATE BOX

ANNEX 61 HEAT PUMPS IN POSITIVE ENERGY DISTRICTS

Challenges today

- Large **uncertainties** for future energy prices
- In many countries **fossil gas** prices have been **low** in relation to electricity – even been **subsidized**

Challenges tomorrow

- To have a chance to **reach climate targets** – taxes, fees, and subsidies need to **“make the polluter pay”** – advantageous for electricity and heat pumps!

Solutions

- Convince policymakers to **”make the polluter pay”** – adjust taxes, fees and subsidies
- Smart control – benefit **on hours with low electricity price** – digitalization
- **Insulate** buildings to reduce heating need
- Combine with **Solar PV**
- **Ban** fossil fuel boilers

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ANNEX 55 COMFORT AND CLIMATE BOX

ANNEX 61 HEAT PUMPS IN POSITIVE ENERGY DISTRICTS

High upfront cost

Challenges today

- The **upfront cost** of a heat pump is normally higher than fossil fuel boiler

Challenges tomorrow

- **”Economy of scale**” will result in lower cost to produce heat pumps
- Better **insulated** buildings, will result in **smaller** heat pumps at **lower** cost

Solutions

- **Ban** of fossil boilers (already on its way in several regions)
- **Alternative business models** (e.g. heat-as-a-service) – reduce upfront cost and stimulate accelerated deployment and ”economy of scale”

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ANNEX 42	HEAT PUMPS IN SMART GRID	ANNEX 55	COMFORT AND CLIMATE BOX
ANNEX 56	INTERNET OF THINGS FOR HEAT PUMPS	ANNEX 57	FLEXIBILITY BY IMPLEMENTATION OF HEAT PUMPS IN MULTI-VECTOR ENERGY SYSTEMS AND THERMAL NETWORKS

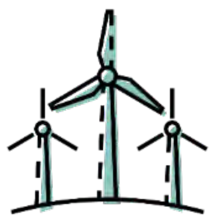
Not sufficient power capacity in electric grids

Challenges today

- Still low penetration, traditionally no challenge – a **strained** situation the **coming winter**

Challenges tomorrow

- Larger share of **renewable intermittent** power production
- **Digitalization** and **cyber security** – many connected HP
- Electric grids are **enforced**



Solutions

- **Capacity-controlled** compressors, pumps, and fans – avoid frequent start/stop and electric back-up heaters
- **Smart control** of heat pumps - load balancing, load shifting, system services
- Use of the **thermal mass** of buildings as an energy storage
- **Enforcement** of electric grid and production

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ANNEX 52 LONG TERM PERFORMANCE MEASUREMENT OF GSHP SYSTEMS SERVING COMMERCIAL, INSTITUTIONAL AND MULTI-FAMILY BUILDINGS

ANNEX 53 ADVANCED COOLING/ REFRIGERATION TECHNOLOGIES DEVELOPMENT

Increasing cooling demand, decreasing heating need

Challenges today

- The demand for **comfort cooling** is **increasing**
- The **average efficiency** of ACs sold in emerging countries **low** compared to BAT

Challenges tomorrow

- The demand for cooling will **continue to increase**
- Heat pumps might be **oversized** when buildings are insulated

Solutions

- MEPs, energy labelling and **information** campaigns
- **Training** of electricians/installers to deal with modern technology
- **R&D** on more efficient ACs
- Development of solutions where the **cold and the warm side** of the cycle **is utilized**
- **Modular design** of heat pumps/ACs – when the heating/cooling need has decreased, move units to other buildings

ANNEX 62 CCB FOR WARM AND HUMID CLIMATES

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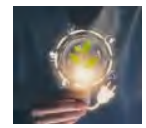
HPT TCP RDD&D priority areas 2023-2028

System integration	Robust, sustainable and affordable value chains	Extending operation range and applications	New technologies and refrigerants
			 
Sector coupling, energy efficiency, flexibility, resilience, storage, digitalization, positive energy districts	Improving affordability, securing value chains, circular economy, removing barriers for mass deployment	To fulfill demand from all climate zones, new markets, new applications and new demand. Refrigeration in emerging countries.	Non-traditional heat pumping technologies (for heating and cooling) Refrigerants (low GWP, safety etc.)
• Annex 57: Heat pumps in multi-vector energy systems • Annex 61: Heat Pumps for Positive Energy Districts • CCB for warm and humid climates • Sector Coupling - Survey of practical examples • Digitalization and IoT for heat pumps II	• Placement Impact on Heat Pump Acoustics • Heat Pumps in a Circular Economy • New or alternative business models	• Annex 60: Retrofit Heat Pump in Larger Non-domestic Buildings • Annex 58: High Temperature Heat Pumps • Annex 59: Heat Pumps for Drying • Heat Pumps in residential multifamily buildings in cities	• Annex 53: Advanced Cooling/Refrigeration Technologies • Annex 54: Heat Pump Systems with low GWP Refrigerants • Safety Measures on Flammable Refrigerants

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Prompts for discussion

- How to increase **end-user awareness** and **confidence** in clean energy technologies
- How to increase **capacity building** in the whole **value chain** for clean energy technologies
- How to unleash the full ”**cost reduction potential**” for clean energy technologies (economy of scale, synergies, spill-over etc)
- How to design and deploy sustainable, smart, flexible, integrated system solutions where the **full benefit** of **all clean energy technologies** are **utilized**?

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THANK YOU FOR YOUR ATTENTION!

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Additional slides

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Circular economy for heat pumps

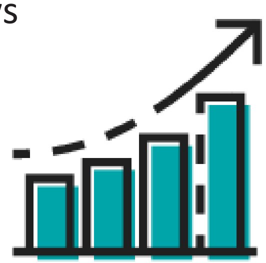
ANNEX 6V
HEAT PUMPS IN A CIRCULAR ECONOMY

Challenges today

- No/few systems for reuse and recover material and components

Challenges tomorrow

- The need and requirement to reuse and recover will increase as the installed stock grows



Solutions

- Design heat pumps to enable reuse and recovering
- Develop systems for reuse and recovering of material and components
- Design heat pumps as modular units

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ANNEX 54 HEAT PUMP SYSTEMS WITH LOW GWP REFRIGERANTS

ANNEX 6W SAFETY MEASURES ON FLAMMABLE REFRIGERANTS

Flammability of low GWP refrigerants

Challenges today

- **Insecurity** about future F-gas regulations
- **Lack of experience** and safety systems for use of highly flammable refrigerants
- Standards under **development**

Challenges tomorrow

- Traditional non-flammable will probably be **phased out** (due to high GWPs)
- **Experience** will grow!

Solutions

- Gaining experience
- Development of **standards and safety systems** for use of highly flammable refrigerants
- Development of **safe and efficient** components and systems for flammable refrigerants

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Heat Challenge – the Needs

End-user

- A comfortable home
- Hot showers
- Reasonable energy bills
- A compact plug & play solution
- Environmental awareness

Policymakers

- Reach climatic targets
- Ensure security of supply
- Reasonable energy bills for the population

Utilities and grid owners

- Acceptable return on investments
- Reaching emission targets
- Flexibility providers to ensure the security of supply and optimize investments

Implementation strategies

- Differ between markets

Affordability Flexibility Compactness Efficiency

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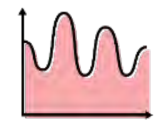
A solution – Comfort and Climate Box (CCB)

ANNEX 55
START DATE: 1 April 2019
END DATE: 30 September 2021

Integrated solutions of heat pump, energy storage and control – in a virtual box

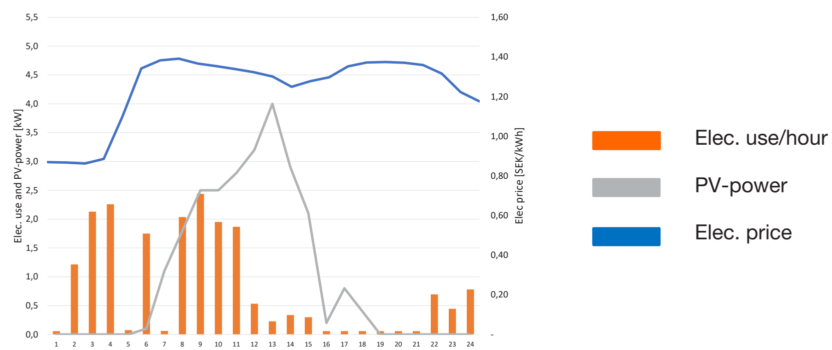
A prototype developed within HPT Annex 55/ ES Task 34 in collaboration with MI IC7

Two “Smart control functions“



- Price: Minimize the electricity cost
- Sun: Maximizing self-consumption of PV-power

- **Combination of above**



Policy Recommendations

- **Prioritize heat pumps in policy!**
- **Ban** of installation of fossil fuel boilers
- Make **clean heating** the most **economically attractive** solution
  - Remove subsidies on fossil fuels
  - Introduce CO_2 fees, tax, ETS, etc
  - Reduce (remove) VAT on heat pumps and electricity for heat pumps
  - Introduce subsidies for heat pumps (kick-start of market, low-income households)
- **Support retraining** of installers to heat pumps installers
- **Information campaigns** and **education**
- Promote **standards** and communication protocols for **smart, flexible heat pumps**
- Stimulate **energy efficiency renovation**
- Invest in **clean and renewable power** generation
- Support and ensure **funding of RDD&D** for heat pumping technologies

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Advanced Smart Lighting must also be Energy Smart

Casper Kofod

IEA Future Buildings Forum Think Tank Workshop

October 2022

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IEA Future Buildings Forum Think Tank Workshop - Existing Buildings: Pathways to Net Zero Carbon 2035

19th - 21st October 2022, Gatineau, Québec, Canada

Agenda

1. IEA 4E SSL Annex
2. What is Smart Lighting?
3. Market and Barriers
4. Standby power measurements
5. Huge standby saving potential
6. Standby regulation in California and Energy Star
7. Standby share of the total energy consumption
8. Efficacy when dimming or changing colour
9. Recommendations

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4E NZE input: All LED in 2025

- LED provides huge energy savings
- Today: Efficacy 10 X better than incandescent lamps
- Future: Efficacy 20 X better …
- Could come campaigns for shifting 1. generation of LED lamps - anyhow they still provided light.

4

IEA 4E SSL Annex (2019-23)

- Tools to assess the performance of SSL,
- Information assisting formation of energy-efficient lighting policies, and
- Support for use of harmonised test methods and laboratory accreditation

Task 1. Human Centric Lighting, Health and Comfort
Interpretation and guidance on setting requirements on health-related aspects

Task 2. Lifetime of SSL Lamps and Luminaires
Review of methods, conduct accelerated aging tests and driver quality.

Task 3. Lighting and the Environment
LCA's and disposal/recycling issues and wider environmental impacts.

Task 4. Interlaboratory Comparison for Temporal Light Modulation
Develop a proficiency test for accreditation due IEC TR 61547-1 and TR 63158.

Task 5. Test Method Assessment
Review requirements/standards to assess the accuracy and cost of conducting .

Task 6. Quality and Performance Tiers
Defined levels of quality and performance tiers for LED lamps.

Task 7. Smart Solid-State Lighting
Study how the new smart features are impacting the energy consumption.

Task 8. SSL Annex Product Database
Internal benchmarking LED database including performance and test data.

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What is Smart Lighting?

- ***LED lighting + wireless control***
- ***Dimming, Change colour, Timers, Programming***
- ***Non-lighting: Music, Camera, WiFi booster …***
- ***In some museums and shopping centres, the lamps are used as WiFi nodes for navigation with possibility for activating visual and aural information.***
- ***"Cost": standby energy consumption (always on).***

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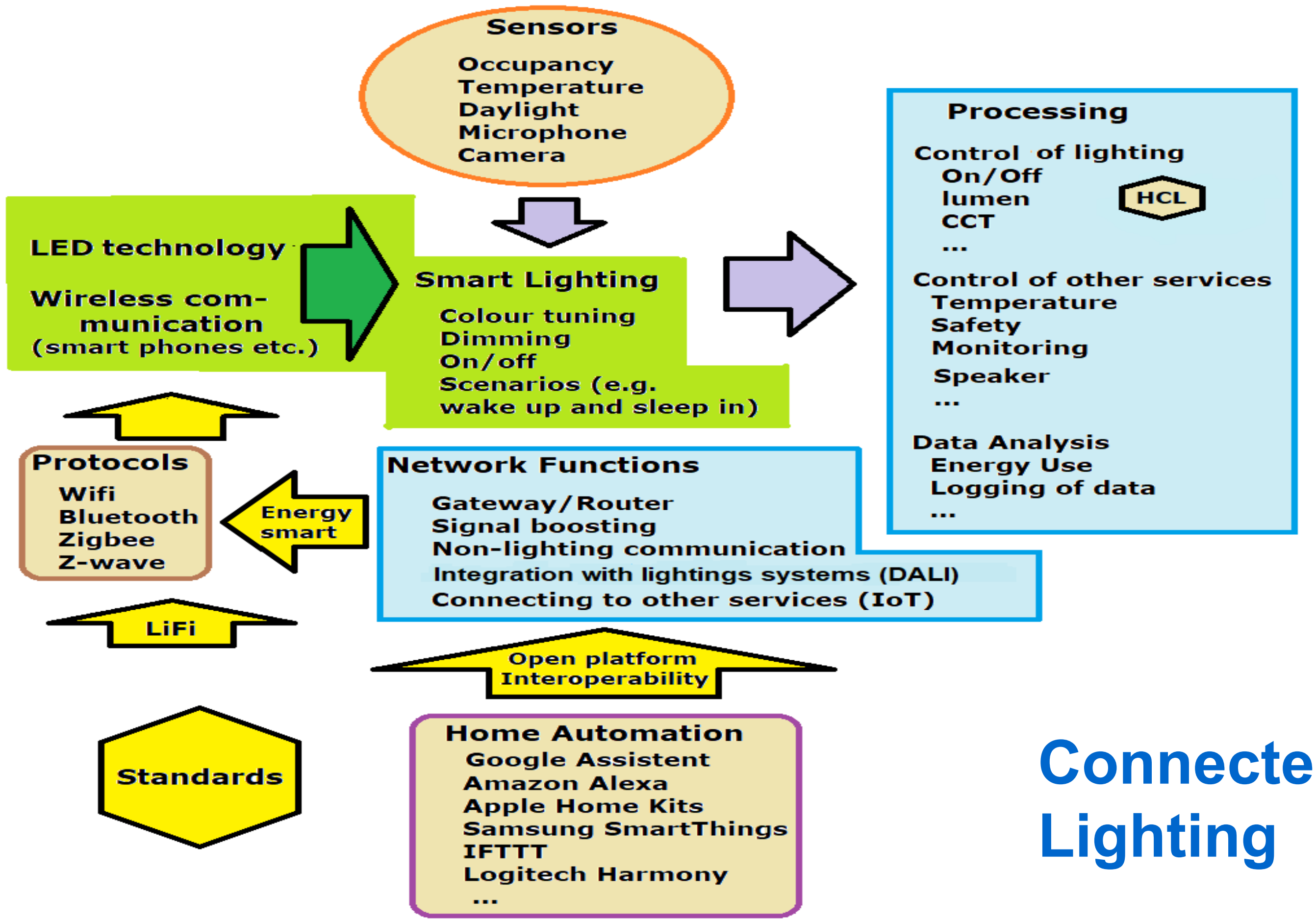
More Complex Smart Lighting



Connected Lighting

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Market and Barriers

- Large investments
- Uptake lower than expected
- Barriers: cost, complexity, lack of open systems, interoperability, standards and consistent systems, no connection to wired systems, ...
- Decreasing prices – going mainstream
- The industry works on simplification, plug and play, higher user-friendliness, …
- Gateways to wired control (DALI)
- HCL used in hospitals/Nursing homes – Offices?

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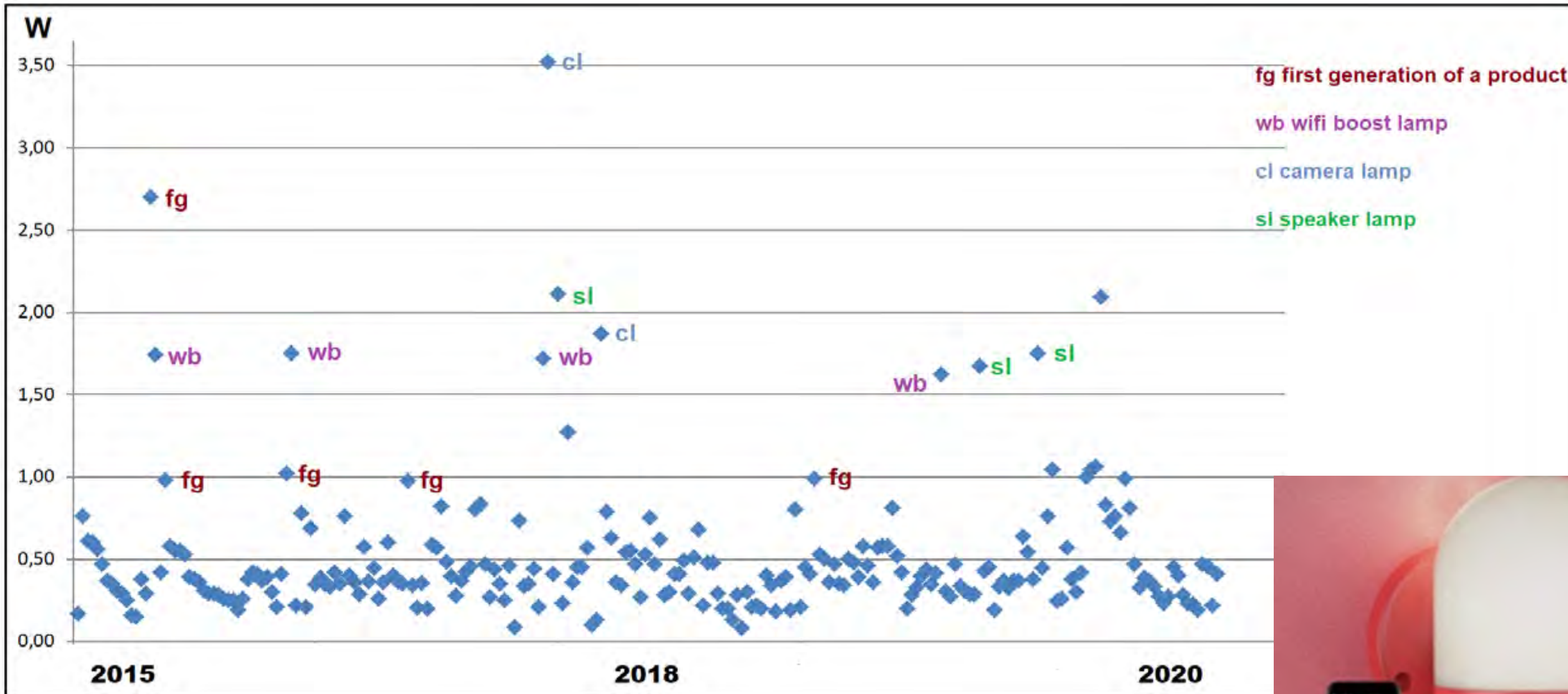
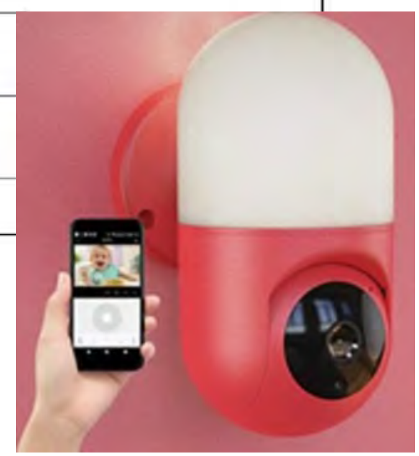
Standby Power for 236 lighting products





- Lowest 0.08W and highest 3.5W
- Average 0.51W (median 0.39W)

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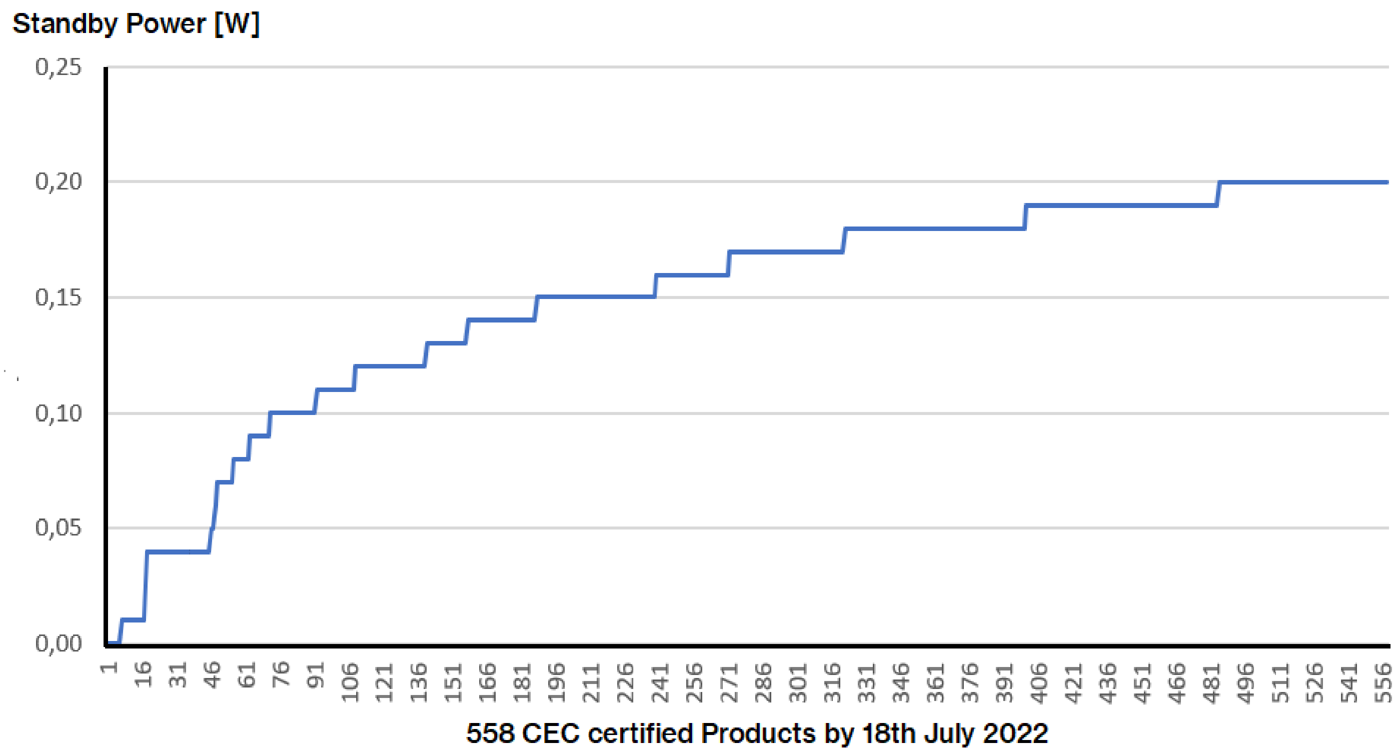
Standby Power Regulation in California

1/9 2019 California the standby power ≤ 0.2 W.



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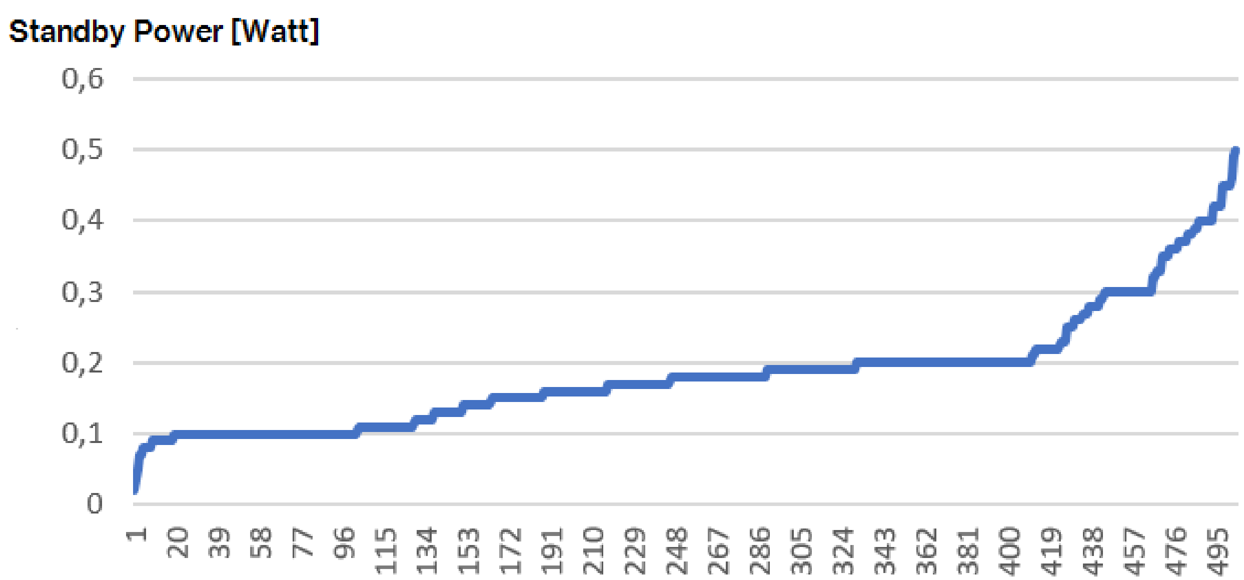
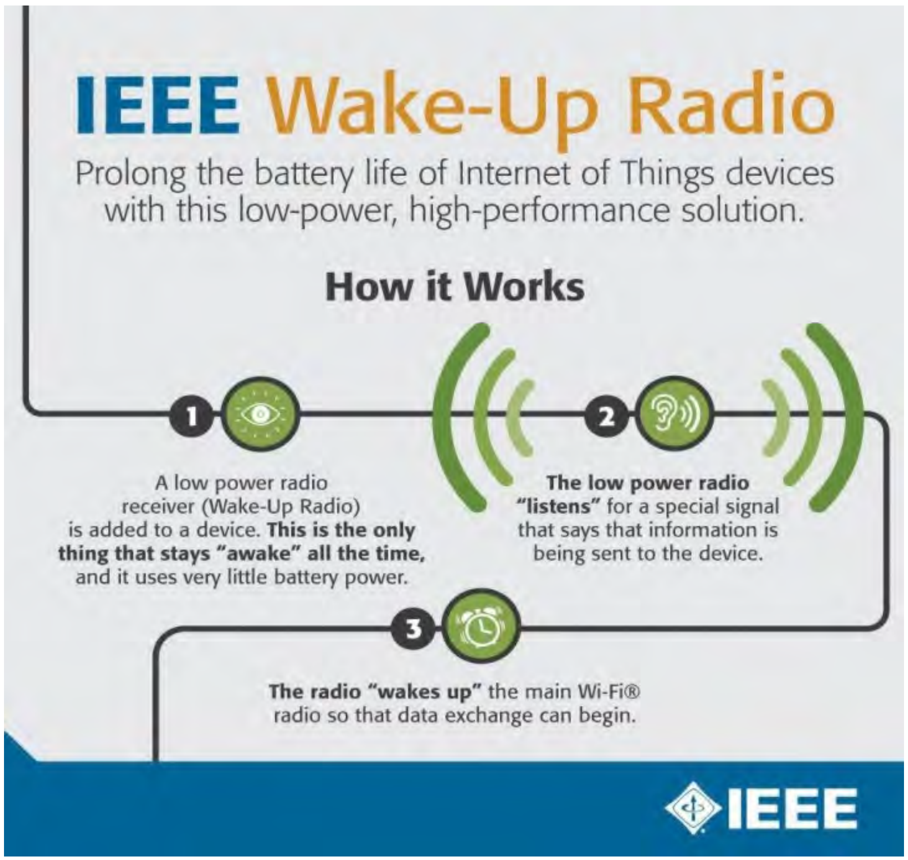
Standby Power for Energy Star certified products

Energy Star (USA and Canada) certified LED products with standby power ≤ 0.5 W ¤). The Energy Star product database show 81% of the products fulfill the CA requirement ≤ 0.2W.



¤) 1/9 2021 EU Ecodesign regulation also included standby power ≤ 0.5 W

Huge Standby Saving Potential



- Developed for connected devices on battery.
- Wake up 2 millisec. out of every 100 second reduces the average power from 100 mW to around 1.6 mW.

Standby Consumption Share of the total

			Usage 1 hour/day				Usage 2 hours/day			
Lamp	ON (W)	Standby (W)	ON (kWh)	Standby (kWh)	Standby (%)	Total (kWh)	ON (kWh)	Standby (kWh)	Standby (%)	Total (kWh)
360 lm 3 W	3.0	0.50	1.10	4,20	**79%**	5,3	2,19	4,02	**65%**	6,2
		0.20		1,68	**61%**	2,8		1,61	**42%**	3,8
		0.10		0,84	**43%**	1,9		0,80	**27%**	3,0
		0.01		0,08	**7%**	1,2		0,08	**4%**	2,3
806 lm 6.7 W	6.7	0.50	2.45	4,20	**63%**	6,6	4,89	4,02	**45%**	8,9
		0.20		1,68	**41%**	4,1		1,61	**25%**	6,5
		0.10		0,84	**26%**	3,3		0,80	**14%**	5,7
		0.01		0,08	**3%**	2,5		0,08	**2%**	5,0

The standby power consumption doesn't become insignificant until it is lowered to around 0.01 W.

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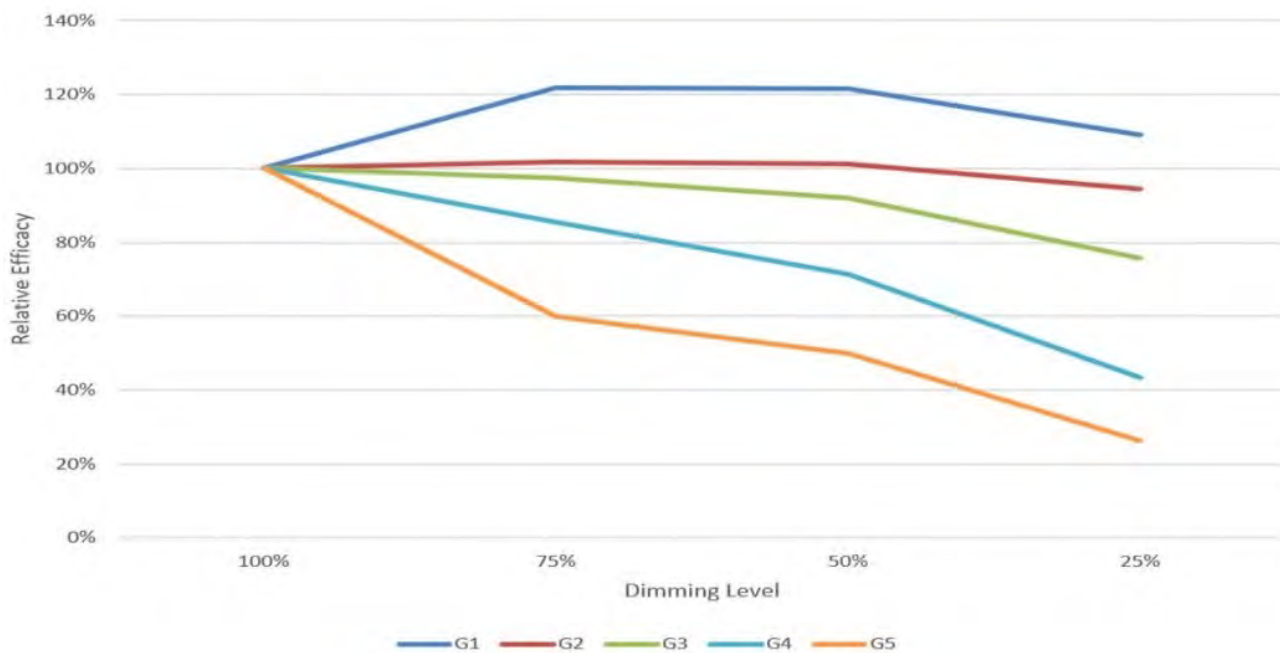
Luminous Efficacy when Dimming

Efficacy relative to the efficacy without dimming



Five types of products. G4 and G5 (24% of the productsl) are critical as hardly any energy savings by dimming.

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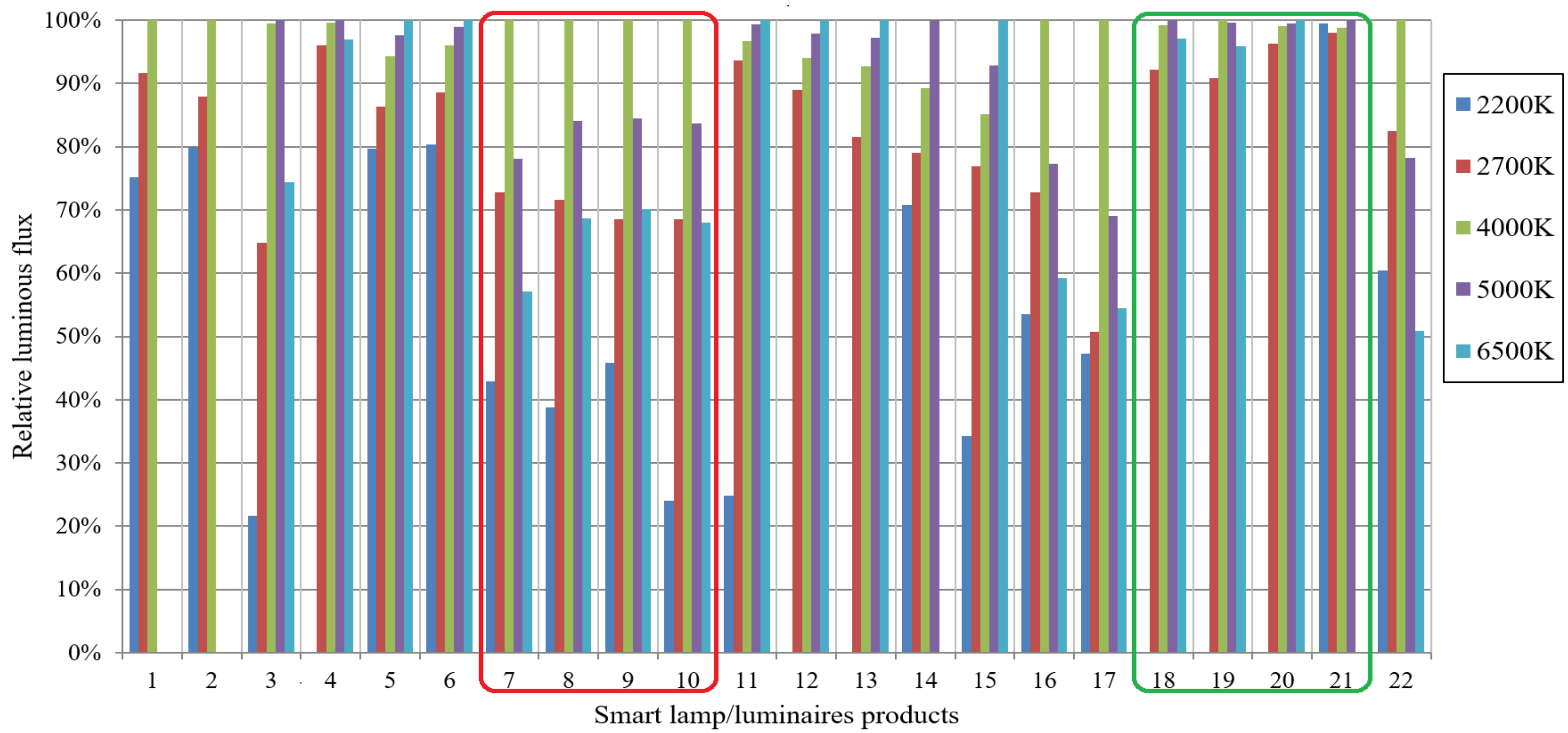
Luminous flux for 5 white Colours



Product 18-21: Lumen output closed to the claimed for all CCT's,
Product 7-10: Lumen output much lower than claimed for some CCT's.

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Luminous Efficacy for 5 white Colours

Some products: Efficacy down to 20-50% of rated efficacy for some CCT's.

Recommendations

- Actually: Standby should be power ≤ 0.2 W everywhere
- Future goal: Standby power ≤ 0.01 W
- Non-lighting features: Should be possible to switch ON/OFF. Consider use of wake-up standby technology.
- CCT: Claimed performance for all CCT's or at least lumen, power info for two CCT's: 2700K and 4000/5000K.
- Dimming+CCT: Claimed performance in all stages or lumen + power info for stages (five CCT's versus dimming 75, 50 and 25%).

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Session 5

October 21st, 2022, AM

Building Energy and Carbon Codes

Session Coordinators

Meredydd Evans

Operating Agent, EBC Energy Codes Working Group, Senior Staff Scientist and Team Lead, Joint Global Change Research Institute, Pacific Northwest National Laboratory

Takao Sawachi

Chair, ExCo, Energy in Buildings and Communities TCP / President, Building Research Institute

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Building Energy & Carbon Codes
Considerations, opportunities, and challenges

Future of Buildings Forum
October 21, 2022

Meredydd Evans
Pacific Northwest National Laboratory

PNNL is operated by Battelle for the U.S. Department of Energy

IEA EBC Building Energy Codes Working Group

18 member countries and ASHRAE, International Code Council

Chairs:

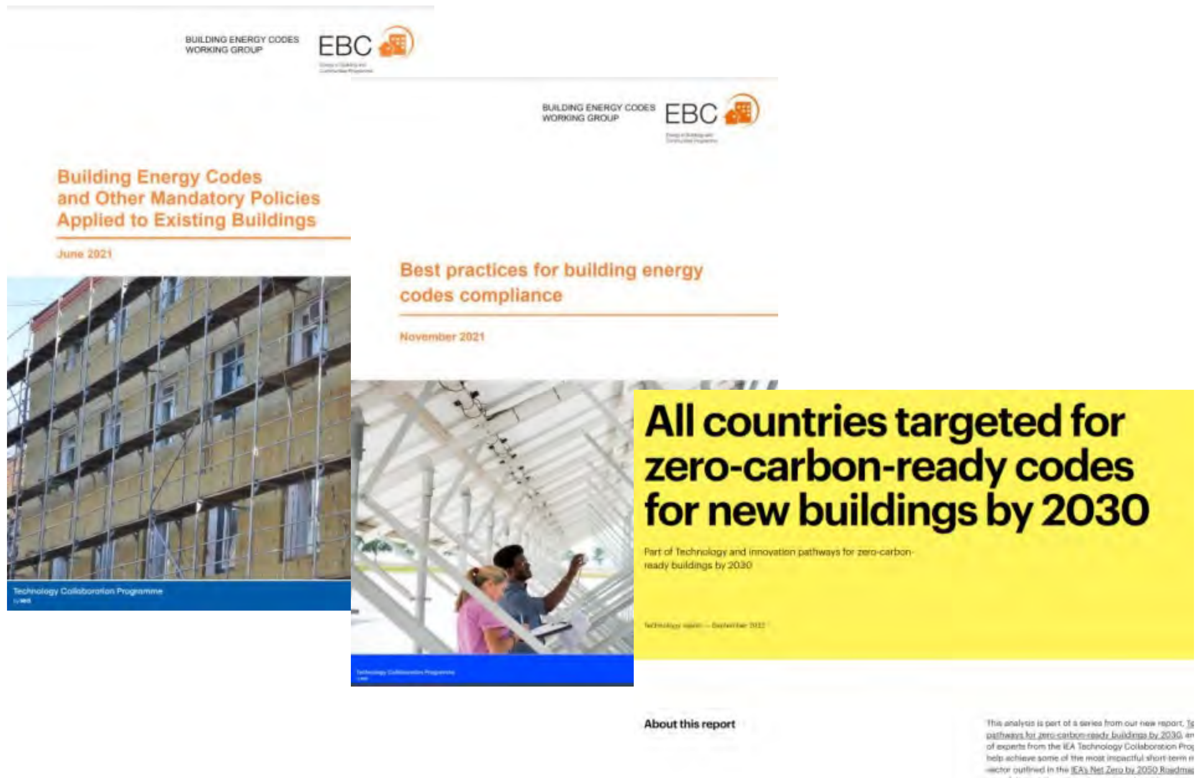
- Michael Donn, Victoria University of Wellington, N.Z.
- Meli Stylianou, Natural Resources Canada
- TBD

U.S. Delegate:

Jeremy Williams, U.S. Department of Energy (BTO)

Operating Agent:

Meredydd Evans, U.S. Pacific Northwest National Laboratory



2

Overview

- It is estimated that by 2040, 2/3 of the global building stock will be buildings that exist today.
- A combination of advanced technologies, regulations and policies are needed to bring global energy-related carbon dioxide emissions to net zero by 2050.
- Building energy codes currently provide the most effective way to improve energy performance.

Figure source: Hinge, A. and F. Brocklehurst (2021). Building Energy Codes and Other Mandatory Policies Applied to Existing Buildings. Energy in Buildings and Communities Programme Building Energy Codes Working Group.

Data source: IEA Energy Technology Perspectives 2020, February 2021 Revised Edition

3

Trend towards Building Performance Standards

Traditional Energy Codes	vs.	BPS
Generally **developed for new construction**; some new construction requirements also applied to **significant renovation or alteration projects**		Based on **building energy or carbon performance threshold** or a **measured energy or carbon intensity**
One-time requirement to meet prescribed energy efficiency levels or performance when renovating, refurbishing or remodeling an existing building		Meet a prescribed energy performance level by a given date, and/or after change of tenancy or ownership

4

BPS in selected EBC countries

Country/ Jurisdiction	Res.	Com.	Size Threshold / Typical Trigger
England and Wales	✓	✓	Applied when change or extension in tenancy; later to all properties
New York City, U.S.	✓	✓	Buildings >25,000 square feet (approx. 2,320 m^2)
The Netherlands		✓	All office buildings by a given date
Tokyo, Japan		✓	Very large "facilities" consuming more than 1,500 kiloliters of annual crude oil equivalent energy

Source: Hinge, A. and F. Brocklehurst (2021). Building Energy Codes and Other Mandatory Policies Applied to Existing Buildings. Energy in Buildings and Communities Programme Building Energy Codes Working Group.

5

Challenges: Code adoption

Many jurisdictions around the world still lack building energy codes, or face traditional barriers such as workforce training, compliance-support programs, or limited enforcement

Source: IEA EBC TCP, updated from IEA Building Envelopes (2021), IEA Energy Efficiency 2021 and Global Status Report on Buildings and Construction 2021.

6

Challenges: Enforcement

- Successfully implementing and enforcing codes requires resources to support staff time and expertise, acquire necessary training, and develop tools to assist in verifying compliance.

Survey of 38 representatives from various jurisdictions in 11 BECWG countries

Enforcement set-up

"Uneven enforcement from a lack of compliance checks" "Lack of understanding of the code"

Capacity building and education

"Lack of exposure by building officials to more complex aspects of the codes"

Penalties and other mechanisms for improving compliance

"Limited penalties or incentives in some jurisdictions"

Code compliance assessments

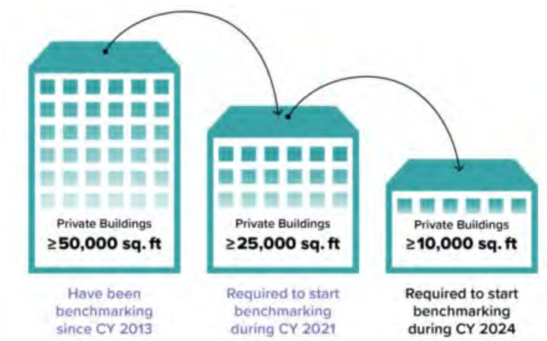
"Code compliance assessments are not widely or regularly conducted"

Delgado A., A. Mott, and M. Evans. 2021. Best practices for building energy codes compliance. PNNL-32155. Richland, WA: Pacific Northwest National Laboratory.

7

Opportunities: New codes and enhanced enforcement

Strategies	Policy recommendations
Develop and deploy zero-carbon-ready building (ZCRB) codes by 2030	**Building codes and BPS.** Consider and adopt performance codes, in addition to prescriptive ones, as well as hybrid performance-prescriptive ones, to promote wider trade-off for increased design flexibility across measures.
Review enforcement, monitoring and compliance practices	**Enforcement practices.** Reduce the burden on administrators, architects, engineers and builders by also taking advantage of digitalisation and smart metering for monitoring and control.



DC Building Energy Performance Standards

8

Opportunities: Data and metrics

Strategies	Policy recommendations
Enforce data collection campaigns and define data communication protocols	Data communication protocols. Define and implement data communication procedures and routines that are easy to maintain and update to ensure rigorous statistical studies of construction practices to comply with ZCRB codes and to support the enforcement of such codes. Consolidate energy performance certificates, improve energy audits and disclosure programmes.

9

Opportunities: Cooperation-based instruments

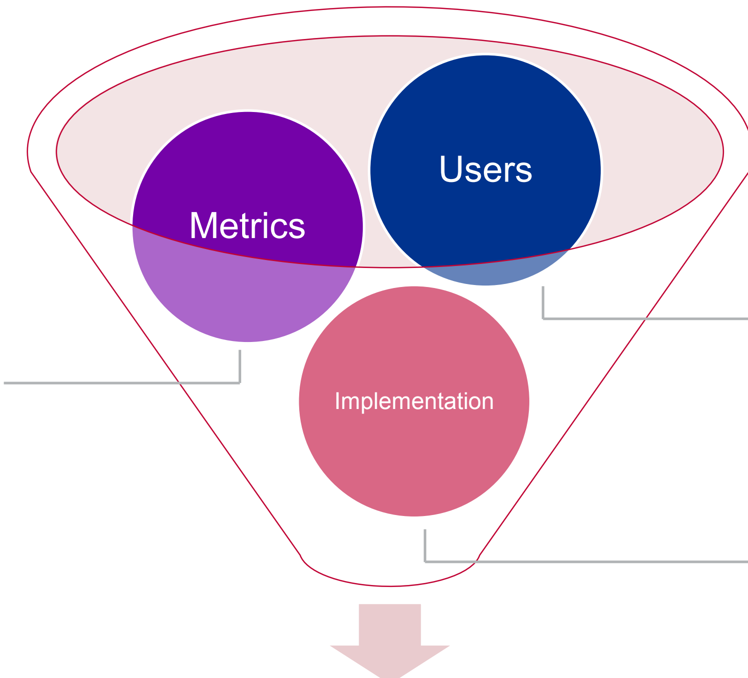
Strategies	Policy recommendations
Enable cooperation-based programmes	**National and international collaboration programmes.** Programmes such as IEA TCPs - including the Building Energy Codes Working Group of the TCP's Energy in Buildings and Communities - speed knowledge creation and learning on policy and technology innovation.
	Intergovernmental cooperation. Adopt a more collaborative approach in the development of certification tools, monitoring and compliance.
Develop open-source platforms and tools	**National open-source simulation tools.** Work with stakeholders to provide improved buildings simulation methods and tools for assessing clear lifecycle cost-benefit information, reflecting energy costs over the building's lifetime.
	Stakeholder engagement. Regularly engage key stakeholders to review the existing requirements and enforcement practices.

10

Brainstorming sessions

Metrics for decarbonizing existing buildings

- E.g., understanding real-time carbon emissions associated with power in buildings to shift loads to low-carbon periods
- Key is brainstorming to understand options and opportunities for new metrics



Key considerations for this session

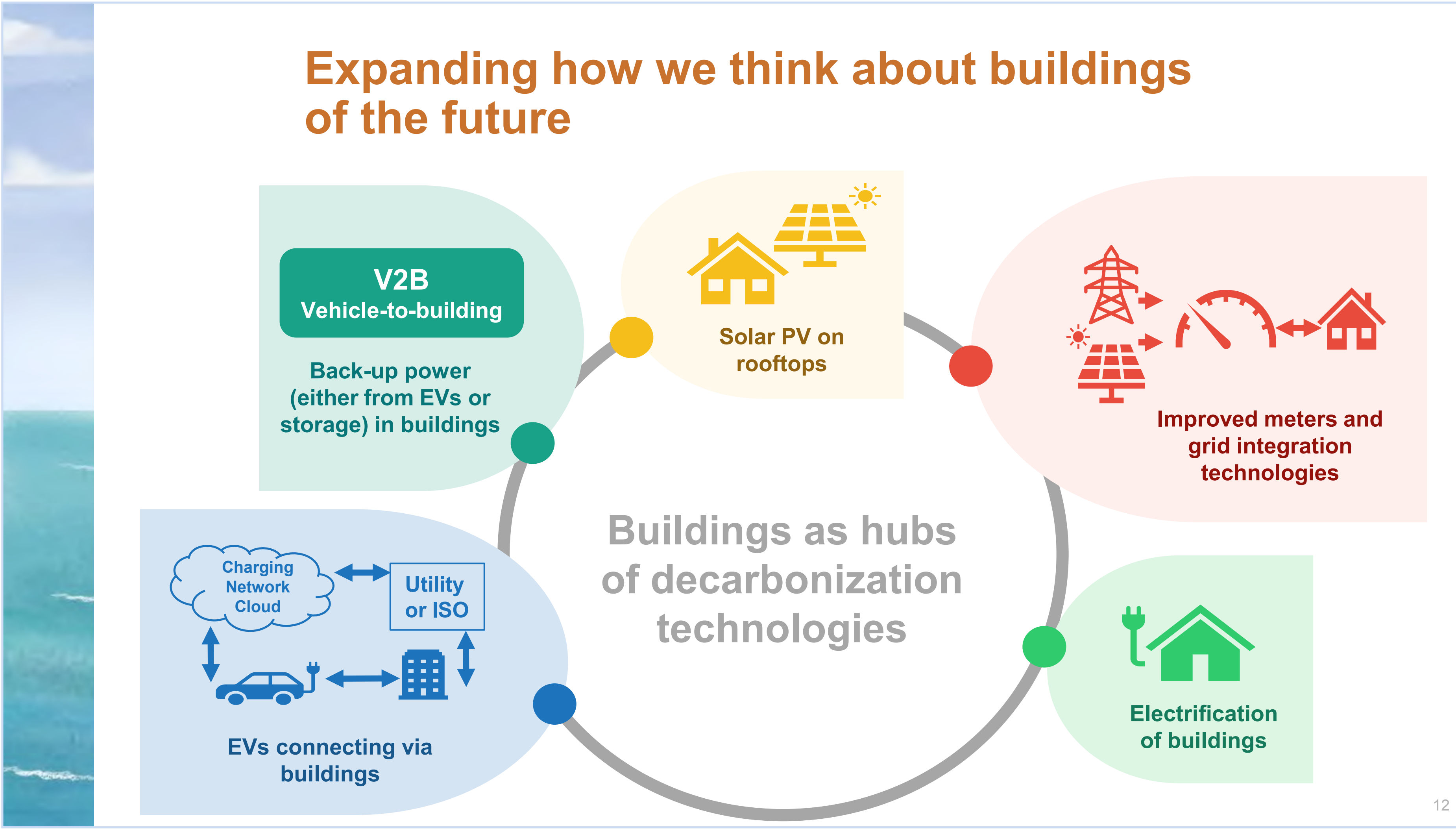
Occupants and utilities

- Occupants need to feel like policies meet their needs, providing affordable comfort
- Resilient buildings are important to meeting needs (need metrics for this too)
- Utilities can help with incentives, data for grid-connected buildings

Implementation

- Key to making all of this work!

11


Expanding how we think about buildings of the future
V2B
Vehicle-to-building
Back-up power (either from EVs or storage) in buildings
Solar PV on rooftops
Improved meters and grid integration technologies
Buildings as hubs of decarbonization technologies
Charging Network Cloud
Utility or ISO
EVs connecting via buildings
Electrification of buildings
12

Thank You!

m.evans (at) pnnl.gov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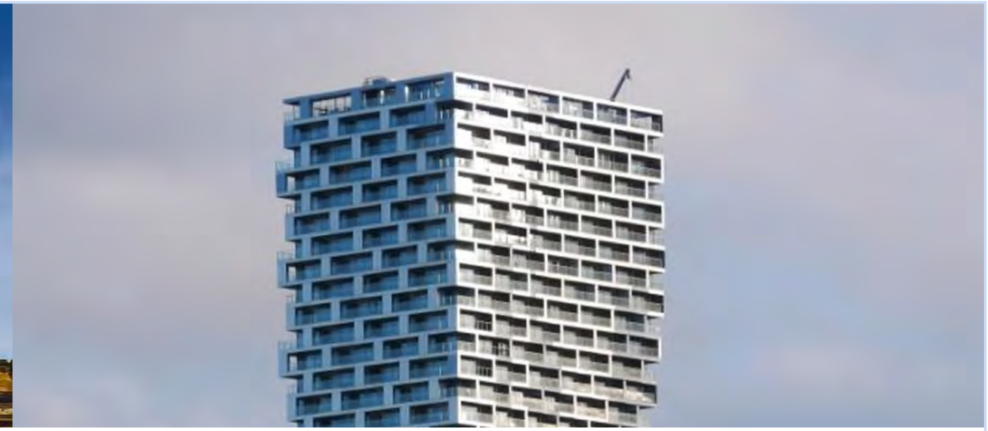
Ressources naturelles Canada
Building Code Metrics
Future Buildings Forum
Canada

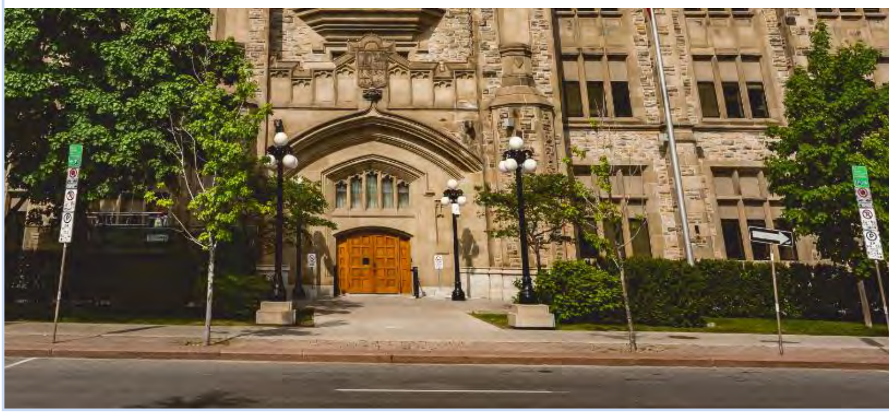


PERSCRIPTIVE CODES

- Informed by traditional knowledge
- Shaped by accepted practices
- Generally inflexible & slow to innovate

PERFORMANCE CODES

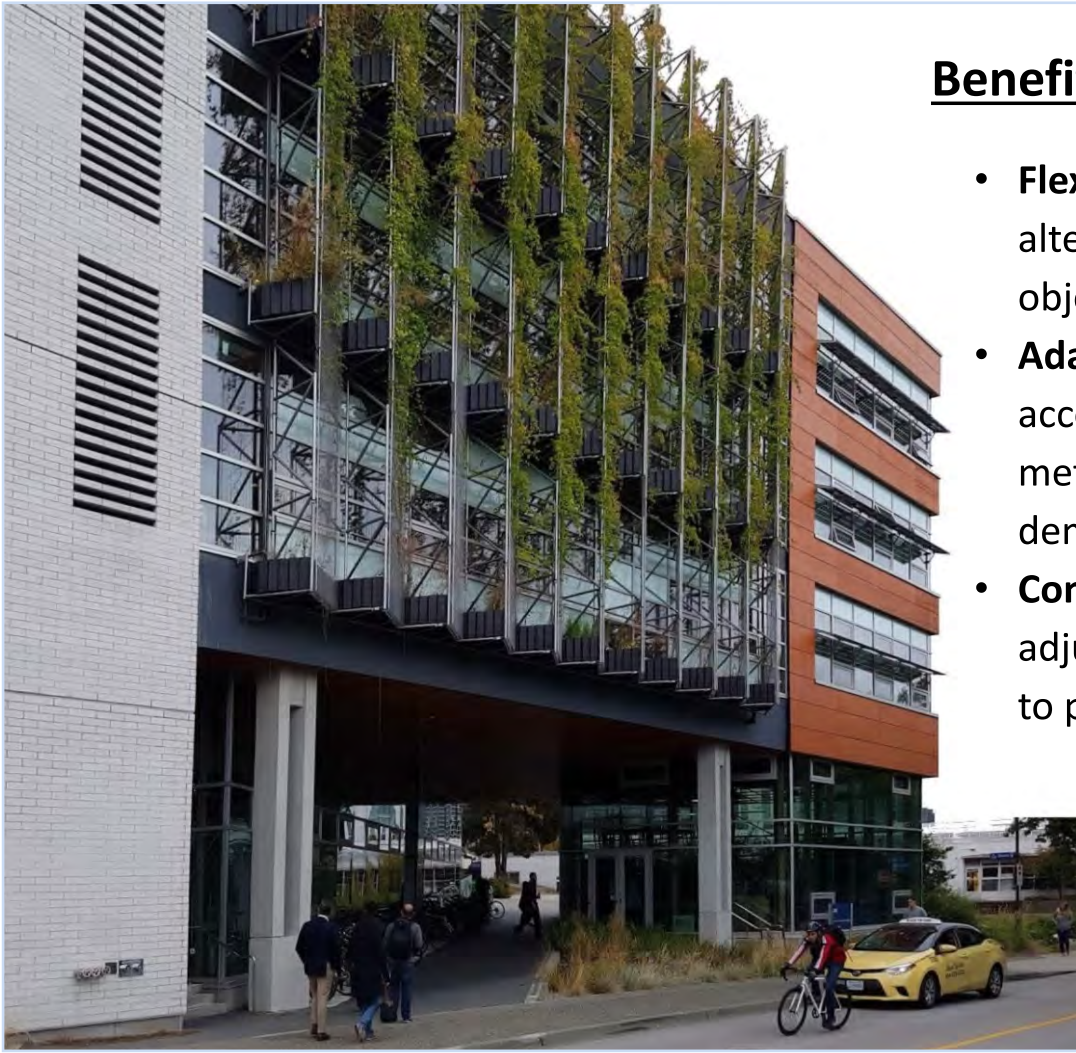
- Informed by building science principles,
- Shaped by policy objectives
- Generally flexible & encourage innovation



Elements of Performance Codes

- **Objectives:** Set forward the goals that buildings are intended to meet during design, construction and operation
- **Metrics:** provide an accepted and meaningful way of measuring a building’s performance towards those goals
- **Targets:** define minimum levels of performance that new buildings must comply with.

3

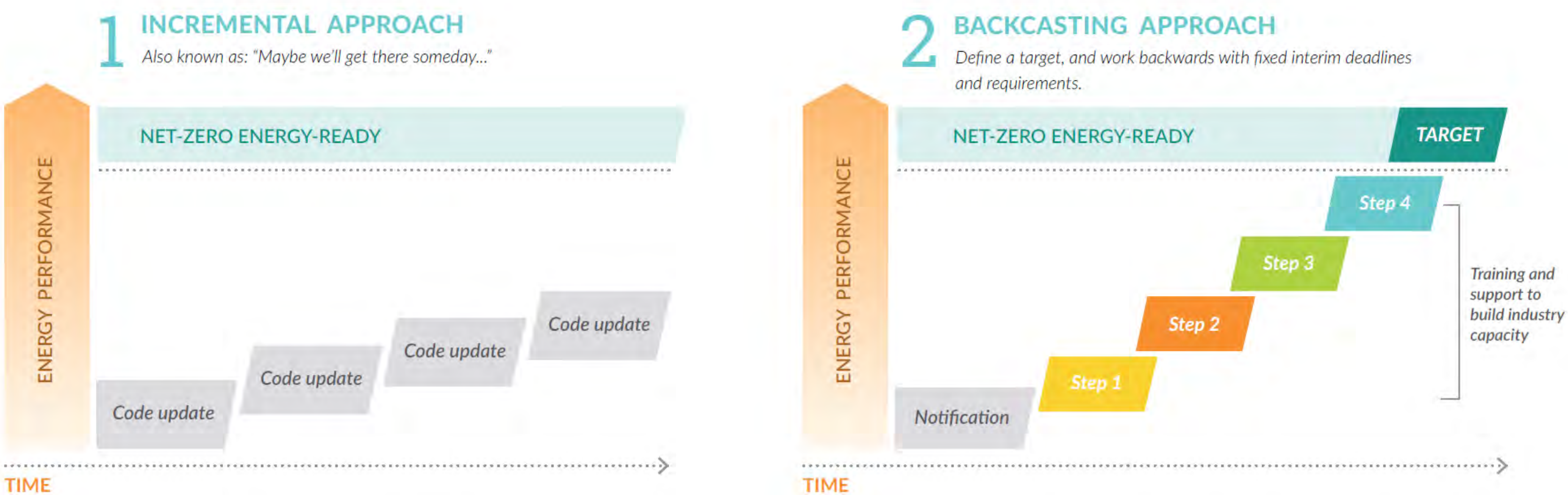


Benefits of Performance Codes

- **Flexibility:** Performance codes allow alternate solutions that achieve the same objectives
- **Adaptability:** Performance codes can accommodate new objectives and new metrics to reflect changing policies, demographics, and climates
- **Continuous Improvement:** Year-over-year adjustments to targets become a useful tool to push industry toward higher standards.

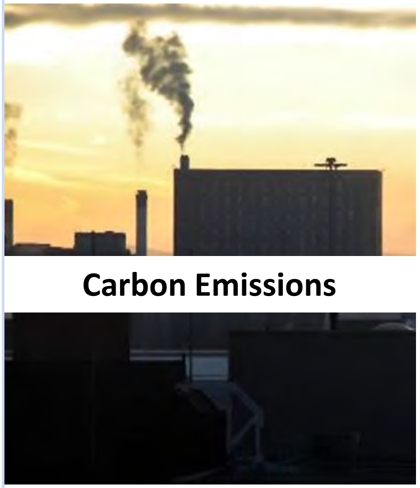
Future Looking Codes

"Step" / "Stretch" / "Tiered" codes look beyond current minimums to set targets for future cycles



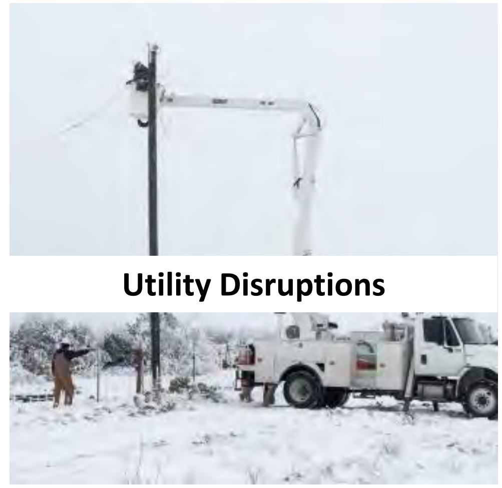
Source: *Lessons Learned from the BC Step Code:* https://www2.gov.bc.ca/assets/download/BF7BC92738AE4CACA5F5A521CB7DBCCE

Objectives Supporting Climate Change Mitigation & Adaption



Carbon Emissions

Limited Renewable Resources

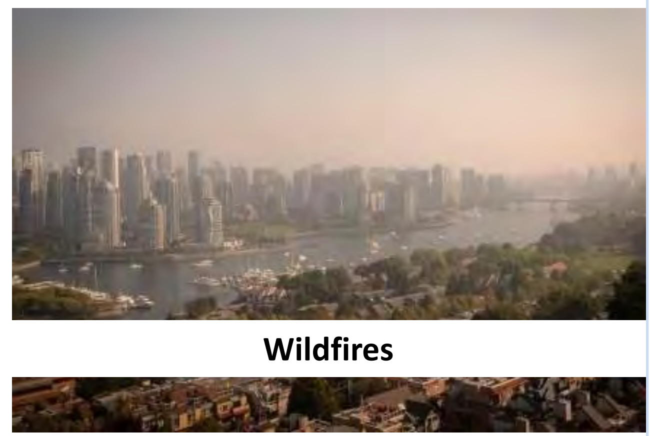


Utility Disruptions

Hotter Summers

Water Scarcity

Severe Weather



Wildfires

1. ENERGY USE

OBJECTIVE: Reduce the amount of energy required to operate a building

RATIONALE: Energy use reductions generally make buildings more affordable to operate and reduce burden on utilities, improved energy efficiency makes economies more cooperative.

Commonly Used Metrics	Emerging Metrics
Reference building comparison *% better than reference*	Energy Use Intensity, including TEDI & MEUI *kWh/m²·yr*

Notes

- Can we reliably forecast future source energy intensities?
- Should codes regulate primary energy use outside of their jurisdictions (e.g. imported electricity?)
- Can we use metered utilities to verify performance of existing buuldings?

2. CARBON EMISSIONS

OBJECTIVE: Reduce the amount of carbon emitted during building construction and operation

RATIONALE: Building operations comprise 27% of global GHG emissions, while emissions associated with construction materials are estimated to comprise another 20%.

Commonly Used Metrics	Emerging Metrics
—	Green House Gas Intensity (GHGi) $Kg\ CO_2\ equiv.\ /\ m^2 \cdot yr$

Notes

- Can we reliably forecast emission intensities of electricity utilities?
- Should codes regulate embodied carbon associated with imported materials?

3. ELECTRICITY DEMAND

OBJECTIVE: Reduce the instantaneous demand that buildings place on the electric grid

RATIONALE: Non-emitting electricity generation will be in high-demand in a Net-Zero Carbon world. Efforts to flatten building electrical demand help ensure there will be enough electricity.

Commonly Used Metrics	Emerging Metrics
—	Maximum Coincident Peak Electrical Demand *[TBD]*

Notes

- Is the time of the peak important? Or should the building strive for the flattest-possible profile?
- Should targets be adjusted to reflect occupancy types?
- What about emerging loads (for example, vehicle charging?)

4. WATER USE

OBJECTIVE: Reduce the water requirements inside the building

RATIONALE: Water is increasingly scarce in many regions. Building-level conservation and re-use efforts can help preserve this diminishing resource

Commonly Used Metrics	Emerging Metrics
—	Water Use Intensity $k\ell/m^2 \cdot yr$

Notes

- Is the time of the peak important? Or should the building strive for the flattest-possible profile?
- Should targets reflect occupancy?

5. OVERHEATING

OBJECTIVE: Ensure interior conditions remain survivable in the event of extreme heat

RATIONALE: Many regions now routinely cope with higher than expected summers; existing infrastructure struggles to maintain healthy conditions inside buildings. Occupants are at risk.

Commonly Used Metrics	Emerging Metrics
—	Design cooling load kW/m^2

Notes
• Is provision of mechanical cooling an acceptable compliance pathway?

6. ENDURANCE

OBJECTIVE: Ensure critical building operations continue during unexpected utility disruptions

RATIONALE: Utility outages are increasingly common. Enhanced endurance minimizes disruption to building operations, and affords more flexibility to utilities as they restore service.

Commonly Used Metrics	Emerging Metrics
—	—

Notes

- How should we balance active (ie – battery assisted) and passive (ie – envelope) enduranc ?

7. INDOOR AIR QUALITY

OBJECTIVE: Ensure occupied spaces meet adequate health standards

RATIONALE: Indoor pollutants greatly affect occupant health and productivity. Recent pandemic also highlighted the importance of reducing the spread of viruses.

Commonly Used Metrics	Emerging Metrics
—	Carbon dioxide concentrations *PPM* CO_2

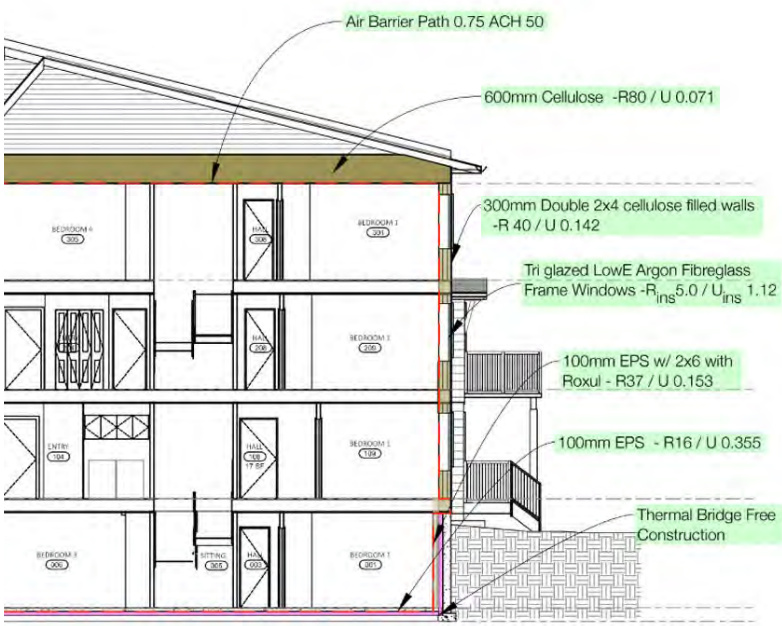
Notes
• Does the carbon dioxide concentration ensure adequate ventilation to manage all IAQ pollutants? • How should buildings respond to exterior pollutants (e.g. wildfire smoke)?

14

Comments on Outcome-based Codes

"This approach focuses on real and measurable energy performance improvement rather than on the relationship of the buildings' energy characteristics compared to a theoretical building built to a code baseline." [New Buildings Institute – 2012]

PROS	CONS
• When fully implemented, assures actual building performance achieves • Encourage more energy efficient building forms • Simplify code design, compliance and administration	• May limit functional forms that are otherwise necessary in some applications • Regulatory path for limiting operational energy use unclear in many regions, sectors. • More sensitive to accuracy, use of building simulation tools

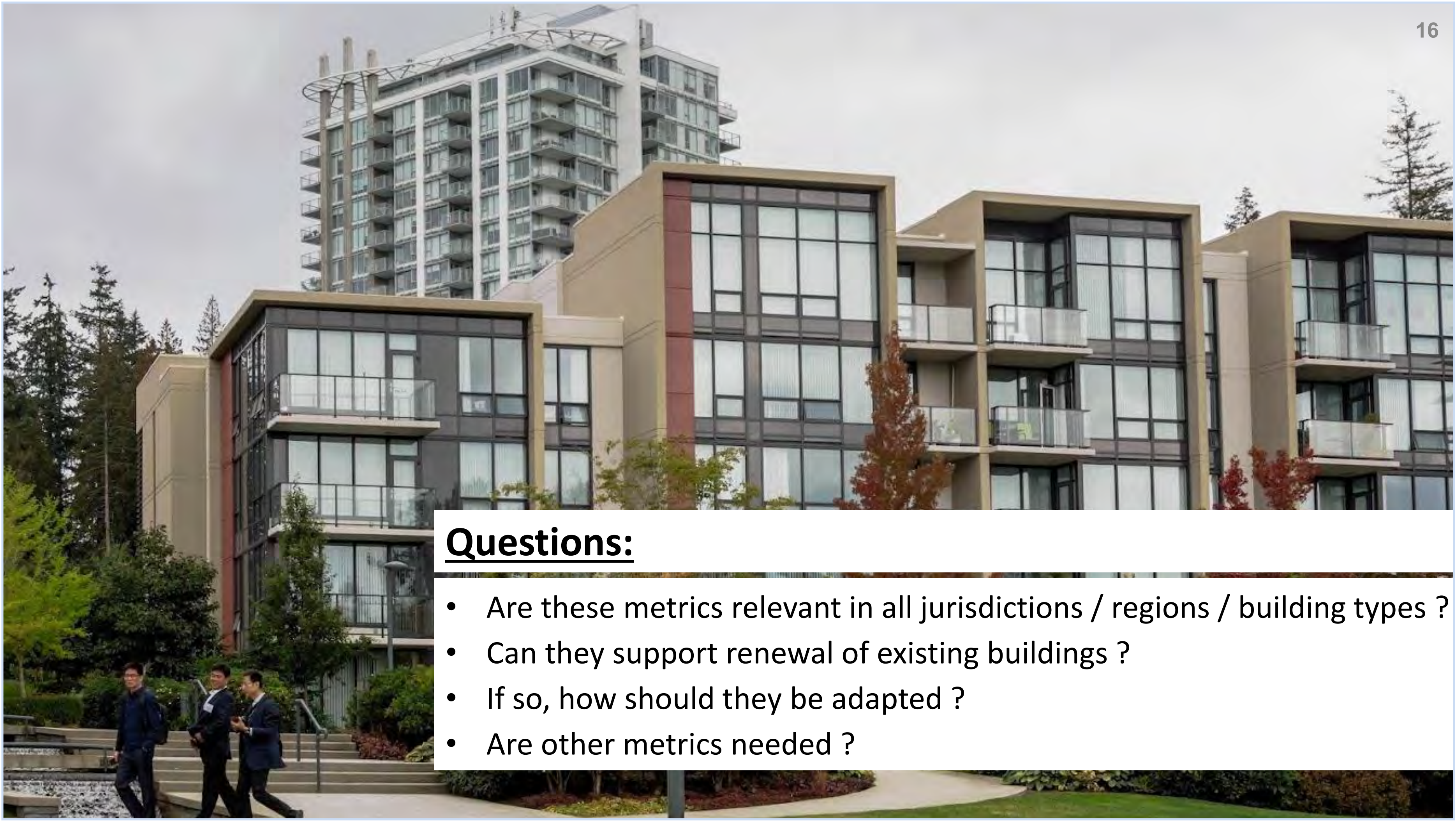


OBJECTIVE BASED CODES

- Ensure the home is designed according to the intent of the code
- Ensure that all of the design elements are installed during construction
- Do not verify as-operated performance

OUTCOME BASED CODES

- Endeavor to regulate as-operated energy use
- May include novel whole-building metrics and monitoring to close the performance gap
- Compatibility with regulatory scope unclear


16
Questions:
• Are these metrics relevant in all jurisdictions / regions / building types ?
• Can they support renewal of existing buildings ?
• If so, how should they be adapted ?
• Are other metrics needed ?

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3 – Right At Home Housing, Edmonton	Peter Amerongen, Edmonton
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All other photos — Collection of NRCan.

Canada

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EBC Annex 79: "Building codes and considerations for occupants"

IEA Future Buildings Forum Think Tank Workshop

Prof. Elie Azar, Carleton University

October 2022

IEA Future Buildings Forum Think Tank Workshop - Existing Buildings: Pathways to Net Zero Carbon 2035

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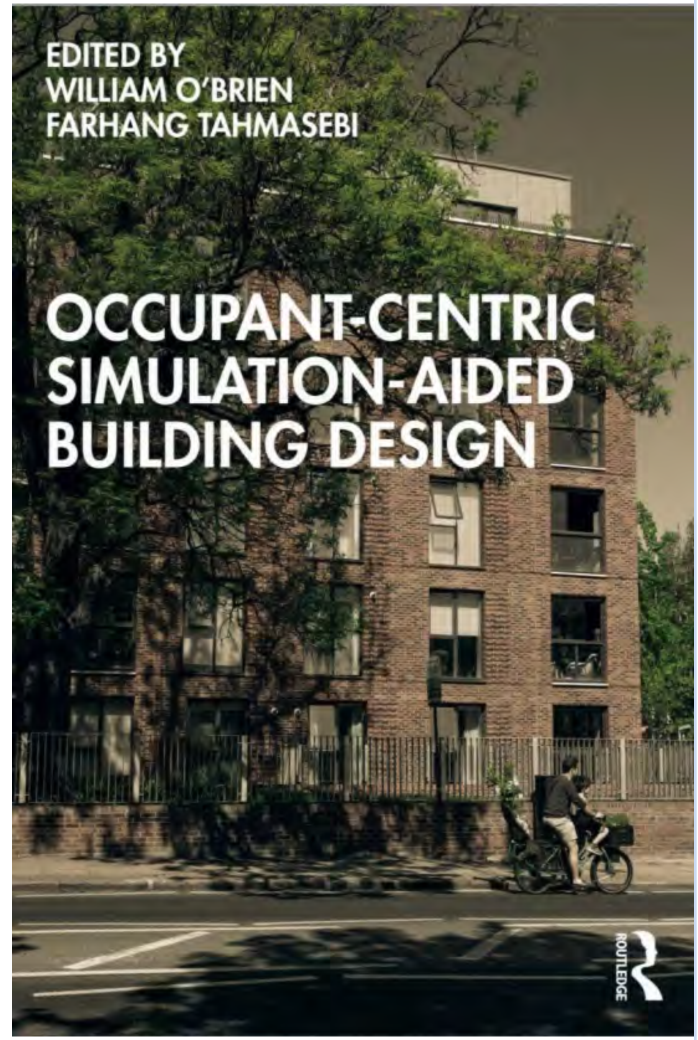
EBC Annex 79: Occupant-centric building design and operation (2018-2023)

ST1: Multi-aspect environmental exposure, building interfaces, and human behaviour

ST2: Data-driven occupant modeling strategies and digital tools

ST3: Applying occupant behavior models in a performance-based design process

ST4: Development and demonstration of occupant-centric building operating strategies



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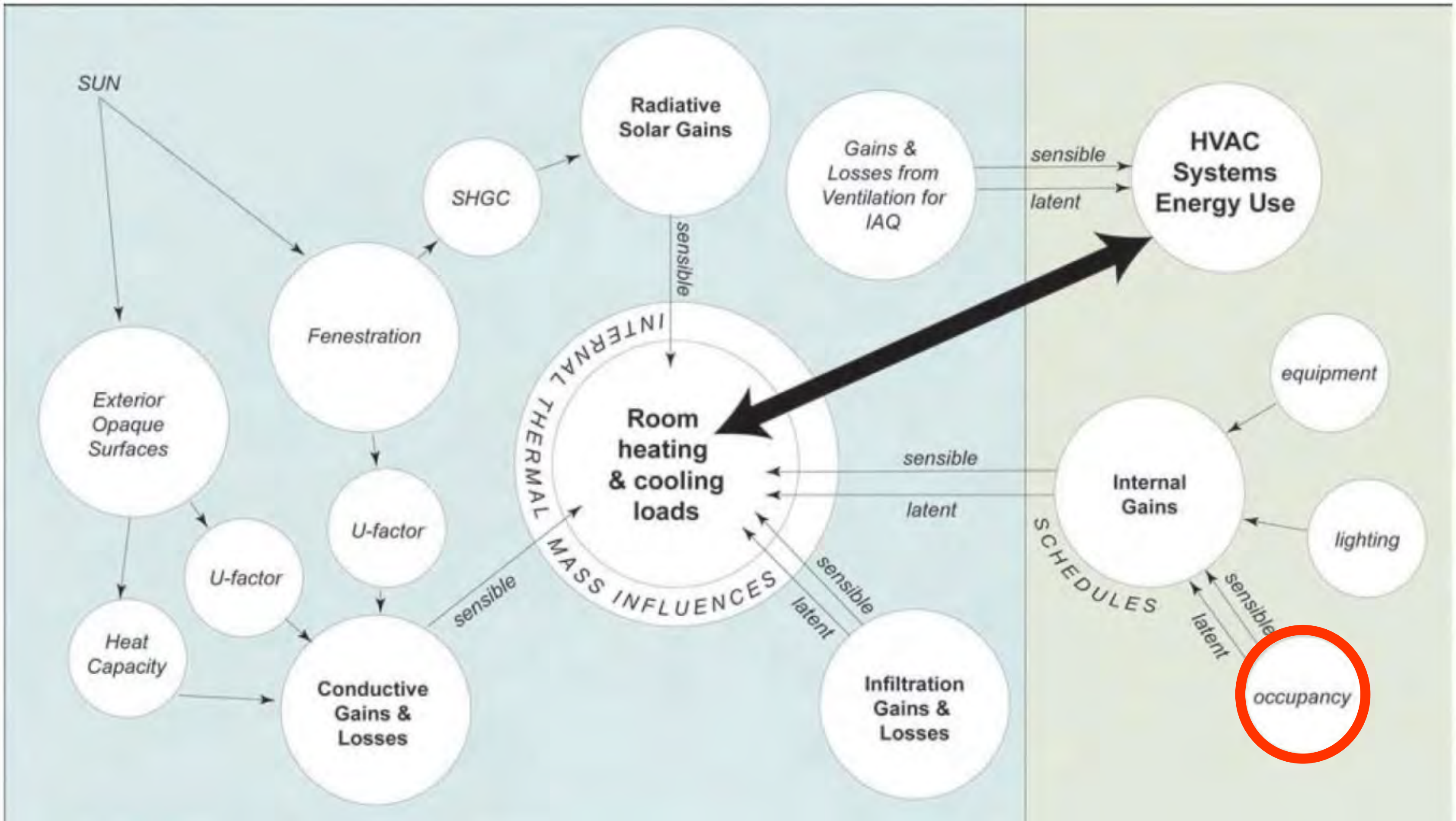
Current approach to occupants in design and code compliance



Source: ASHRAE Advanced Energy Design Guide

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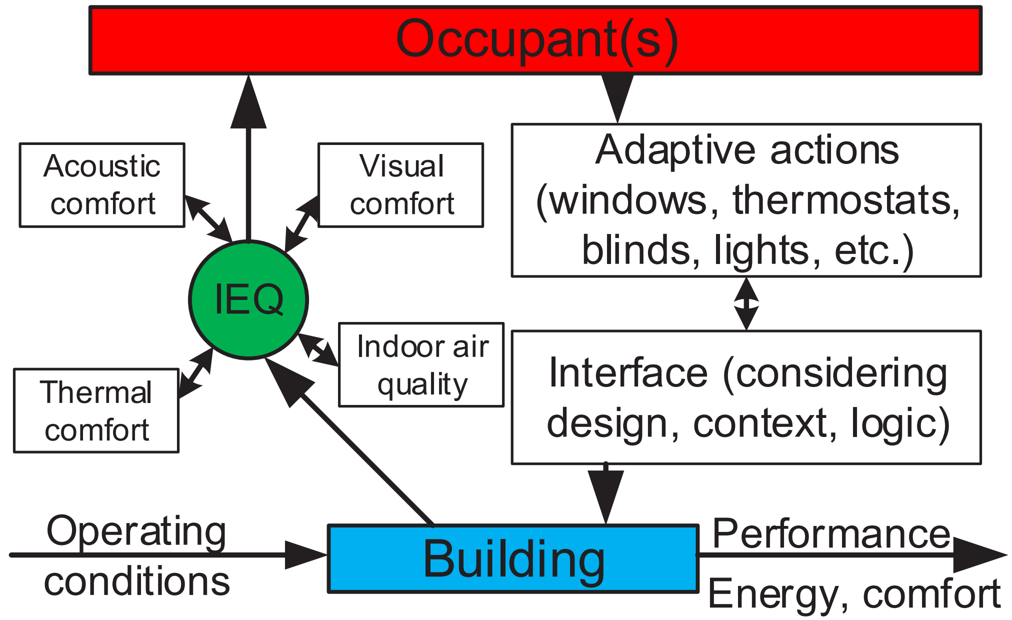
Two-way interaction between people and buildings



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Building energy codes have focused on hardware

- Codes focus on envelope, HVAC, and lighting
- Occupants play an increasing role in resource use AND timing: water use, window opening, appliances/equipment, purchasing decisions, etc.
- Occupants add uncertainty, but we cannot neglect them

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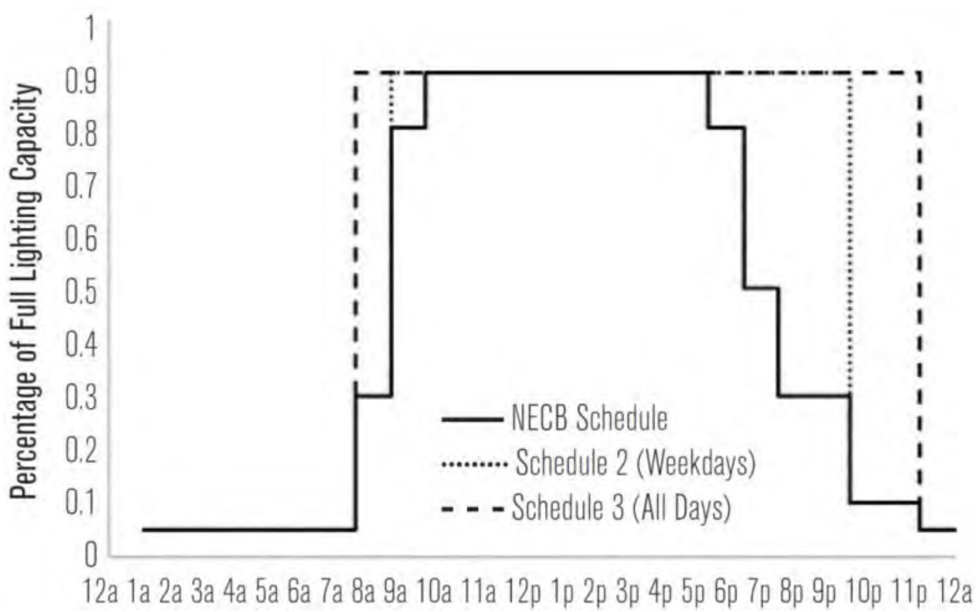
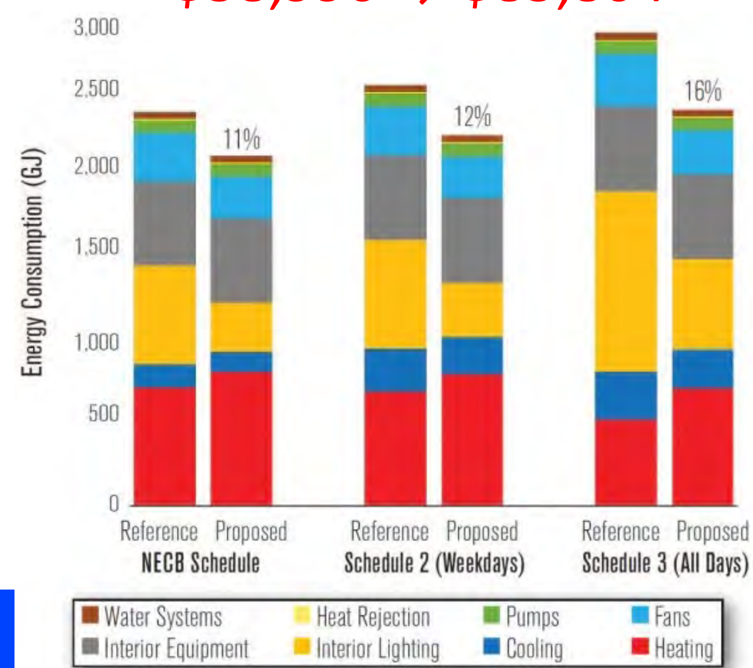
Two risks of inappropriate occupant modeling

1. Performance gap between predictions and reality
2. Inaccurate performance predictions mislead design teams and code committees



$58,990 → $85,804



Technology Collaboration Programme
by iea

International review of building energy codes (24 codes/standards)

- Large variety in how occupants are referenced
- Most codes assume occupants cannot be relied upon to save energy
- Very few codes assume design affects behavior

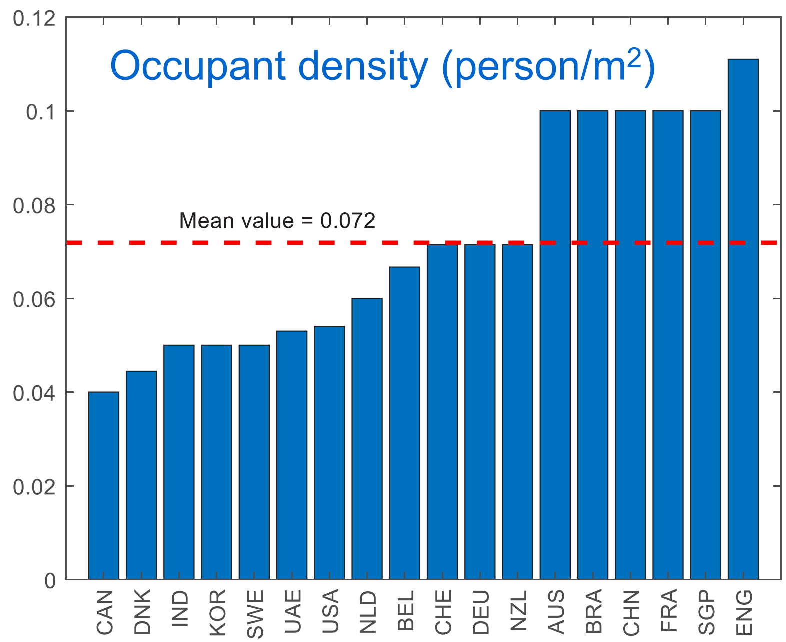
Technology Collaboration Programme
by iea

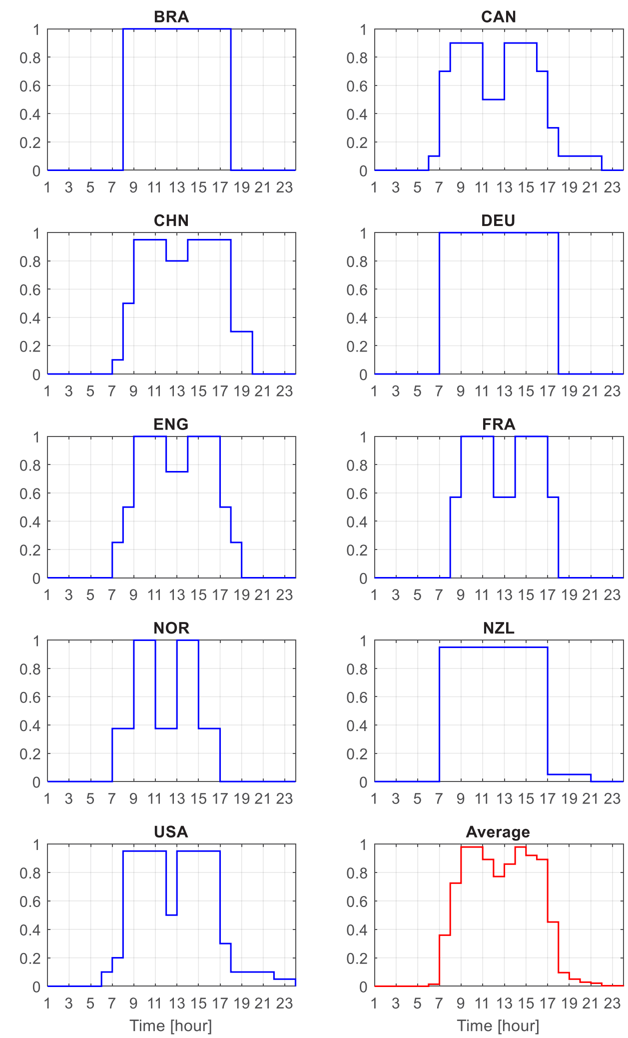
IEA Future Buildings Forum Think Tank Workshop - Existing Buildings: Pathways to Net Zero Carbon 2035

19th - 21st October 2022, Gatineau, Québec, Canada

International review of building energy codes

- Densities/schedules are dominant; some codes allow defaults to be customized





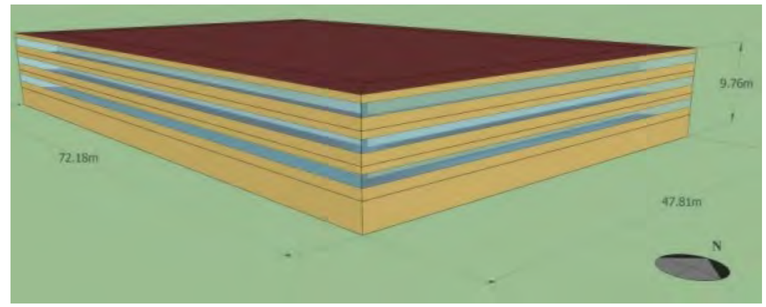
Technology Collaboration Programme by iea

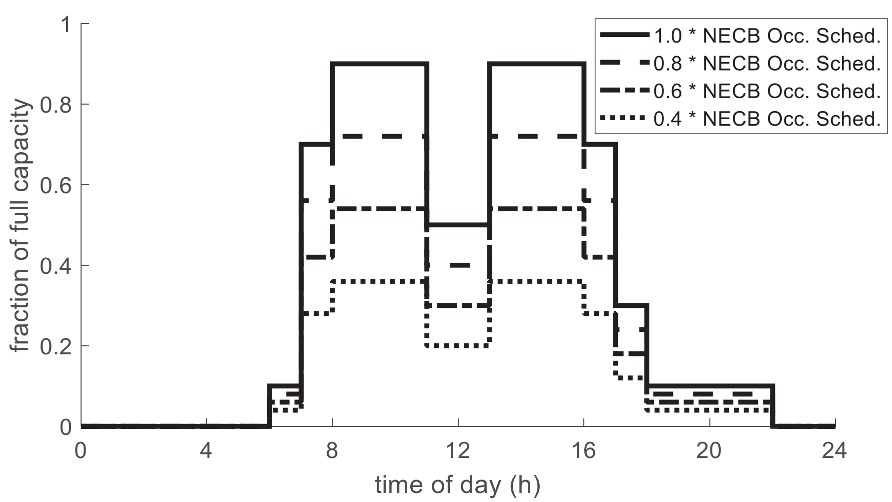
Encouraging occupancy-adaptability

- Most performance path requirements focus on a single set of occupant modeling assumptions
- Fixed assumptions do not push designers (or code committees) to consider occupancy adaptability
- A metric for occupancy-adaptability would help quantify this feature

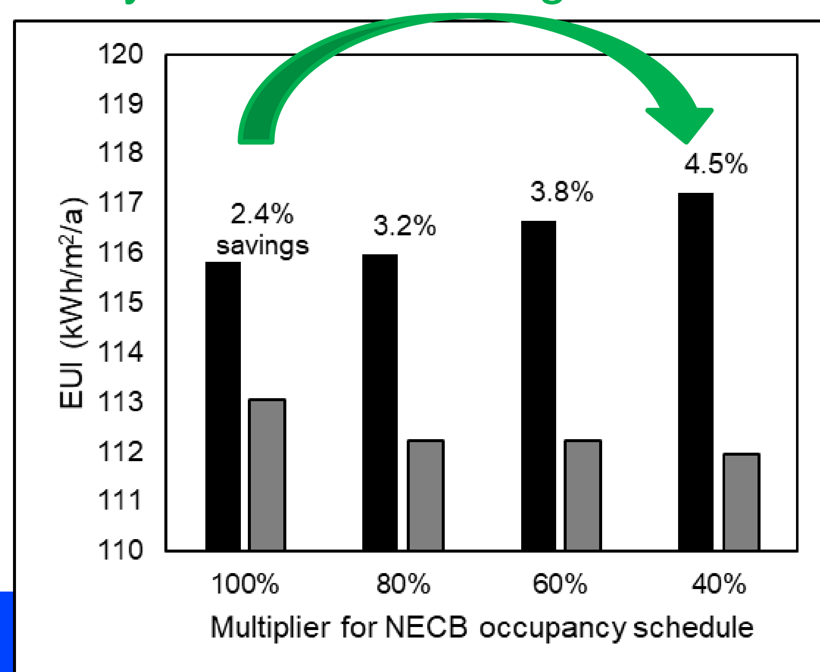
Encouraging occupancy-adaptability

- Occupancy-adaptability becomes vastly more critical for sub-maximum occupancy





Nearly double the savings from DCV



Existing buildings and occupants

- Occupancy sensing is becoming ubiquitous
- While there is uncertainty about new buildings, existing buildings are less uncertain
- Occupant data can and should be used to inform energy/carbon retrofits

Technology Collaboration Programme
by iea

Recommendations – simple to advanced

1. Add new requirements based on literature or other data sources *(prescriptive path)*
2. Update current schedules/densities/values *(performance path)*
3. Add additional occupant-related domains (e.g., window shades) *(performance path)*
4. Require several occupancy scenarios to be analyzed/modelled *(prescriptive or performance)*
5. Mandate measurement campaign as basis for occupant assumptions in retrofit projects *(performance)*

Technology Collaboration Programme
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Open questions

1. How should we address the uncertainty of occupants in codes, recognizing the consequences of simplistic assumptions (neglect of two-way interactions, optimization of design for a single scenario)?
2. What workflows could/should be developed to incorporate knowledge of occupants/occupancy in codes for existing buildings?
3. How should building codes be updated to reflect changing occupancy and space use (e.g., from telework)?
4. What metrics would be most suitable to quantify building energy/carbon performance regarding occupants?

Appendix 4: Participants

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Appendix 5:
Forum Program

Summary of the Forum Roadmap

Time	Day 1 | October 19	Day 2 | October 20	Day 3 | October 21
8:00	**Welcome & Networking**	**Welcome & Networking**	**Welcome & Networking**
9:00	**Session 1** • Opening of the 2022 Forum Introductions • Presentation on the importance of TCP • Presentations by TCP representatives	**Session 3** • Systems as Transformational Process • Presentations • Four 15-minute presentations • Q&A	**Session 5** • Building Energy and Carbon Codes • Presentations • Three 15-minute presentations • Q&A
15 minutes | Refreshment Break			
	Review of the agenda flow, outcomes, and key considerations	**Breakout Groups** • Group A: System Optimization • Group B: Districts and Cities	**Breakout Groups** • Group A: Metrics for building energy codes • Group B: The role of occupants in codes • Group C: Implementation challenges
	• Opening table discussions • Plenary debrief	• Plenary Presentations • Breakout Room Recommendations	• Plenary Presentations • Breakout Room Recommendations

Time	Day 1 | October 19	Day 2 | October 20	Day 3 | October 21
	12:00 | Lunch		
1:00	**Session 2** • 'Deep' Energy Retrofit • Challenges & Opportunities • Presentations • Four 15-minute presentations • Q&A	**Session 4** • Technological Systems as Catalysts for Future Proofing Buildings • Lessons learned and future readiness • Presentations • Four 15-minute presentations • Q&A	**Session 6** • Consolidation of session results & identification of common activities • Presentations • Four 10-minute presentations • Q&A
	15 minutes | Refreshment Break		
	Breakout Groups • Group A: Residential • Group B: Commercial & Public buildings	**Breakout Groups** • Group A: Ensuring performance of housing • Group B: Ensuring performance of buildings	**Breakout Groups** • Validation and prioritization process
	• Plenary Presentations • Breakout Room Recommendations	• Plenary Presentations • Breakout Room Recommendations	• Plenary Presentations • Breakout Room Recommendations
4:15	• Plus/Delta- Evaluation of the day • Review of agenda for day 2	• Plus/Delta- Evaluation of the day • Review of agenda for day 3	• Plus/Delta- Evaluation of the day • Closing Remarks
4:30	**Adjournment**	**Adjournment**	**Adjournment**
6:00		Dinner at *Mill Street Brew Pub*	