ANNEX 75

EBC
Energy in Buildings and Communities Programme

International Energy Agency

The District as Action Level for Building Renovation Combining Energy Efficiency & Renewables

A Short Guide for Investors and Decision-Makers

Energy in Buildings and Communities Technology Collaboration Programme

May 2023

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International Energy Agency

The District as Action Level for Building Renovation Combining Energy Efficiency & Renewables: Making use of the Potentials

A Short Guide for Investors and Decision-Makers

Energy in Buildings and Communities Technology Collaboration Programme

May 2023

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Preface

The International Energy Agency

The International Energy Agency (IEA) was established in 1974 within the framework of the Organisation for Economic Cooperation and Development (OECD) to implement an international energy programme. A basic aim of the IEA is to foster international cooperation among the 30 IEA participating countries and to increase energy security through energy research, development and demonstration in the fields of technologies for energy efficiency and renewable energy sources.

The IEA Energy in Buildings and Communities Programme

The IEA coordinates international energy research and development (R&D) activities through a comprehensive portfolio of Technology Collaboration Programmes (TCPs). The mission of the IEA Energy in Buildings and Communities (IEA EBC) TCP is to support the acceleration of the transformation of the built environment towards more energy efficient and sustainable buildings and communities, by the development and dissemination of knowledge, technologies and processes and other solutions through international collaborative research and open innovation. (Until 2013, the IEA EBC Programme was known as the IEA Energy Conservation in Buildings and Community Systems Programme, ECBCS.)

The high priority research themes in the EBC Strategic Plan 2019-2024 are based on research drivers, national programmes within the EBC participating countries, the Future Buildings Forum (FBF) Think Tank Workshop held in Singapore in October 2017 and a Strategy Planning Workshop held at the EBC Executive Committee Meeting in November 2017. The research themes represent a collective input of the Executive Committee members and Operating Agents to exploit technological and other opportunities to save energy in the buildings sector, and to remove technical obstacles to market penetration of new energy technologies, systems and processes. Future EBC collaborative research and innovation work should have its focus on these themes.

At the Strategy Planning Workshop in 2017, some 40 research themes were developed. From those 40 themes, 10 themes of special high priority have been extracted, taking into consideration a score that was given to each theme at the workshop. The 10 high priority themes can be separated in two types namely 'Objectives' and 'Means'. These two groups are distinguished for a better understanding of the different themes.

Objectives - The strategic objectives of the EBC TCP are as follows:

- reinforcing the technical and economic basis for refurbishment of existing buildings, including financing, engagement of stakeholders and promotion of co-benefits;
- improvement of planning, construction and management processes to reduce the performance gap between design stage assessments and real-world operation;
- the creation of 'low tech', robust and affordable technologies;
- the further development of energy efficient cooling in hot and humid, or dry climates, avoiding mechanical cooling if possible;
- the creation of holistic solution sets for district level systems taking into account energy grids, overall performance, business models, engagement of stakeholders, and transport energy system implications.

Means - The strategic objectives of the EBC TCP will be achieved by the means listed below:

- the creation of tools for supporting design and construction through to operations and maintenance, including building energy standards and life cycle analysis (LCA);
- benefitting from 'living labs' to provide experience of and overcome barriers to adoption of energy efficiency measures;
- improving smart control of building services technical installations, including occupant and operator interfaces;
- addressing data issues in buildings, including non-intrusive and secure data collection;
- the development of building information modelling (BIM) as a game changer, from design and construction through to operations and maintenance.

The themes in both groups can be the subject for new Annexes, but what distinguishes them is that the 'objectives' themes are final goals or solutions (or part of) for an energy efficient built environment, while the 'means' themes are instruments or enablers to reach such a goal. These themes are explained in more detail in the EBC Strategic Plan 2019-2024.

The Executive Committee

Overall control of the IEA EBC Programme is maintained by an Executive Committee, which not only monitors existing projects, but also identifies new strategic areas in which collaborative efforts may be beneficial. As the Programme is based on a contract with the IEA, the projects are legally established as Annexes to the IEA EBC Implementing Agreement. At the present time, the following projects have been initiated by the IEA EBC Executive Committee, with completed projects identified by (*) and joint projects with the IEA Solar Heating and Cooling Technology Collaboration Programme by (☼):

Annex 1: Load Energy Determination of Buildings (*)
Annex 2: Ekistics and Advanced Community Energy Systems (*)
Annex 3: Energy Conservation in Residential Buildings (*)
Annex 4: Glasgow Commercial Building Monitoring (*)
Annex 5: Air Infiltration and Ventilation Centre
Annex 6: Energy Systems and Design of Communities (*)
Annex 7: Local Government Energy Planning (*)
Annex 8: Inhabitants Behaviour with Regard to Ventilation (*)
Annex 9: Minimum Ventilation Rates (*)
Annex 10: Building HVAC System Simulation (*)
Annex 11: Energy Auditing (*)
Annex 12: Windows and Fenestration (*)
Annex 13: Energy Management in Hospitals (*)
Annex 14: Condensation and Energy (*)
Annex 15: Energy Efficiency in Schools (*)
Annex 16: BEMS 1- User Interfaces and System Integration (*)
Annex 17: BEMS 2- Evaluation and Emulation Techniques (*)
Annex 18: Demand Controlled Ventilation Systems (*)
Annex 19: Low Slope Roof Systems (*)
Annex 20: Air Flow Patterns within Buildings (*)
Annex 21: Thermal Modelling (*)
Annex 22: Energy Efficient Communities (*)
Annex 23: Multi Zone Air Flow Modelling (COMIS) (*)
Annex 24: Heat, Air and Moisture Transfer in Envelopes (*)
Annex 25: Real time HVAC Simulation (*)
Annex 26: Energy Efficient Ventilation of Large Enclosures (*)
Annex 27: Evaluation and Demonstration of Domestic Ventilation Systems (*)
Annex 28: Low Energy Cooling Systems (*)
Annex 29: ☼ Daylight in Buildings (*)
Annex 30: Bringing Simulation to Application (*)
Annex 31: Energy-Related Environmental Impact of Buildings (*)
Annex 32: Integral Building Envelope Performance Assessment (*)
Annex 33: Advanced Local Energy Planning (*)
Annex 34: Computer-Aided Evaluation of HVAC System Performance (*)
Annex 35: Design of Energy Efficient Hybrid Ventilation (HYBVENT) (*)
Annex 36: Retrofitting of Educational Buildings (*)
Annex 37: Low Exergy Systems for Heating and Cooling of Buildings (LowEx) (*)
Annex 38: ☼ Solar Sustainable Housing (*)
Annex 39: High Performance Insulation Systems (*)
Annex 40: Building Commissioning to Improve Energy Performance (*)
Annex 41: Whole Building Heat, Air and Moisture Response (MOIST-ENG) (*)
Annex 42: The Simulation of Building-Integrated Fuel Cell and Other Cogeneration Systems (FC+COGEN-SIM) (*)
Annex 43: ☼ Testing and Validation of Building Energy Simulation Tools (*)
Annex 44: Integrating Environmentally Responsive Elements in Buildings (*)
Annex 45: Energy Efficient Electric Lighting for Buildings (*)
Annex 46: Holistic Assessment Tool-kit on Energy Efficient Retrofit Measures for Government Buildings (EnERGo) (*)
Annex 47: Cost-Effective Commissioning for Existing and Low Energy Buildings (*)
Annex 48: Heat Pumping and Reversible Air Conditioning (*)
Annex 49: Low Exergy Systems for High Performance Buildings and Communities (*)
Annex 50: Prefabricated Systems for Low Energy Renovation of Residential Buildings (*)
Annex 51: Energy Efficient Communities (*)
Annex 52: ☼ Towards Net Zero Energy Solar Buildings (*)
Annex 53: Total Energy Use in Buildings: Analysis and Evaluation Methods (*)
Annexe 54: Integration of Micro-Generation and Related Energy Technologies in Buildings (*)

Annex 55: Reliability of Energy Efficient Building Retrofitting - Probability Assessment of Performance and Cost (RAP-RETRO) (*)
Annex 56: Cost Effective Energy and CO2 Emissions Optimisation in Building Renovation (*)
Annex 57: Evaluation of Embodied Energy and CO2 Equivalent Emissions for Building Construction (*)
Annex 58: Reliable Building Energy Performance Characterisation Based on Full Scale Dynamic Measurements (*)
Annex 59: High Temperature Cooling and Low Temperature Heating in Buildings (*)
Annex 60: New Generation Computational Tools for Building and Community Energy Systems (*)
Annex 61: Business and Technical Concepts for Deep Energy Retrofit of Public Buildings (*)
Annex 62: Ventilative Cooling (*)
Annex 63: Implementation of Energy Strategies in Communities (*)
Annex 64: LowEx Communities - Optimised Performance of Energy Supply Systems with Exergy Principles (*)
Annex 65: Long-Term Performance of Super-Insulating Materials in Building Components and Systems (*)
Annex 66: Definition and Simulation of Occupant Behavior in Buildings (*)
Annex 67: Energy Flexible Buildings (*)
Annex 68: Indoor Air Quality Design and Control in Low Energy Residential Buildings (*)
Annex 69: Strategy and Practice of Adaptive Thermal Comfort in Low Energy Buildings
Annex 70: Energy Epidemiology: Analysis of Real Building Energy Use at Scale
Annex 71: Building Energy Performance Assessment Based on In-situ Measurements
Annex 72: Assessing Life Cycle Related Environmental Impacts Caused by Buildings
Annex 73: Towards Net Zero Energy Resilient Public Communities
Annex 74: Competition and Living Lab Platform
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Annex 83: Positive Energy Districts
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Annex 87: Energy and Indoor Environmental Quality Performance of Personalised Environmental Control Systems
Annex 88: Evaluation and Demonstration of Actual Energy Efficiency of Heat Pump Systems in Buildings

Working Group - Energy Efficiency in Educational Buildings (*)
Working Group - Indicators of Energy Efficiency in Cold Climate Buildings (*)
Working Group - Annex 36 Extension: The Energy Concept Adviser (*)
Working Group - HVAC Energy Calculation Methodologies for Non-residential Buildings (*)
Working Group - Cities and Communities (*)
Working Group - Building Energy Codes
(*) – completed working groups

Summary

Urgent actions must be taken to decarbonise the building stock and meet the targets established in the Paris Agreement. Renovating the existing building stock to a zero-carbon level is a key priority to meet the decarbonisation goals. Apart from energy efficiency measures on the building envelopes, a switch to renewable energy-based heating and cooling systems is urgently required. Furthermore, in addition to building renovation at the individual building level, building renovation at the district level offers a promising perspective as a strategy to promote the much-needed acceleration of the decarbonisation of the building sector.

With this background, the IEA EBC Annex 75 - Cost-effective Building Renovation at District Level Combining Energy Efficiency & Renewables[1] aimed to clarify the cost-effectiveness of various building renovation approaches combining energy efficiency and renewable energy measures at the district level. The objective was to provide guidance to balance and enable an innovative and optimal mix of measures to decarbonise the existing residential buildings at the district level. Taking advantage of the potential synergies between energy efficiency measures and measures that promote the use of renewable energy, the aim was to show the possible combinations of technologies and the contexts in which they are most viable. It also aimed to show which business models can support the processes and which policies and processes organisations can help modernise and accelerate building renovation processes.

In this context, a comprehensive and detailed Guidebook[2] (Meyer et al., 2023) was prepared to provide target group-oriented recommendations for policymakers and investors/decision-makers. As a supplement to this Guidebook, two complementary versions offer more straightforward guidelines oriented to each target audience, with a summary of the main recommendations.

This document provides guidance to investors and decision-makers only. A similar document is also available with guidance to policymakers.

All project documents are available on the IEA EBC Annex 75 website (https://annex75.iea-ebc.org/publications). On this website, a document with the terminology used in all the reports produced within this project and the definitions of the terms used (Hidalgo-Betanzos et al., 2023) is also available.

[1] https://annex75.iea-ebc.org/about

[2] https://annex75.iea-ebc.org/publications

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Overview of Fields of Action

The guidelines presented in this document give recommendations for investors and decision-makers on upscaling building renovation to a district level, considering both energy efficiency and renewable energy measures towards the decarbonisation of the building sector. The guidelines advise investors and decision-makers based on the most relevant outcomes of the work carried out in IEA EBC "Annex 75 - Cost-effective Building Renovation at District Level Combining Energy Efficiency & Renewables".

Throughout this document, all actors or stakeholders who make investment decisions for building renovation or are involved in this decision-making process are considered investors and decision-makers. These guidelines intend to serve a diverse group of actors involved in building renovation, such as private or public building owners, assemblies of homeowners, housing associations, public housing companies, private housing companies, investment funds, consultants, building companies, energy companies, etc. Each of these actors has highly specialised knowledge within their field and operates in specific local markets. These guidelines do not intend to provide concrete business advice for specific investment groups or local markets. Instead, the present document intends to guide investors and decision-makers on the topic of the Annex 75 project. However, it remains necessary to reflect, adapt, interpret and examine the applicability of the recommendations before applying them to any market or investment project.

The present document gives a brief thematic overview of the issues related to building renovation at the district level. It provides key recommendations for investors and decision-makers for six specific fields of action. Detailed background information and recommendations based on the findings of this project can be found in the extensive Guidebook (Meyer et al., 2023) and several topic-specific reports.[3]

This document is structured as follows:

1. Establishing the District as Action Level for Building Renovation
2. Techno-Economic Potentials of Upscaling Building Renovation to the District Level
3. Business Models Supporting Upscaling of Building Renovation to the District Level
4. Local Policy Instruments for Upscaling Building Renovation to the District Level
5. Supporting Building Renovation at District Scale through Process Organization & Stakeholder Dialogue
6. District-Oriented Mobilisation for Building Renovation
7. Conclusions

[3] See https://annex75.iea-ebc.org/publications

1. Establishing the District as Action Level for Building Renovation

Changing the scope of policy action for building renovations from individual buildings to groups of buildings in districts (district approach) holds several technological, economic, organisational and mobilisation potentials. These potentials can be economies of scale, integrated approaches to building renovation that allows considering additional issues and plans for infrastructure and urban development, communication synergies within a district, or the use of district solutions for heating or cooling supply systems that allow the integration of renewable energy sources that could not be accessed through decentralised systems.

In addition, other reasons for promoting district solutions are the opportunity to overcome space or noise restrictions possibly related to decentralised systems in some of the buildings within a district, increased flexibility, the possibility to increase resilience through multiple energy systems, the opportunity to apply particularly innovative systems associated with fewer emissions, and the possibility of greater engagement among building owners when acting collectively.

Furthermore, there are indications that synergies between energy efficiency measures and renewable energy are greater for district systems than for decentralised systems when environmental heat is used through heat pumps. Although complexity grows by "zooming out" from the individual building level, the district level allows a more tailored perspective and approach compared to a broader scope, such as the city level.

However, the district, as the action level, can be associated with various challenges, depending on its concrete characteristics. Districts can have complex stakeholder structures with different interests and tasks. This can be a limitation for the potential synergies. Especially at the beginning, significant efforts in planning, coordination and communication are necessary to make use of the potential of district projects. Also, from a techno-economic perspective, building renovation projects at the district level are associated with high upfront costs and potential risks due to a dependency on a set number of customers for profitability. Furthermore, district approaches are overall not necessarily more cost-effective than decentralised solutions.

Investors and decision-makers can benefit from the stated potential. They can look for specific support to address the challenges.

The key recommendations below can be helpful in profitably making use of this potential.

OPERATIONAL RECOMMENDATIONS
Cooperate with local policymakers, local actors and others involved in the energy transition, and take advantage of their additional specific knowledge or the better anticipation of their actions and positions
Offer/use integrated services where possible, e.g., profit from a more holistic view on building renovation and potentially more individually balanced and efficient multi-measured building renovations
Set the base for district approaches in building renovations that combine renewable energy supply and energy efficiency measures, leveraging the potential of related synergies and profiting from the

associated techno-economic possibilities and synergies, such as economies of scale or more renewable energy integration options
Take advantage of existing subsidies and be proactive in upscaling the decarbonisation of building stock and energy supply systems, as regulative pressure is likely to grow further

2. Techno-Economic Potentials of Upscaling Building Renovation at the District Level

Upscaling building renovation at the district level involves multiple interdependent investments, energy consumption decisions and the selection of different technology options and their combinations. These decisions are often fragmented and mainly made by private actors. In this context, it is important for investors to consider the techno-economical potentials of building renovation at the district level in assessments and investment decisions.

Based on the work carried out in IEA EBC Annex 75 and specifically on the report on barriers and drivers for energy-efficient renovation at the district level (Johansson et al., 2023) and the report on strategies to transform existing districts into low-energy and low-emission districts (Walnum et al., 2023), the most important key recommendations for investors and decision-makers are listed below.

Furthermore, the various strategies to transform existing districts into low-energy and low-emission districts and the opportunities and risks of such strategies are also outlined. The developed strategies were derived from the starting conditions defined in the IEA EBC Annex 75 methodology report (Bolliger et al., 2023) and the calculations performed on generic districts (Säwén et al., 2023) and specific case studies (Venus et al., 2023a).

OPERATIONAL RECOMMENDATIONS
Keep in mind the potential effects of specific local preconditions, such as energy and building materials prices, regulatory frameworks and user behaviour, when estimating potential techno-economic benefits and cost-effectiveness
Be transparent about these specific influencing factors when communicating with potential costumers
Take into account synergies between energy efficiency measures and the use of renewable energy when developing projects for building renovation at the district level
Analyse each precondition: the best building renovation options can be narrowed down significantly by analysing climatic conditions, spatial restrictions and available natural resources, existing supply infrastructure, individual building and district-wide energy needs, technical capacities, possibilities for energy storage, free heat access, etc.
Compare and evaluate, from a life cycle perspective, energy consumption costs, investment costs and operational costs, but also consider the potential socio-economic effects and possible acceptance issues of planned technological interventions
Plan any district intervention in such a way that it integrates well with the external energy system
Keep using the existing district thermal grid if it is in good shape as, usually, it is more cost-effective
Explore or encourage the reduction of temperature in the heat grids while ensuring the necessary hygienic conditions

Take the opportunity to implement energy efficiency measures in building envelopes whenever renovations are required anyway
Elaborate options for standardisation and prefab products to increase cost-effectiveness
Ensure that the workforce is knowledgeable about energy efficiency and the use of renewables, as a skilled workforce is an essential precondition for innovative upscaling of building renovation
Analyse situations individually according to the aforementioned recommendations since it is not possible to generalise about the cost-effectiveness of heat supply solutions, whether centralised or decentralised

Several strategies to transform the existing districts into low-energy and low-emission districts and related advantages, disadvantages, opportunities and risks when developing neighbourhood renovation plans are described next.

The developed strategies were derived from the starting conditions defined in the IEA EBC Annex 75 methodology report (Bolliger et al., 2023) and the calculations performed on generic districts (Säwén et al., 2023) and specific case studies (Venus et al., 2023a). The strategies are further distinguished into two levels:

- Thermal energy production and distribution concept: Centralised approaches are distinguished from decentralised approaches. A centralised approach refers to one production unit distributing thermal energy to several buildings, while a decentralised approach refers to one production unit per building;
- Heating and cooling production technology.

Starting condition S1

Urban districts decentrally heated by natural gas, oil or electricity, or decentrally cooled through individual cooling devices

In starting condition 1, buildings are heated or cooled decentrally, not existing a central heating system in the district. The main strategic choice regarding the energy supply systems is whether a centralised heating system is installed or whether decentralised systems are replaced with new decentralised systems based on renewable energy.

Strategy S1.1 | New central district systems based on heat pumps, biomass or seasonal thermal energy storage

KEY ADVANTAGES AND OPPORTUNITIES	Allows to tap into large-scale heat sources, such as waste heat, surface water, groundwater, seasonal storage of waste heat or seasonal solar thermal storage
	Economies of scale in heat generation, more professional operation
	Lower electricity tariff due to being a large electricity consumer

	Can overcome challenges related to space or noise restrictions for individual heating systems
	Potentially large synergies with energy efficiency measures on building envelopes
	As the energy efficiency of building envelopes increases through renovation measures, the area covered by the district heating system can potentially be expanded to make use of its capacity, which, otherwise, is no longer needed
	Flexibility in energy source
	Large scale may allow applying particularly advanced solutions, e.g., better filters for burning biomass leading to higher air quality, or refrigerants for heat pumps with a low global warming potential
KEY DISADVANTAGES AND RISKS	Energy losses and lower heat pump efficiency due to higher heat distribution temperature
	To fully harness the benefits of energy efficiency measures, all buildings are required to achieve a high energy performance to allow a reduction of the supply temperature
	Depends on the willingness of building owners to connect; risk that project cannot be launched
	A complex process that takes time
STRATEGY RECOMMENDATIONS	This strategy is suited for districts with the following properties:
	Large heat sources that otherwise could not be used
	Overall high linear heat density
	Space restrictions or noise restrictions make the installation of individual heating systems based on renewable energy challenging
	Feasibility to develop new infrastructure without significant practical limitations
	Available space and sources to develop a central thermal energy system

Strategy S1.2 | Switching to decentralised heat pumps

KEY ADVANTAGES AND OPPORTUNITIES	Heat pumps are a cost-effective solution available for individual buildings, which do not have the challenges related to local air pollution as is the case with decentralised wood energy systems
	No need to develop an external infrastructure for district heating
	Less energy losses and higher heat pump efficiency compared to a centralised system due to lower energy supply temperature and optimum adjustment to each building

	Synergies with energy efficiency measures occur at each building directly and do not depend on energy efficiency measures in other buildings
	Decentralised heat pumps can easily deliver different temperatures for domestic hot water and space heating, which improves efficiency
	Easy to combine with covering cooling needs
	The solution can efficiently be combined with free cooling for ground or water-based heat sources
	Combining a heat pump-based heating/cooling system and photovoltaics is a good solution as it increases self-consumption and reduces grid issues due to high export power
	Two or three neighbouring buildings could be connected to microgrids, allowing them to benefit from some advantages of a district approach without creating many dependencies
KEY DISADVANTAGES AND RISKS	In contrast to wood, heat pumps require a significant amount of electricity at a time of the year when electricity production through photovoltaics is weak
	Potential challenges regarding noise from air source heat pumps, potential challenges regarding the possibility of drilling boreholes for ground source heat pumps
	No energy exchange between buildings typically means that the sum of installed capacity will be greater than the necessary installed capacity for a central system
	Connection of many small heat pumps may cause grid connection issues
	Focusing on decentralised systems only could make it more challenging to switch all buildings to renewable energy in a district, as for some buildings, this might be particularly challenging to achieve and, thus, it could be highly beneficial if there was a district approach
	Efficient large-scale heat sources might not be made use of
	No fuel source flexibility
STRATEGY RECOMMENDATIONS	This strategy is recommended for districts with the following main properties:
	No existing thermal network
	Overall low linear energy density
	Few challenges for drilling boreholes for ground source heat pumps or few challenges for conforming with noise restrictions for air source heat pumps
	Lack of availability of a large-scale heat source that could be used efficiently

Starting condition S2

Urban districts connected to district heating systems with a high share of non-renewable energy

In starting condition 2, there is an existing central heating system in the district with a high share of non-renewable energy. For this starting condition, the main strategic choice is to maintain the central heating system and switch it to district renewable energy sources or to disconnect the district system and use renewable energy sources per building. Another option, not considered here, is to disconnect a district from a large district heating system and install its own renewable energy-based district heating system.

Strategy S2.1 | Switching the existing central heating system to renewables

KEY ADVANTAGES AND OPPORTUNITIES	Minimum work is necessary on the thermal energy systems of the buildings, as the system, in principle, remains unchanged
	If the buildings are already connected to a district heating system, it is likely that there will not be space readily available to install a heating system in each building
	Economies of scale in the heating system; more professional operation
	If the existing infrastructure is in good shape, this is usually a more cost-effective solution than disconnecting from the grid
	A large-scale system often increases the number of possible renewable energy sources and opens the possibility of accessing large-scale renewable heat sources. For example, the combination of solar thermal systems with seasonal storage and top-up heaters is only reasonable for large-scale systems
	The approach allows network operators to provide heating to buildings where, due to space or noise restrictions, installing individual heating systems in each would be a challenge
	Lower electricity tariff for being a large electricity consumer
KEY DISADVANTAGES AND RISKS	There are more energy losses than in decentralised systems
	The system must operate at a higher temperature than the individual systems because it has to meet the needs of the building with the highest temperature requirements in the grid, which is not favourable for the efficiency of a centralised heat pump. To fully harness the benefits of energy efficiency measures, all buildings are required to achieve high energy performance to allow for a reduction in the supply temperature
	In the case of an existing district heating system, energy efficiency measures on building envelopes create fewer synergies with the district heating system, as pipes are not likely to be replaced soon

	If significant energy efficiency measures are implemented on the buildings within the district, the efficiency of the distribution system will be reduced due to higher relative heat losses. This can be counteracted if the energy efficiency measures mean lower distribution temperature, which reduces the heat losses and can improve the efficiency of the heat production
STRATEGY RECOMMENDATIONS	This strategy is recommended for districts with the following main properties:
	As a precondition: Districts already connected to a district heating system
	The existing district heating infrastructure is in good shape
	Possibilities to influence the investments in the central district heating system
	Large renewable energy-based heat sources that otherwise could not be used
	Space or noise restrictions make installing individual heating systems based on renewable energy challenging
	Clear vision to move towards medium or low-temperature heat grids

Strategy S2.2 | Switching to decentralised heat pumps[4]

KEY ADVANTAGES AND OPPORTUNITIES	Heat pumps are a cost-effective solution available for individual buildings, which do not have the challenges related to local air pollution as is the case for decentralised wood energy systems
	Attractive solution, if energy efficiency measures carried out in buildings result in low linear heat density and/or the existing grid is in poor condition
	No need to develop an external infrastructure for district heating
	Fewer energy losses and higher heat pump efficiency compared to a centralised system due to lower energy supply temperature
	Synergies with energy efficiency measures occur at each building directly and do not depend on energy efficiency measures in other buildings
	Decentralised heat pumps can easily deliver different temperatures for domestic hot water and space heating, which improves efficiency
	Easy to combine with covering cooling needs
	The solution can efficiently be combined with free cooling for ground or water-based heat sources
	Combining a heat pump-based heating/cooling system and photovoltaics is a good solution as it increases self-consumption and reduces grid issues due to high export power

[4] A switch to district heat pumps was not studied within the IEA EBC Annex 75. It requires that the grid within the district has the correct layout and that the district owns the grid. Nevertheless, it is a very relevant option for some scenarios.

	Two or three neighbouring buildings can be connected to microgrids, allowing them to benefit from some of the advantages of a district approach without creating too much dependency.
KEY DISADVANTAGES AND RISKS	In contrast to wood, heat pumps require a significant amount of electricity at a time of the year when electricity production through photovoltaics is weak
	Potential challenges regarding noise from air source heat pumps, potential challenges regarding the possibility of drilling boreholes for ground source heat pumps
	No energy exchange between buildings typically means that the sum of installed capacity will be greater than the necessary installed capacity for a central system
	The connection of many small heat pumps may cause grid connection issues
	Focusing on decentralised systems only could make it more challenging to switch all buildings to renewable energy in a district, as for some buildings, this might be particularly difficult to achieve, and for those buildings, it could be highly beneficial if there was a district approach
	Efficient large-scale heat sources may not be used
	No fuel source flexibility
STRATEGY RECOMMENDATIONS	This strategy is recommended for districts with the following main properties:
	The existing thermal energy grid is in poor shape
	Overall low linear energy density
	Few challenges for drilling boreholes for ground source heat pumps or few challenges for conforming with noise restrictions for air source heat pumps
	Lack of availability of a large-scale heat source that could be used efficiently

Starting condition S3

Urban districts connected to district heating systems with a substantial share of renewable energy carriers

In starting condition 3, there is an existing central heating system in the district with a substantial share of renewable energy. This starting condition is typical for the Nordic countries, where district heating infrastructure is well developed and the heat is usually based on biomass boilers, waste incineration or heat pumps. For this starting condition, the main question is whether the connection to the district heating system is preserved and the district heating system is switched entirely to renewables, or whether the district is disconnected from the existing district heating system and switched to renewable energy sources per building. Another option, which is not considered here, is if a district is disconnected from a large district heating system and gets its own renewable energy-based district heating system.

Strategy S3.1 | Keep the connection to the district heating system and fully switch it to renewables

KEY ADVANTAGES AND OPPORTUNITIES	As for S2.1.
KEY DISADVANTAGES AND RISKS	As for S2.1, with the following difference: In the case of an existing district heating system with a substantial share of renewable energy carriers already in its mix, energy efficiency measures on building envelopes create even fewer synergies with the district heating system, as not only pipes but also large parts of the heat generation systems are not likely to be replaced soon
STRATEGY RECOMMENDATIONS	This strategy is recommended for districts with the following main properties:
	As a precondition: Districts already connected to a district heating system
	The existing district heating infrastructure is in good shape
	Few additional costs to switch the central system fully to renewables
	Possibilities to influence the investments in the central district heating system
	Large renewable energy-based heat sources that could otherwise not be used
	Space or noise restrictions make the installation of individual heating systems based on renewable energy challenging
	Clear vision to move towards medium or low-temperature heat grids

Strategy S3.2 | Switching to decentralised heat pumps

KEY ADVANTAGES AND OPPORTUNITIES	As for S2.2.
KEY DISADVANTAGES AND RISKS	As for S2.2.
STRATEGY RECOMMENDATIONS	This strategy is recommended for districts with the following main properties:
	The existing thermal energy grid is in poor shape
	Overall low linear energy density
	Few challenges for drilling boreholes for ground source heat pumps or few challenges for conforming with noise restrictions for air source heat pumps
	Lack of availability of a large-scale heat source that could be efficiently used

3. Business Models Supporting Upscaling of Building Renovation to the District Level

Business models can support the upscaling process of building renovation to a district scale. Upscaling building renovation to the district level can lead to new levels and scopes of building stock renovation, energy supply strategies, and change cost scenarios, which is important to consider in developing business models.

Business models are primarily relevant to investors and decision-makers. Long-term and forward-looking planning of building renovation is necessary. Building owners, from private homeowners to housing associations, need to coordinate the renovation cycles of their properties to align with the district solutions, as outlined in long-term integrated district renovation plans. This is a highly challenging task, both at an individual house or building level, considering mixed ownership, short turnover periods, limited funds and other constraints.

Depending on their capacities, possible investors should take advantage of policy instruments, such as subsidies, and innovative financial schemes, such as EPCs, prosumer revenues, and crowdfunding.

Intermediary actors and energy service companies or utilities could support private and small-scale homeowners with a more long-term and forward-looking assessment of building renovation options, utilising financing options and potentially developing new business models around these tasks.

A long-term planning perspective can be achieved with coordination between the policymakers and the investors/decision-makers, with the help of advisors and other market intermediaries with the knowledge and experience to facilitate the investors' decision-making.

Based on the work of IEA EBC Annex 75, specifically on the report on business models (Konstantinou et al., 2023), the following table lists the most important key recommendations for supporting investors and decision-makers regarding the development of business models for upscaling building renovation through district projects, and to also make use of synergies between energy efficiency measures and renewables.

OPERATIONAL RECOMMENDATIONS
Combine energy efficiency and renewables in business models for building renovation at the district level
Identify and, if possible, streamline the renovation cycles of properties to align with the district solutions, as outlined in long-term energy plans
Participate in the dialogue between the policymakers, investors and implementing actors e.g., with the help of advisors and other market intermediaries
Put the requirements for innovative energy improvements in districts forward to policymakers
Explore different levels and scopes of building stock renovation and energy supply strategies (include additional value propositions)

Offer decarbonisation (which also helps to achieve energy security and affordable energy prices) as a new value proposition that aligns with national and international goals of the policymakers and is expressed in the energy planning (anticipating future regulation)
Offer district quality and infrastructure, including the buildings, as part of the integral values of the interventions, in coordination with the urban planning of the policy actors
Use the potential for upscaling and replication of district decarbonisation solutions in energy communities, also considering optimisation through digital processes and technologies
Structure tariffs of district heating or cooling systems in a way to provide incentives for energy efficiency measures on building envelopes, in particular, if achieved in all the districts and temperature in the grid can accordingly be lowered
Consider planning an extension of a district heating system as energy efficiency measures reduce energy needs within a given area
Offer interim solutions for building owners who need to replace their heating system while the district heating system is not yet in place
Establish partnerships of energy companies with renovation solution suppliers and further practitioners in the implementation of building renovation

4. Local Policy Instruments for Upscaling Building Renovation to the District Level

Municipalities have a key role in advancing building renovation at the district level and can assume various functions: As initiators, they can provide an initial impetus for building renovation projects at the district level. Municipalities can also develop concepts and municipal energy planning for setting the cornerstones for future district projects. From a strategic planning view, the municipality is a potential decision-maker, legislator or regulator. It is also up to local policymakers to connect existing concepts, procedures, strategies and tools related to district-level renovation efforts with each other.

Municipalities also have an important role to play as role models, for example, in the form of model renovations and pilot projects, but also by selecting the tender with the most attractive project from an energy/environmental perspective.

Municipalities can be facilitators to obtain funding, information hubs, and communicators. They can provide advice and organisational support to enable district projects. They can assume functions as mediators, coordinators, motivators, or funding institutions. Among various government institutions, they have the best knowledge about local conditions and are best positioned to interact with citizens and stakeholders at the local level. For example, they can also be producers or suppliers of heat or cooling through public companies they own.

In addition, local authorities already have the task of carrying out urban planning and authorising or monitoring construction and renovation projects. Thus, there are numerous opportunities to link ongoing local processes to new activities to encourage building renovation at the district scale. There is a significant opportunity for local authorities to advance district projects by being involved from the outset and by providing support through their commitment.

Naturally, recommendations regarding local policy instruments are primarily intended to serve policymakers, utilities, and energy suppliers in charge of the local energy and heat infrastructure. Nevertheless, also some specific recommendations can be made in this context to investors and decision-makers.

The following table shows key recommendations for this specific target group. Detailed information about this topic can be found in the related IEA EBC Annex 75 report on policy instruments (Mlecnik et al., 2023).

OPERATIONAL RECOMMENDATIONS
Exploit the potential of formal or informal participation processes offered by public administrations
Follow and comprehend current discussions and options of policymaking, as they might affect you sooner or later

Feed in your practical knowledge into policymaking processes/ into your own business model where possible

Take a look at building renovation at the district level from the point of view of your (future) tenants. What is the best system for them to have a secure, safe, affordable and long-term energy solution for their households? How can you help avoid energy poverty?

Don't stop engaging in a project after its realisation. The results of a monitoring system could directly inform current and future investors' decisions and plans.

5. Supporting Building Renovation at District Scale through Process Organization & Stakeholder Dialogue

The benefits of positive stakeholder involvement are clear. Engaging diverse interested parties may present an organisational challenge but provides benefits essential to successful implementation and acceptance. Developing a workable strategy to integrate stakeholders within a project's development should therefore be seen as a fundamental part of the overall planning process.

In such a process, investors and decision-makers are essential stakeholders in establishing dialogue and communication.

This is particularly important for district-level building renovation projects that combine energy efficiency and renewable energy measures. Sharing common heating/cooling systems or engaging in coordinated activities to increase the efficiency of building envelopes requires a high level of trust between the concerned building owners and other building owners, and other stakeholders involved in the process. This is because these activities involve high costs and uncertainties regarding future energy markets, the renovations are associated with interventions in the personal living environment, and the reliability of a heating/cooling system or another type of energy system is of key importance to building owners and tenants.

The following table provides, in this context, operational recommendations dedicated explicitly to investors and decision-makers.

OPERATIONAL RECOMMENDATIONS
Use existing platforms for residents and formats to make yourself and your ideas visible
Be clear and honest about deep renovation's benefits, costs and burdens. Exploit the potential of focussing on the benefits, not only for energy efficiency but also comfort, enhanced security, adaptation to disabled and senior citizens' needs
Use analogue and digital tools to visualise your vision – to get all target groups into the communication
Be available on-site – a one-stop-shop and regular information times/events will help to get the attention and acceptance of the residents

6. District-Oriented Mobilisation for Building Renovation

To bring energy efficiency measures and renewable energy into the districts, it is essential to get building owners, owner-occupiers and tenants on board. They are crucial investment decision-makers or have a crucial role in determining the acceptance of such projects. Therefore, they are the key players in accepting and implementing renovation measures and transforming related policies into action.

However, these players constitute a highly diverse target group. The suitable measures to address them depend strongly on the housing market structure of the respective country, region, or district. In addition, the age of the building stock varies by country, region and district, which is a good indicator of its average efficiency, determining suitable measures as well.

Building renovation is a complex techno-economic and social process, especially when it combines energy efficiency and renewables and upscales them to the district level. Many aspects are hard to grasp for non-experts. Accordingly, diverse advisory support is needed to boost building renovation activity.

The following recommendations advise how non-professional end-users can be mobilised for broader action, improving the consultation landscape and creating networks among the many actors involved. These networks with a common knowledge base enable an end-user-friendly reference culture and a common language that helps dismantle barriers in complex renovation processes. Investors and decision-makers can participate in such a mobilisation process and benefit from a consultation landscape by following the recommendations below. More detailed instruments and practical examples of incentivising, mobilisation and consultation instruments at a local level are also elaborated in the IEA EBC Annex 75 report on policy instruments (Mlecnik et al., 2023).

OPERATIONAL RECOMMENDATIONS
Seek support along the whole renovation process, from initial information and planning until realisation and operation, to be able to make the best building renovation investment
For professional actors: engage in consultation networks and with different stages of the "consultation chain". The holistic view of the building renovation process through these engagements can help offer more tailored services and mobilise end users for your services. Also, practical knowledge and advice can be transferred to policy and decision-makers
For professional actors: engage in the situation and target group-oriented approaches for mobilisation of homeowners, e.g., consultancy centres, local energy desks or pop-ups, outreach-counselling or one-stop-shops
For professional actors: engage in quality networks and apply co-developed quality standards to gain the trust of homeowners
Take advantage of existing umbrella brands and communication to profit from their recognition value

7. Conclusions

As a complement to the comprehensive Guidebook prepared based on the main results and conclusions of the IEA EBC Annex 75 project, this short guide for policymakers summarises the main recommendations addressed to this specific target group to promote the district as an action-level for cost-effective building renovation combining energy-efficiency measures and renewables.

Building renovation at the district level can offer several synergies and cost-effective solutions in addition to building renovation at the individual building level. But, complexity grows with upscaling, and tailored strategies, technology combinations, and policy frameworks are needed together with integrated thinking and cooperation between the different stakeholders.

A major conclusion is that at the district level, there are no "ready-made" or "one size fits all" solutions regarding cost-effectiveness, but several techno-economic potentials of district solutions exist, enabling the development of suitable and tailored solutions to each local context.

Finding a local optimum renovation strategy requires an integrated approach to district-specific building renovation based on cooperation, the balance of needs, in-depth knowledge, information, and regulatory frameworks.

The key factors for a successful building renovation at the district level are effective communication and stakeholder coordination. In particular, the involvement and collaboration of residents in defining the renovation proposal and throughout the entire process are crucial to the acceptance and understanding of the implemented solutions, contributing to a successful renovation project. Local authorities, in turn, can have a vital role in the renovation process as facilitators, mediators, coordinators, and motivators.

While the integrated and district-oriented approach to building renovation is shaped and implemented locally, the role of higher-level policymakers is crucial in establishing agendas, funding, and enabling legal frameworks. Higher-level policymakers working together with local policymakers and supporting them towards integrated and interconnected multi-level governance are essential to advancing our path towards carbon neutrality.

An entire framework needs to be created to make deep renovation the rule rather than the exception. It starts with adapting regulations and building codes to building renovation rather than only new buildings and to the district level as a complement to the single-building level.

Policy measures are essential to implement building renovation at the district level because the market is unlikely to deliver district solutions to a large extent, especially as the benefits are often not clearly related to direct economic advantages but to public interests.

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