ANNEX 75

EBC
Energy in Buildings and Communities Programme

International Energy Agency

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

A Guide for Policy and Decision-Makers

Energy in Buildings and Communities
Technology Collaboration Programme

May 2023

ANNEX 75

EBC
Energy in Buildings and Communities Programme

International Energy Agency

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

A Guide for Policy and Decision-Makers

Energy in Buildings and Communities Technology Collaboration Programme

May 2023

Authors

Hauke Meyer & Maximilian Pechstein, German Association for Housing, Urban and Spatial Development, Germany (h.meyer@deutscher-verband.org, m.pechstein@deutscher-verband.org),

Manuela Almeida & Anita Tan De Domenico, University of Minho, Portugal (malmeida@civil.uminho.pt, anitadomenico@civil.uminho.pt)

Roman Bolliger, INDP - Institut für Nachhaltigkeits und Demokratiepolitik, Switzerland (roman.bolliger@indp.ch)

Bernhard Gugg, SIR - Salzburg Institute for Regional Planning and Housing GmbH, Austria (bernhard.gugg@salzburg.gv.at)

Uta Schneider Gräfin zu Lynar, B.&S.U. Beratungs- und Service-Gesellschaft Umwelt mbH, Germany (ulynar@bsu-berlin.de)

Harald Taxt Walnum, SINTEF, Norway (harald.walnum@sintef.no)

Contributing Authors

Jørgen Rose, Aalborg University - Department of the Built Environment, Denmark (jro@build.aau.dk)

Erwin Mlecnik & Thaleia Konstantinou, TU Delft / Faculty of Architecture and the Built Environment, the Netherlands (E.mlecnik@tudelft.nl, T.Konstantinou@tudelft.nl)

Published by the University of Minho, Largo do Paço, 4700-320 Braga, Portugal.

ISBN: 978-989-35039-2-8

Additional copies of this report may be obtained from: EBC Executive Committee Support Services Unit (ESSU), C/o AECOM Ltd, The Colmore Building, Colmore Circus Queensway, Birmingham B4 6AT, United Kingdom.

www.iea-ebc.org

essu@iea-ebc.org

Preface

The International Energy Agency

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

The IEA Energy in Buildings and Communities Programme

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

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

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

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

- reinforcing the technical and economic basis for refurbishment of existing buildings, including financing, engagement of stakeholders and promotion of co-benefits;
- improvement of planning, construction and management processes to reduce the performance gap between design stage assessments and real-world operation;
- the creation of 'low tech', robust and affordable technologies;
- the further development of energy efficient cooling in hot and humid, or dry climates, avoiding mechanical cooling if possible;
- the creation of holistic solution sets for district level systems 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 (*)
Annex 54: Integration of Micro-Generation and Related Energy Technologies in Buildings (*)
Annex 55: Reliability of Energy Efficient Building Retrofitting - Probability Assessment of Performance and Cost (RAP-RETRO) (*)
Annex 56: Cost Effective Energy and CO2 Emissions Optimization in Building Renovation (*)
Annex 57: Evaluation of Embodied Energy and CO2 Equivalent Emissions for Building Construction (*)
Annex 58: Reliable Building Energy Performance Characterisation Based on Full Scale Dynamic Measurements (*)
Annex 59: High Temperature Cooling and Low Temperature Heating in Buildings (*)
Annex 60: New Generation Computational Tools for Building and Community Energy Systems (*)
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
Annex 75: Cost-effective Building Renovation at District Level Combining Energy Efficiency and Renewables
Annex 76: ☼ Deep Renovation of Historic Buildings Towards Lowest Possible Energy Demand and CO_2 Emissions
Annex 77: ☼ Integrated Solutions for Daylight and Electric Lighting
Annex 78: Supplementing Ventilation with Gas-phase Air Cleaning, Implementation and Energy Implications
Annex 79: Occupant-Centric Building Design and Operation
Annex 80: Resilient Cooling
Annex 81: Data-Driven Smart Buildings
Annex 82: Energy Flexible Buildings Towards Resilient Low Carbon Energy Systems
Annex 83: Positive Energy Districts
Annex 84: Demand Management of Buildings in Thermal Networks
Annex 85: Indirect Evaporative Cooling
Annex 86: Energy Efficient Indoor Air Quality Management in Residential Buildings
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

Executive Summary

Urgent actions must be taken to decarbonise the building stock and meet the 1.5 °C target established in the Paris Agreement. Currently, the building renovation rate is less than 1% at the European level. The European Commission considers it necessary to increase it to 3% per year to meet the decarbonisation goals (EUROPEAN COMMISSION, 2018). To increase the building renovation rate and accomplish these goals, building renovation comprising energy efficiency measures on the building envelope combined with 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 aims to clarify the cost-effectiveness of various building renovation approaches combining energy efficiency and renewable energy measures at the district level. The objective is to provide guidance to balance and enable an innovative and optimal combination 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 is to show the possible combinations of technologies and the contexts in which they are most viable. It also aims to show which business models can support the processes and which policies and process organisations can help modernise and accelerate building renovation processes.

In this context, this guidebook provides recommendations for specific target groups, particularly policymakers and investors/decision-makers.

The guidebook illustrates that the district, as an action level for building renovation, allows for synergies through combinations of energy efficiency measures and measures that promote the use of renewable energy and opportunities for stakeholders to cooperate, compared to an individual building approach. But building renovation at the district level also presents challenges. These include high upfront costs, a long payback time, and risks of not being implemented due to a potential withdrawal of some building owners at different stages. However, the studies also show that often the opportunities are greater than the challenges in district approaches, even if the cost-effectiveness of certain measures may not necessarily be one of these opportunities.

One main conclusion from IEA EBC Annex 75 is that assessments must be carried out for each district renovation project since no "ready-made" or "one size fits all" solutions exist. Still, several techno-economic potentials for district solutions are apparent. Furthermore, the research indicates that the best renovation solutions for a district-level renovation depend on the district's starting situation. The building insulation level, the installed heating/cooling systems, the availability of renewable energy sources and the possibility of integrating renewable energy are determining factors.

Energy efficiency measures are relevant for building renovation at the district level, especially if the initial conditions of the building envelopes have poor thermal performance. The calculations carried out in this project indicate that the same package of energy efficiency measures applied to a building envelope is usually the most cost-effective regardless of the type of heating system and, in particular, whether a centralised or decentralised system is chosen.

There are good reasons, though, that might favour choosing district rather than decentralised approaches, especially when energy efficiency measures and renewable energy use are combined. These can be the potential use of large renewable energy sources or storage systems that may not be accessed through decentralised systems. Others can be the chance of overcoming space or noise restrictions related to decentralised systems, the increased flexibility, the opportunity to apply innovative systems associated with fewer carbon emissions, the possibility of increasing resilience through multiple energy systems, and the possibility of having a greater engagement of building owners when acting collectively. There are indications that the synergies between energy efficiency measures and the use of renewable energy are even greater for district systems than for decentralised systems when environmental heat is used through heat pumps. This could occur because energy efficiency measures would reduce the temperature in the grid and, thus, the related heat losses, and increase the overall efficiency of the systems. However, harnessing these synergies is not easy and, until now, also not common, as district renovation projects are complex in themselves, and harnessing the synergies is associated with additional challenges.

Another relevant conclusion regards the criteria for choosing the best renovation package. Sometimes, even if certain measures are not cost-effective, their co-benefits will be the main reason to choose them. Therefore, a holistic approach must be taken when analysing different district renovation solutions, with the techno-economic viewpoint being one of many factors to be considered in the decision-making process. Considering public interests, social and urban aspects are also essential, aiming at the general improvement of the indoor and outdoor spatial quality, comfort conditions and the residents' quality of life, which also contributes to greater acceptance and participation of residents in the process. It is also crucial that the different stakeholders' points of view and objectives converge towards a common agreement on decarbonisation targets.

However, in many cases, conditions are still lacking for building renovation at the district level to be possible, and an entire framework needs to be created to make deep renovation the rule rather than the exception.

This starts with adapting regulations, building codes and energy certificates to building renovation rather than only new buildings and to the district level as a complement to the single-building level. It is recommended that regulations also facilitate and require switching building systems from fossil fuels to renewable energy sources and even ban fossil fuel systems at international, national, regional, and local levels.

Furthermore, overarching financial incentives, such as those provided through a carbon tax, to reflect more strongly the external costs of the consumption of fossil fuels or through emissions trading schemes are crucial. Funding must be provided, guaranteeing the planning and implementation of the entire district renovation project rather than just partial measures.

It is also recommended to test new financing models and to develop new business models, ensuring that benefits can be harnessed despite different building ownerships and existing district heating/cooling systems. These business and financing models should be targeted at different groups, especially the most vulnerable ones, such as low-income groups and tenants.

The quality and the acceleration of building renovation projects must also be guaranteed by achieving a sound understanding of deep renovations and, thus, addressing the lack of knowledge by offering training to the entire chain of professionals in the building sector, building owners, and local staff of city administrations.

Nevertheless, the key factor for successful building renovation at the district level is effective communication and coordination, without which the other aspects will not be applied to their full potential. The availability and easy access to transparent and clear information combined with stakeholder dialogue and knowledge exchange lead to greater adherence and participation. In particular, the involvement and collaboration of residents in the definition of the renovation proposal and throughout the entire process help with its acceptance and the understanding of the solutions. This approach can contribute to achieving more ambitious renovation levels and the expected operational performance due to behavioural use patterns.

Local authorities, specifically, can play a key role in ensuring appropriate communication and advice to building owners and in supporting the coordination and organisation of building renovation processes at the district level, as they can assume various functions, such as facilitators, mediators, coordinators, and motivators. They are well positioned to establish co-creation trajectories with citizens in target areas, co-create local renovation hubs, demonstrate fossil-free pilot districts, and define specific local targets that motivate building owners to participate in energy transition and related building renovation activities. They can also further encourage building renovation at the district scale through local energy planning, local regulations, and local financial incentives, particularly promoting the combination of energy efficiency measures and renewables. Depending on the country's context, they may introduce specific local regulations, such as making building envelope renovation and switching to renewable energy-based heating and cooling systems mandatory or providing related regulatory incentives. They may also introduce local financial incentives or financing schemes to make building renovation attractive and promote appropriate business models.

In short, cost-effective technological combinations suitable and tailored to each local context are needed, aiming at the public interest and improving the citizens' quality of life. An integrated approach to district-specific building renovation is required to find a site optimum deep renovation, not only balancing energy efficiency measures and renewables, yet beyond that, also balanced with other interests. It is recommended to base this approach on stakeholders' cooperation, the balance of needs, in-depth knowledge, information, appropriate incentives, and regulatory frameworks that enable building renovations at the district level, leveraging synergies between energy efficiency measures and the use of renewable energy sources, as illustrated in the several IEA EBC Annex 75 reports.

This implies that if policymakers want to implement district-level renovation projects to take advantage of the additional stated benefits, they will have to take appropriate policy action, as the market by itself is unlikely to deliver decarbonisation through district solutions to a large extent.

Table of Contents

Abbreviations

Abbreviations	Countries
BE	Belgium
DE	Germany
FR	France
NL	The Netherlands

Abbreviations	Meaning
ASHP	Air source heat pump
CSR	Corporate Social Responsibility
DH	District heating
DHW	Domestic Hot Water
EBC	Energy in Buildings and Communities Programme
EE	Energy efficiency
EPC	Energy performance certificate
ETICS	External Thermal Insulation Composite System
GSHP	Ground source heat pump
HVAC	Heating, Ventilation and Air Conditioning
IEA	International Energy Agency
PVT	Combined photovoltaic and solar thermal plants
RES	Renewable energy sources

Definitions[1]

Various IEA EBC Annex 75 reports use a common language for communication between local authorities, professionals, researchers, inhabitants and, in general, all stakeholders and international partners.

Each term is defined in the context and scope of IEA EBC Annex 75, namely building renovations at the district level, and combines definitions from the European legal framework, common definitions of English dictionaries, related projects, research papers, and other professional publications. The concepts are sorted alphabetically.

Actors: The persons and entities active during the planning and implementation of energy renovation processes in buildings and districts.

Anyway Renovation: Renovation measures necessary to restore a building's functionality without improving its energy performance. The anyway measures may be hypothetical if the renovations without improving energy efficiency are legally not allowed or are not practically reasonable.

Building renovation: An improvement of the building envelope or the energy system of a building, at least to restore its functionality, and usually to improve its energy performance. Within IEA EBC Annex 75, building renovation is understood to refer to energy efficiency measures in buildings, particularly on building envelopes, as well as renewable energy measures in buildings, in particular for heating or cooling purposes, whether through a decentralised energy system of a building or a connection to a centralised district heating/cooling system.

Business model: A model that describes the value logic of an organisation in terms of how it creates and captures customer value, and which can be concisely represented by an interrelated set of elements that address the customer, contain a value proposition and address organisational architecture and economics dimensions (Fielt, 2014) (Seddon et al., 2004) (BPIE, 2016) (Laffont-Eloire et al., 2019).

Carbon emissions: Shorthand expression used by IEA EBC to represent all greenhouse gas emissions to the atmosphere (this means carbon dioxide, methane, certain refrigerants, and so on) from the combustion of fossil fuels and non-combustion sources such as refrigerant leakage. It should be quantified in terms of 'CO_2 equivalent emissions'.

Centralised or decentralised thermal energy system: Centralised systems can either refer to a connection to an external district heating or district cooling system, covering a larger area, or to a local thermal energy production system covering only the district in question. A decentralised system refers to a single-building heating or cooling system.

Cost-optimal level: The energy performance level which leads to the lowest cost during the estimated economic life cycle of a building (European Commission, 2010).

[1] A comprehensive list of all IEA EBC Annex 75 definitions can be found in (Hidalgo-Betanzos et al., 2023) - https://annex73.iea-ebc.org/publications

Deep renovation: A renovation which transforms a building or building unit into a nearly zero-energy building (until 2030) or a zero-emission building (after 2030), according to the latest European Commission proposal (European Commission, 2021). The previous EU legal framework didn't define deep renovations in detail, but they were typical of more than 60% energy savings. (European Commission, DG Energy, 2014) (BPIE – Deep renovation, 2021).

District: A group of buildings in an area of a town or city that has limited borders chosen for purposes of, for example, building renovation projects, energy system planning, or others. This area can be defined by building owners, local government, urban planners, or project developers, e.g. along realities of social interactions, the proximity of buildings or infrastructural preconditions in certain territorial units within a municipality. IEA EBC Annex 75 focuses on residential buildings, both single and multi-family houses, but districts with other buildings with similar characteristics, such as schools or simple office buildings without complex HVAC systems, can also be included in the district.

District heating or District cooling: A centralised system with the distribution of thermal energy in the form of steam, hot water, or chilled liquids, from a central production source through a network to multiple buildings or sites, for use in space heating or cooling, domestic hot water, or other services.

Energy Master Plan: A holistic roadmap that enables planners to work constructively toward various framing energy goals within defined community-specific constraints (Zhivov A., 2022).

Energy source: Source from which useful energy can be extracted or recovered either directly or by means of a conversion or transformation process.

Housing association: An association that owns, lets and manages rented housing, usually under special conditions, for people that cannot reach the market or rented housing due to vulnerability or other socio-economic situations.

Investors: Stakeholders that act as clients or beneficiaries of building renovation or renewable energy projects. There is a wide range of demand organisations which can be private or social, public, semi-public, or mixed, depending on the situation. For instance, private owners or assemblies of homeowners are typically in this category, as well as investment funds, housing associations, housing cooperatives and housing companies, as they may be owners of buildings to be renovated.

Linear heat density: Annual heat delivered per meter of piping for a district heating system.

Local policy: Policy developed, controlled, or enforced by local public bodies to promote building renovation in number and depth. Local policy is made by the locally elected council and is implemented by the municipal administration. A wide range of persons and entities can act within the local policy framework, such as district developers, urban planners, municipality departments and regional institutions.

Non-renewable energy: Energy taken from a source depleted by extraction (e.g., fossil fuels).

Policy instrument: A new regulation, support scheme, communication programme or organisational service defined by policymakers. Within IEA EBC Annex 75, policy instruments intend to increase the building renovation rate (number of renovations undertaken due to economic and organisational & mobilisation potentials) and/or renovation depth (higher energy efficiency and more renewables due to the technological potentials). The instruments often serve specific purposes within a policy strategy, including multi-level actions and multi-actor governance (Rosenow et al., 2016; BPIE, 2018). For example, EU Regulations (European Commission, 2012) identify policy instruments such as (article 7): energy efficiency obligations; energy or CO_2 taxes; grants; loans; on-bill finance; tax rebates, regulations; voluntary agreements; standards and norms (that aim at improving the energy efficiency of products and services); and energy labelling schemes.

Policymakers: All kinds of actors and stakeholders who define, develop, and implement policy instruments regarding building renovation or renewable energy projects. That includes all political levels: local, regional, national, and international, as well as all administrative levels and to a certain extent also administrative decision-makers.

Renewable energy: Energy from sources that are not depleted by extraction, such as wind power, solar power, hydroelectric power, ocean energy, geothermal energy, heat from the ambient air, surface water or the ground, or biomass and biofuels. These alternatives to fossil fuels contribute to reducing greenhouse gas emissions, diversifying the energy supply and reducing dependence on unreliable and volatile fossil fuel markets, particularly oil and gas.

Renovation: Construction activities related to interventions onto existing buildings or connected infrastructure. These interventions range from simple repairs and maintenance to adaptive conversion, transformation, and reuse. In the framework of IEA EBC Annex 75, renovation can refer to both renewal/retrofit of building envelopes and energy system changes.

Stakeholders: The persons, homeowners, companies, public institutions and in general every agent with an interest or concern in an ongoing or future project. The stakeholders in renovation projects can be a wide and diverse list of agents, including decision-making actors and also other involved participants that can influence the success or failure of the renovation process.

Stakeholder dialogue: The process whereby a lead actor, usually a local administration, facilitates communication and interaction with stakeholders, particularly also building owners, in a certain community area/neighbourhood/district to get them going in the direction that is politically favoured i.e., climate neutrality, energy efficiency, enhanced use of renewables. This dialogue can be implemented through various formats of information and communication and can be based either on regulations (if applicable) or on persuasion and commitment.

1. The District as Action Level for Building Renovation

It is consensual that urgent actions must be taken to decarbonise the building stock and meet the targets established in the Paris Agreement. Currently, the building renovation rate is less than 1% at the European level. The European Commission considered it necessary to increase this rate to 3% per year to meet the decarbonisation goals (EUROPEAN COMMISSION, 2018). Apart from energy efficiency measures on the building envelopes, a switch to renewable energy-based acclimatization and DHW systems is urgently required to meet remaining carbon budgets compatible with the 1.5 °C target set in the Paris Agreement. In addition to building renovation at the building level, building renovation at the district level, combining energy efficiency measures with renewable energy, 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 aims to clarify the cost-effectiveness of various building renovation approaches combining energy efficiency and renewable energy measures at the district level. The objective is 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 is to show the possible combinations of technologies and the contexts in which they are most viable. It also aims to show which business models can support the processes and which policies and process organisations can help modernise and accelerate building renovation processes.

The key findings from IEA EBC Annex 75 are compiled in this guidebook to reflect on the district's potential as an action level for building renovation and how to use it. The findings address the concrete implementation of building renovation at the district level. Building renovation is understood here to refer to either energy efficiency measures or renewable energy measures in buildings.

This guidebook targets two specific groups: policymakers and investors/decision-makers. Policymakers are understood as all kinds of actors and stakeholders who define, develop, and implement policy instruments regarding building renovation, whether referring to energy efficiency measures or renewable energy projects. That includes all political levels: local, regional, national, and international, as well as all administrative levels and, to a certain extent, administrative decision-makers. The group of investors and decision-makers is defined as all kinds of actors or stakeholders who make investment decisions for building renovation or are involved in such a decision process. Private or public building owners, assemblies of homeowners, housing companies, housing associations, energy companies or investment funds fall into this category. But intermediaries – stakeholders that act as a third party or interact or connect supply and demand – are also considered potential investors and decision-makers within building renovation processes at the district level. Hence, the definitions for the two groups are quite broad, reflecting the diversity of districts and related energy actors from an international perspective as of the IEA EBC Annex 75. With such a broad definition and perspective, this guidebook provides a structural overview of the topic

of cost-effective building renovation at the district level rather than giving concrete instructions for individual homeowners or private companies. Individual framework conditions have to be considered.

The following chapters illustrate key aspects of the district's approach to building renovation.

Chapter 2 identifies the advantages and synergies of the district approach to building renovation and overall recommendations derived from IEA EBC Annex 75. In chapter 3, there is an overview of the techno-economic potentials of technology combinations based on a limited number of analysed international case studies within IEA EBC Annex 75. Further, in chapter 4, there are derivations from expert interviews on potential business models to support upscaling of building renovation. Additionally, guidance for encouraging the use of a district approach to building renovation is given through local policy instruments (chapter 5), the organization of stakeholder dialogues (chapter 6), as well as low threshold mobilization strategies within the district (chapter 7). Each chapter extracts recommendations regarding buildings and district renovations for local policymakers, investors, and decision-makers. Finally, chapter 8 presents the main conclusions.

In the respective chapters, the guidebook explores how the district can offer synergies by combining energy efficiency and renewable energy measures as an action level for building renovation.

Target group-oriented short versions of this guidebook, with a summary of key recommendations, are offered for policymakers, investors, and decision-makers in separate documents[2] [3].

[2] A Short Guide for Policymakers (Meyer et al., 2023) - https://annex75.iea-ebc.org/publications

[3] A Short Guide for Investors and Decision-Makers (Meyer et al., 2023) - https://annex75.iea-ebc.org/publications

2. Potential Advantages of the District as Action Level for Building Renovation and Overall Recommendations

Building renovation at the district level brings both opportunities and challenges.

Opportunities are, among other benefits, associated with centralised renewable energy approaches and economies of scale for energy efficiency measures due to aggregated demands and synergies in construction procurement, processes, and planning. On top of that, it offers an opportunity to address transversal issues, such as housing affordability, energy grid integration and urban planning (mobility, accessibility, culture and leisure, green and blue spaces, etc.).

Concerning the challenges, the following can be mentioned:

Synergies between energy efficiency measures and the installation of renewable energy systems might be difficult to achieve at the district level, as they depend on the existing heating systems and synchronisation of buildings' renovation cycles. Furthermore, building renovation at the district level is associated with high upfront costs, long payback time, and risks of not being implemented due to the potential withdrawal of some building owners that are at different stages.

The district as the action level can have – depending on its concrete characteristics - a complex stakeholder structure with different interests and tasks. This can be a limitation for the mentioned synergies. That puts the district approach in the dilemma that, especially in the beginning, significant efforts in planning, coordination and communication must be made. A heterogeneous ownership structure complicates coordinated action and synchronization of energy efficiency measures on building envelopes, as well as the implementation of large-scale heat supply infrastructure. The potential synergies and monetary savings through scale effects are thus at risk where initial costs are high, and no anchor clients are available due to a fragmented and heterogeneous ownership and building structure.

In the same way, integrated approaches to building renovation combining energy efficiency and renewable energy measures, imply more coordination and communication efforts for investors and decision-makers. Furthermore, depending on the local market situation concerning financing schemes and the financial means of building owners or project developers, the initial investments in such new approaches may be a barrier to transformation.

While there are several benefits associated with centralised heating or cooling systems at the district level, there is often no clear benefit in terms of cost-effectiveness. The economies of scale are at least partially offset by additional heat losses through the grid and a decreased efficiency of central heat pumps due to the higher temperature required in the system. Also, district approaches potentially make the energy system more vulnerable to disruption and require space for pipes and for the central heat generation or heat distribution units. There may also be challenges related to carbon emissions at the place of the centralised

heat generation, and building owners may be reluctant to participate in a district approach due to a lack of trust or customization to individual requirements. Furthermore, a lack of appropriate incentives associated with a district approach may be counterproductive for encouraging energy efficiency measures by building owners.

Nevertheless, despite such challenges, other good reasons may favour choosing district rather than decentralised approaches. These could be greater flexibility and the potential use of large renewable energy sources or storage systems that could not be installed in a decentralised approach. Another advantage is overcoming eventual space or noise restrictions related to decentralised systems. Centralised approaches also have the potential to increase resilience through the use of multiple energy systems and provide the opportunity to apply innovative systems associated with lower carbon emissions and the possibility of having greater engagement among building owners when acting collectively.

It is also crucial that any district project's heating or cooling systems must be based entirely on renewable energy to ensure compatibility with climate protection targets.

Energy efficiency measures are relevant for building renovation at the district level, especially if the building envelope's starting condition has poor thermal performance. The calculations carried out in Annex 75 indicate that the same package of energy efficiency measures applied to the building envelope is usually the most cost-effective regardless of the type of heating system and, in particular, whether a centralised or decentralised system is chosen. There are even indications that the synergies between energy efficiency measures and renewable energy use are greater for district systems than for decentralised systems when environmental heat is used through heat pumps. This could occur because the energy efficiency measures allow to reduce the temperature in the grid and, thus, reduce the related heat losses, which increases the system’s overall efficiency. However, harnessing these synergies is not easy and, until now, also not common, as district renovation projects are complex by themselves, and harnessing the synergies is associated with additional challenges.

Accordingly, significant opportunities are associated with district approaches for building renovation, particularly when combining energy efficiency and renewable energy measures. Challenges may be dealt with, and often the opportunities are greater than the challenges. However, cost-effectiveness is not necessarily one of these opportunities for district approaches. This implies that if policymakers want to implement district-level renovation projects to take advantage of the additional stated benefits, they will have to take appropriate policy action, as the market by itself is unlikely to deliver decarbonisation through district solutions to a large extent.

One main conclusion from the studies carried out in this project is that “no ready-made” or "one size fits all" solutions exist. Still, several techno-economic potentials for district solutions are apparent. Furthermore, the research within IEA EBC Annex 75 indicates that the best renovation solutions for a district-level renovation depend on the starting situation of the district, such as the building insulation level, the installed heating/cooling systems, the availability of renewable energy sources and the possibility of integrating renewable energy.

Sometimes, specific measures will not be the most cost-effective, but this does not mean discarding them is necessary. On the contrary, there are situations when these measures offer co-benefits that will be the main reason to choose them. Therefore, a holistic approach must be taken when analysing different district

renovation solutions, with the techno-economic viewpoint as one of the factors to be considered in the decision-making process. Looking also into public interests, social and urban aspects are essential, aiming at the general improvement of the indoor and outdoor spatial quality, comfort conditions and the residents' quality of life, which also contributes to a greater acceptance and participation of the residents in the process.

As the complexity grows with tailored strategies and upscaling to the district level, it is essential to consider and adequately address several aspects. The points of view and objectives of the different stakeholders involved in the process must converge towards a common agreement concerning the decarbonisation targets. However, in many cases, conditions are still lacking for this to be possible, and an entire framework needs to be created to make deep renovation the rule rather than the exception.

Creating the necessary framework starts with adapting regulations, building codes and energy certificates to building renovation rather than only new buildings and to the district level as a complement to the single-building level. It is recommended that regulations also facilitate and require switching building systems from fossil fuels to renewable energy sources and even ban fossil fuel systems at international, national, regional, and local levels.

Furthermore, overarching financial incentives, such as those provided through a carbon tax, to reflect more strongly the external costs of the consumption of fossil fuels or through emissions trading schemes are crucial. In addition, to advance building renovation at the district level, it is necessary that funding is provided to plan and implement the entire district renovation project rather than just individual measures.

It is also important to address the lack of knowledge and achieve a sound understanding of deep renovations by offering training to the entire chain of professionals in the building sector, building owners, and local staff of city administrations.

In addition, new business models are required to support district renovations combining energy efficiency and renewable energy measures, ensuring that related benefits can be harnessed despite different ownerships of buildings and existing district heating/cooling systems. It is also recommended to test new financing models and target business and financing models to different target groups, paying particular attention to the most vulnerable groups, such as low-income groups and tenants.

Local authorities play a crucial role in these renovation processes. They can assume various functions, such as facilitators, mediators, coordinators, and motivators. First, they are well positioned to establish co-creation trajectories with citizens in target areas and define specific local targets that motivate building owners to participate in the energy transition and related building renovation activities. They can influence building renovation through energy planning. Depending on the country's context, they may introduce specific local regulations which make building envelope renovations or a switch to renewable energy-based heating systems mandatory or provide related regulatory incentives. They may also introduce local financial incentives or financing schemes to make building renovation attractive and promote appropriate business models.

It is important that such policy instruments specifically also address the combination of energy efficiency measures and renewable energy to harness related synergies. In addition, such policy instruments can be designed to take into account particular vulnerable groups, such as low-income groups or tenants.

Nevertheless, the key factor for successful building renovation at the district level is effective communication and coordination, without which the other aspects will not be applied to their full potential. Local authorities play a key role also in this field, as they are the government institution closest to the citizens which can best support related interactions with building owners, other local energy actors and citizens in general. The availability and easy access to transparent and clear information combined with stakeholder dialogue and knowledge exchange lead to greater adherence and participation. In particular, the involvement and collaboration of residents in defining the renovation proposal and throughout the entire process helps with its acceptance and their understanding of the solutions. This approach can contribute to achieving more ambitious renovation levels and the expected operational performance due to behavioural use patterns.

Local authorities, in particular, can assume a crucial role in ensuring appropriate communication and advice to building owners and offering support for coordinating and organizing processes for building renovation at the district level. It is best if such guidance and support cover the project's development from the planning phase and the setting up of appropriate legal structures, if necessary, through to implementation and up to the operation and monitoring of building renovation projects at the district level.

Local authorities can ensure that experts in various fields, such as energy, legal, and social aspects, provide related knowledge and organizational support. These experts may be part of the local administration or external experts mandated by the local authority. Local authorities may also co-create local renovation hubs and demonstrate fossil-free pilot districts for this purpose.

In short, cost-effective technological combinations suitable and tailored to each local context are needed, aiming at the public interest and improving the citizens' quality of life. An integrated approach to district-specific building renovation is required to find a deep local renovation optimum, balancing energy efficiency measures and renewables and, beyond that, also balanced with other interests. It is recommended to base this approach on stakeholders' cooperation, the balance of needs, in-depth knowledge, information, appropriate incentives, and regulatory frameworks that enable building renovations at the district level, leveraging synergies between energy efficiency measures and renewable energy sources, as illustrated in the several IEA EBC Annex 75 reports. Specific challenges and opportunities for combining energy efficiency measures and renewables in district approaches are addressed in more detail in the various chapters of the present guidebook.

In addition to the operational guidance and target-group-oriented recommendations for policymakers and investors presented and discussed in the following chapters, some general derivations and overall recommendations can be made from the work of IEA EBC Annex 75.

These derivations address especially higher-level policymakers and call for an enabling environment for the integrated approach, upscaling building renovation to the district level and combining energy efficiency measures with renewable energy sources.

OVERALL RECOMMENDATIONS FOR HIGH-LEVEL POLICYMAKERS

REGULATIONS STANDARDS AND PLANNING	Provide a legal framework to foster target-orientated building renovations at the district level. Adapt laws and regulations to stimulate building renovation at both the building and the district levels
	Deploy building codes with clear goals and standards aiming at zero-carbon building renovation and an overarching goal of zero-carbon districts
	Guide the deployment of district solutions combining energy efficiency measures and renewables through energy planning covering the entire city
	Create a certification system to set standards also at the cluster and district levels while maintaining high ambitions at the building level
	Promote a holistic approach combining building renovation, urban planning, energy grid development and carbon reduction goals so that overall quality of life can be achieved and residents' acceptance increased
	Support and develop incentives and regulations, as well as coordination and planning at overarching policy levels, and enable local authorities to assume an active role
	Guide local actors and decision-makers by defining a clear and practice-oriented decarbonisation path, developing clear definitions of zero-carbon standards involving a broad spectrum of practitioners
	Take advantage of the time when regular maintenance of building elements or a district grid is required to improve their energy performance and synchronise related renovation activities within a district
	Tighten regulations requiring the use of renewable energy whenever a heating system is replaced or newly installed and ban, at some point, the use of fossil fuel-based heating and cooling systems at international, national, regional and local levels, while strongly supporting vulnerable groups during the transition periods/processes to maintain overall acceptance for decarbonisation
	Require the combination of energy efficiency measures and renewable energy measures in concessions for district heating systems or public tenders
	Ensure that also the peak capacity of large district heating systems is provided through renewable energy

ECONOMIC AND FINANCIAL INSTRUMENTS	Assure financial support to the energy transition to even out potential (initial) adverse socio-economic effects whenever necessary and prevent thereby that the technological district renovation solutions are being neglected due to high initial and coordination costs
	Ensure that financial support favours a combination of energy efficiency measures and renewable energy measures and that counter-productive incentives are avoided
	Provide financial support for the development of integrated district renovation plans that combine both energy efficiency measures and renewable energy measures
	Deploy financial measures and business models to promote ambitious building renovations, including funding for building renovations at the district level
	Provide incentives and subsidies for comprehensive and multi-measured building renovations that are not yet cost-effective
	Facilitate cross-sector business models and the cooperation of energy companies, renovation solution suppliers and housing companies by eliminating possible legal barriers
	Make financial guarantees and funds available not only for individual measures but for the entire process, ensuring the final performance of the renovation project at the building as well as the district level
	Deploy financial schemes for different target groups, especially low-income households, to unburden them from the upfront and following costs of the building renovation upscaling
INFORMATION AND CAPACITY-BUILDING	Offer integrated solutions and services by providing a single point of contact
	Develop collaborative platforms for different target groups, learning networks, and reliable and easy-to-use tools for professionals and end-users, assuring quality in procurement, design, and execution
	Create transparent and accessible databases by enhancing the collection of energy performance information through building inspections, energy audits, smart meter promotion and big data analysis
	Develop online energy maps as an information resource on connection possibilities to renewable energy sources, energy grids and heating/ cooling networks

	Support and promote capacity-building for the whole chain of the renovation process actors
	Raise awareness and ensure effective communication among the district renovation stakeholders from the early stages and throughout the entire process, especially involving residents
	Help to spread information about local examples, inspiring action
RESEARCH	Support R&D to unravel the needed process innovations at local and regional scales, particularly for developing integrated building renovation services for different target groups and at the district scale
	Provide funding to develop and test innovations related to improved renovation measures for reaching decarbonisation
	Explore innovative solutions in research projects beyond the existing legal structure, granting exemptions through sandbox projects

The previous table addressed especially higher-level policymakers and provided some overall recommendations derived from the most important results of IEA EBC Annex 75.

The following table provides additional operational recommendations dedicated explicitly to two specific target groups: policymakers and investors/decision-makers.

Similar tables can be found at the end of each of the following chapters in this Guidebook related to the topic under discussion in the respective chapter.

OPERATIONAL RECOMMENDATIONS PER TARGET GROUP	
FOR POLICYMAKERS	Make use of the techno-economic**,** as well as the organizational potentials and synergies of upscaling building renovation to the district level, such as a wider scope of action, expertise, and communication through addressing and including more actors
	Ensure that harnessing synergies between energy efficiency measures and renewable energy measures is encouraged through various policy instruments

	Address complex transformation issues like decarbonisation at the district rather than at the building level to be able to integrate interdependencies with other policy issues and goals in the policy action
	Take advantage of the tailored perspective at the district level (e.g., compared to the city level) that allows for better direct involvement of the people and local actors in the energy transition
	Support or bear the additional (especially initial) efforts of coordination, communication and planning that comes with an upscaling to the district level
	Foster an integrated approach to urban development, energy planning and cooperative action of city departments and investors and decision-makers that promote a balance of interests right from the start
FOR INVESTORS/ DECISION-MAKERS	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

3. Techno-economic Potentials of Upscaling Building Renovation at the District Level

3.1 General Assumptions and Limitations of a Techno-economic Perspective on 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. However, policymakers need to consider general techno-economic potentials and their interdependencies with a district's framework conditions and policy goals. This understanding helps to be an enabler of innovative approaches to building renovation through integrated planning and overarching strategies, stakeholder dialogue and extensive mobilization.

In general, there are three levers through which district energy performance can be optimized: energy efficiency measures reducing the energy needed by the district and ensuring the required energy is delivered efficiently; measures to ensure that the delivered energy is based on renewable energy sources; and energy sufficiency measures to reduce demand for energy in general, for example by lowering room temperatures or reducing the amount of heated floor area used per person. Here we focus on the first two of these levers and their combination.

To analyse and compare techno-economic potentials and achieve optimization, extensive information and data are necessary, and many single options for action have to be weighed out along the way. Policymakers can create a framework within which data is collected and provided, which is needed for sound analyses of techno-economic potentials at the district level. This information and data can support investment decisions. However, the security of sensitive private data must be maintained, and data fragmentation in the hands of different involved actors in the district is a challenge.

Within IEA EBC Annex 75, various of the reports that have been prepared served as a basis for recommendations given here: a comprehensive overview of building renovation technologies and their characteristics (MØRCK ET AL. 2023), a methodology for investigating cost-effective building renovation strategies at the district level combining energy efficiency & renewables (BOLLIGER ET AL. 2023), a report on parametric assessments of generic districts (SÄWÉN ET AL. 2023), a report on strategy development (WALNUM ET AL. 2023), a report on success stories of building renovation at the district level (DOMINGO-IRIGOYEN ET AL. 2023), a report on parametric assessments of case studies (VENUS ET AL. 2023a), a report on barriers and drivers for energy efficient renovation at the district level (JOHANSSON ET AL. 2023), and a good practice guidance for transforming existing districts into low-energy and low-emission districts (VENUS ET AL. 2023b).

Based on this work, this chapter describes cost-effective building renovation strategies at a district scale from a techno-economic viewpoint**.** In this context, examples of the most cost-effective technology combinations and renovation strategies are pointed out, as well as some enabling factors and hurdles. However, it is important to note that the number of the analysed cases was limited to the ones selected by the participating countries, and the findings may not be fully representative. The assessment of cost-effective building renovation solutions should always consider specific local pre-conditions and the assessment methodology should be scrutinized for the particular context. Further, it is important to mention that the dynamic energy and building material prices, regulatory frameworks, and user behaviour can significantly impact cost-effectiveness. Furthermore, technological development, such as standardization and prefab solutions, can change the cost-effectiveness of various approaches over time. Finally, the techno-economic approach to district-scale cost-effectiveness, as used in the calculations in the IEA EBC Annex 75 (see also 3.2), analyses the cost-effectiveness from an overall perspective, irrespective of the cost-sharing between users and investors. However, due to the importance of cost distribution, policy ambitions, infrastructure and development goals and pure cost-effectiveness, it is appropriate to make these cost-effectiveness assessments in an integrated perspective, always as a basis for decision-making.

3.2. Technology Options and Potentials

There is a wide range of technology options to increase the energy efficiency of buildings. Concerning insulation of the building envelope, the main renovation measures are insulation of facades, insulation of roofs, insulation of cellar ceiling, and replacement of windows with new energy-efficient ones. In districts where there are several buildings with identical or similar shapes, there is a potential to achieve synergies through renovation at the district level by producing prefabricated modular panels. However, the shape of buildings in a district is often highly diverse, which limits synergies. Even then, there is potential for harnessing economies of scale through other technologies. For example, there is a potential for economies of scale when using ETICS (External Thermal Insulation Composite System) or modular insulation facade panels.

For switching the energy system of a district to renewable energy, the main options are heat pumps, wood energy, solar thermal, and waste heat[4].

The potential of wood energy is limited. Nevertheless, it has the advantage of providing heat relatively easily at temperature levels similar to those offered by fossil fuel systems. This makes wood energy a useful energy source in replacing heating systems previously based on fossil fuels. It can also be easily used in large biomass boilers providing heat to entire districts. Space requirements for wood chips or wood pellets storage can be a disadvantage, yet when replacing oil-based heating systems, the space previously used for storing oil can often be used for storing pellets instead. Wood energy has the additional advantage of being used in co-generation plants to produce heat and electricity from a renewable energy source. When burning wood, filters are required to ensure that local air quality remains high. Such filters are more

[4] Waste incineration is considered RES here. However, it should be clarified that it is debatable and varies also legally from framework to framework if waste incineration can be considered RES.

advanced for larger systems. This is also a reason for using the limited potential of wood energy for heating purposes primarily at large centralised plants, which ideally produce both electricity and heat from this renewable energy source. The availability of such a centralised wood energy plant can be a reason to provide heating from such a plant to an entire district.

The potential of waste heat, for example, from municipal solid waste incineration plants, is also limited. As wood energy, waste heat can easily replace fossil fuels if it has a relatively high temperature, as is the case for waste heat from a waste incineration plant. Where such sources of waste heat exist, it makes sense to use them for heating purposes through district heating. Usually, the potential of waste heat is already used to a large extent. However, further possibilities exist. In particular, there is an unused potential to store waste heat from summer to winter. Waste heat is often produced continuously throughout the year, yet it can be used directly only during the heating season. By making such waste heat produced during the summer available during the winter, it can be used to replace additional fossil fuel-based heating systems. However, storing heat from summer to winter is challenging, associated with a need for large storage tanks or other types of storage systems.

Solar energy is abundant in summer yet scarce in winter when heating needs are high. To harness solar energy as the main energy source for heating purposes, storing it from summer to wintertime is necessary. As for waste heat, this is possible, yet associated with a need for large storage tanks or other storage systems. The tanks for storing solar energy can be placed within buildings when a building is newly constructed. However, this is hardly possible in building renovation. Energy losses associated with seasonal solar heat storage are smaller when the storage systems are large. Therefore, solar thermal systems are most suitable for heating purposes at the district level, with the use of large storage systems.

Heat pumps are the main technology for providing renewable energy for heating and cooling purposes. They can make use of various forms of environmental heat. They may either be installed centrally for an entire district, with an associated network to distribute the heat to each building or decentrally in each building. Heat pumps always require a source of energy, the heat of which they transport into buildings.

The air, the ground, groundwater, surface waters, sewage canals or waste heat are suitable energy sources for heat pumps. Heat pump performance significantly depends on operation temperatures both at the heat extraction and load sides. Usually, the efficiency of heat pumps is higher and, therefore, less electricity is required to produce the necessary heat for ground source heat pumps or water source heat pumps than for air source heat pumps. However, the former is associated with higher investment costs.

For use at central installations at the district level, air is unlikely to be a suitable energy source because air source heat pumps require a large space and cause noise emissions when all in one central place. Air as an energy source is suitable for use in decentralised heat pumps in each building.

Heat from the ground accessed through boreholes is a suitable energy source for decentralised use in each building and a central heat pump operating at a district level. However, economies of scale for centralised ground source heat pumps are limited because it is necessary to distribute the drillings for boreholes similarly to when all buildings concerned have their own ground source heat pump. The reason for the need to spread the drilling of boreholes is that energy in the ground is limited and regenerates itself only slowly. Drillings for boreholes constitute a major share of the costs of ground source heat pumps. Nevertheless, a centralised ground source heat pump for a district heating system benefits from economies of scale concerning the heat pump.

Environmental heat from groundwater or surface waters such as lakes, rivers or the sea is an energy source that usually is accessed only for heating entire districts. In the case of groundwater, there is interest in reducing the number of access points to protect groundwater. In the case of accessing heat from surface water, there are environmental reasons to limit such heat uptake to a small number of large systems. In the case of using groundwater or surface water as an energy source, it is possible to use that water for a centralised heat pump; furthermore, it is also possible to use such an energy source through a cold district heating system by distributing the water to each building in a district and using it there through decentralised water-source heat pumps.

For environmental heat from sewage canals or waste heat, it depends on the nature of those energy sources and whether it makes sense to access them only for district heating systems or also for individual buildings.

Although there are economies of scale for large heat pumps for entire districts, their efficiency is low because district heating systems require high temperatures when applied to replace fossil fuel-based heating systems. This is because the building with the worst energy performance in the district determines the temperature level that must be supplied to the entire district. Furthermore, the heat distribution in the district heating system is associated with unavoidable losses, which need to be compensated with a high temperature of heat generation through the centralised heat pump. For environmental heat from groundwater or surface water, there is the possibility of distributing the water to buildings via “cold” district heating systems and, instead, applying decentralised water-source heat pumps in each building. This option is attractive because it allows heat pumps to work more efficiently, as each heat pump only needs to generate the temperature level for a specific building. This way, the losses associated with heat distribution at a higher temperature can be avoided.

Cooling needs can also influence the choice of the energy system. Ground source heat pump systems offer, for example, the possibility of providing heat in winter and an efficient way of cooling in summer by using the ground as a heat sink, without using the heat pump. District heating systems can be combined with district cooling systems, benefitting from synergies by using the same ditch for two types of piping systems. A cold district heating system, where groundwater or surface water is combined with decentralized heat pumps, offers the possibility of using the same system for cooling purposes.

Synergies between energy efficiency and renewable energy measures on building envelopes can mainly occur as energy efficiency measures reduce the required peak capacity. To use related synergies, it is important, however, that the installation of a heating system is coordinated with energy efficiency measures on the building envelopes. Further, saving potentials of energy efficiency measures and synergies in interaction with renewable energy measures also depend on user behaviour.

The high distribution temperatures required for centralised heat pumps allow significant synergies with energy efficiency measures to be applied in the building envelope. These allow for a lower temperature in the heat distribution system. These measures make it possible to reduce heat losses directly and significantly increase the efficiency of the centralised heat pump.

Another approach to how system temperatures can be lowered in the case of a heating network, or increased in the case of a cooling network, is to use larger heat emitters in buildings to deliver the needed heating/cooling. Furthermore, a district heating or cooling network can be upgraded to reduce system

losses, which can shift the cost-optimal levels regarding energy efficiency measures on the building envelopes.

The supply temperature in a district heating system can be constrained by the temperature needed for domestic hot water production since national regulations to prevent the growth of the *Legionella* bacteria may limit the possibility of lowering the temperature. The regulations differ significantly from country to country, making it difficult to give general recommendations. Still, there are concepts and technologies for solving this locally, either with boosters, sterilization methods, or instantaneous heat exchangers with tankless domestic hot water preparation. Instantaneous heat exchangers offer an attractive solution for reducing temperatures in the grid in combination with energy efficiency measures on building envelopes because the temperatures required for comfort purposes are usually significantly lower than what is required to prevent Legionella growth in storage tanks. Instantaneous heat exchangers to heat domestic hot water (when needed) make district heating grids at lower temperatures viable. This can therefore be a key technology to enable synergies between energy efficiency and renewable energy in building renovation at the district level.

Another type of synergy between energy efficiency measures in the building envelope and the deployment of renewable energy occurs in the case of a district heated by a large number of ground source heat pumps. A large number of boreholes close to each other can lead to a strong cooling of the temperature in the ground and make regeneration of the heat necessary after some time, for example, through solar collectors. The more the energy needs of buildings are reduced through energy efficiency measures, the less energy will be needed to regenerate heat in the ground or the longer it will take before such regeneration is required. This concerns both cases with a centralised ground source heat pump and those with decentralised ground source heat pumps at the district level.

3.3 Assessing Cost-effectiveness for Building Renovation at District Scale and Developing Integrated District Renovation Plans

Each district is unique in terms of the characteristics of the buildings and the available potential for the combination of energy efficiency and renewable energy measures. To assess which far-reaching renovation measures enable a significant reduction in energy use and carbon emissions cost-effectively, it is essential to assess several building renovation options for each district. A methodology report has been prepared for investigating cost-effective building renovation strategies at the district level combining energy efficiency & renewables (BOLLIGER ET AL. 2022). Based on the methodology report, as well as the experience with carrying assessments in IEA EBC Annex 75, it is recommended to proceed as follows for undertaking such assessments:

1. Definition and characterisation of investigated districts/ groups of buildings

At the beginning of the assessment, the district/group of buildings to be investigated is defined. The energy characteristics of the buildings are determined and characterised, including the dimensions of the building and the U-values of the several components of the buildings' envelopes. This may occur in connection with the preparation of the building energy certificates for the buildings in the district. The renewable energy options for the district to be considered in the assessment are then explored and defined.

2. Definition and assessment of the reference case

At the beginning of the assessment, the reference case is defined, i.e., the type of renovation activities which would have to be carried out *anyway*, just to restore the building's functionality. This may include repainting a wall or repairing a roof to make it waterproof again. The reference case is used as a comparison to determine to what extent energy measures are cost-effective.

3. Definition and assessment of building renovation scenarios

For each building in the district, a set of renovation packages on building envelopes, which have progressively higher ambition levels related to the resulting energy performance, is investigated. Such renovation packages differ from each other both by the number of building elements included, the chosen insulation level of these elements or the chosen window U-value. The set of renovation packages on building envelopes is then combined with various types of heating systems. For all these combinations, resulting primary energy use, carbon emissions and costs on a yearly basis and per m^2 of conditioned gross floor area are calculated. A heating system replacement is assumed in all cases, including the reference case of an *anyway* renovation. The dimension of the heating system is calculated by determining the required peak capacity to maintain the indoor target temperature despite heat losses during wintertime. It is considered that new heating systems can be downsized due to better insulation.

For carbon emissions and primary energy use, it is recommended to consider emissions / primary energy use associated with the energy carriers, including upstream emissions / primary energy use related to the transport of such energy carriers and their production. For costs, it is recommended to take the perspective of annualized life cycle costs. Such life cycle costs include investment, maintenance, and energy costs. Furthermore, it is recommended to include embodied carbon emissions and embodied primary energy use associated with energy efficiency and renewable energy measures.

When carrying out such assessments, it is recommended to consider that in the future, the electricity system is likely to be fully decarbonised to meet the objectives of the Paris Agreement. This implies higher costs, yet lower emissions and primary energy use per kWh electricity than today. In this context, it is justified to assume that part of the electricity will be provided through temporary storage in batteries or hydrogen, with associated additional costs for electricity.

4. Results to be obtained

A comparison is made between the reference case and the renovation packages to assess the cost-effectiveness of various renovation packages. Graphs are prepared to show the impact on costs, carbon emissions and primary energy use for various combinations of energy efficiency measures and renewable energy measures.

5. Sensitivity investigations

Investigating the results by varying specific parameters is good practice to identify factors that strongly influence the calculation results. It may be particularly appropriate to consider, for example, varying assumptions regarding the future development of energy prices and various parameters characterising the district.

Through such assessments, it is possible to derive recommendations regarding cost-effective combinations of energy efficiency and renewable energy measures for the district. The co-benefits associated with the renovation measures can also be considered as an additional element. For example, it may not be cost-effective to replace the windows. However, there may be an important co-benefit regarding noise reduction.

Based on these assessments, Integrated District Renovation Plans should be prepared, including interventions to switch to renewable energy and implement energy efficiency measures in the district.

A key element of such plans is to ensure that synergies between energy efficiency and renewable energy measures are used. This requires that all energy efficiency measures are carried out before installing the heating or cooling systems. In the case of a district heating system, for example, the Integrated Urban Rehabilitation Plan can foresee the phasing of energy supply as energy efficiency measures are progressively implemented in the district, reducing the overall energy needs.

3.4 Findings from Assessments carried out within IEA EBC Annex 75

In the assessments carried out within IEA EBC Annex 75, from a life cycle perspective, the difference in the overall cost-effectiveness between centralised and decentralised solutions was often small. Cost-effectiveness is understood as an energy performance level that leads to lower yearly costs than the reference case. Centralised approaches are sometimes economically more attractive than decentralised approaches and vice-versa. Centralised solutions do benefit from economies of scale. However, they are associated with energy distribution losses and bring the distribution network cost. For example, in centralised solutions, the temperature in the district heating system must be higher than in individual heating systems. The higher temperatures are needed because of the distribution losses and because the district system has to consider the building with the highest temperature needed. These effects, to some extent, cancel each other, leading to similar results in the cost-effectiveness calculations of decentralised and centralised solutions.

Also, the scale of centralised solutions brings the need for more planning, coordination efforts, and dependencies on end-users. This carries both costs and risks. Accordingly, there is often no clear economic case for choosing centralised approaches. If an existing thermal network is in good condition in the district, it is usually most cost-effective to continue utilizing it.

However, there may be other good reasons for preferring centralised approaches. Such reasons may be related to using large heat sources or seasonal thermal storage solutions or having more flexibility in the heat supply and reducing the burden on the electricity grid. Furthermore, district approaches can help provide a heating solution for buildings for which switching to a decentralised system based on renewable energy is a major challenge. It may be worth giving preference to district solutions, even if such challenges only exist in part of the district's buildings.

For decentralised solutions, according to IEA EBC Annex 75 assessments carried out, heat pumps are usually the most cost-effective solution over a life cycle analysis, depending on the building envelope condition and expected electricity prices. Local constraints and availability mainly decide the choice of heat pump technology.

In the assessments carried out within this project, renewable energy-based solutions were usually found cost-effective compared to a reference case assuming a continuation of the use of fossil fuels.

Furthermore, to some extent, energy efficiency measures on building envelopes were cost-effective for all types of heating systems. Often, the cost-optimal level of the energy efficiency measures on the envelopes does not differ significantly when these measures are associated with a district heating system based on renewable energy or a decentralised individual heating system based on renewable energy. Synergies between energy efficiency measures and heating systems based on renewable energy occur for all types of heating systems. The cost-effectiveness of these solutions is due to the reduction in the energy costs they cause and the decrease in the needed power of the renewable energy-based equipment to be installed, thus reducing the investment cost. This is important to note because it might be assumed that for existing fossil fuel-based systems, synergies between energy efficiency measures and renewable energy measures are higher than for existing renewable energy-based heating systems. After all, fossil fuel-based systems typically have higher energy costs. This might lead to the assumption that they benefit more from energy efficiency measures, reducing the energy needs. However, if energy efficiency measures are carried out, reducing investment costs due to a smaller required heating capacity benefits renewable energy systems more strongly than fossil fuel-based systems. In addition, in the case of heat pumps, energy efficiency measures on building envelopes leading to lower energy needs allow lower temperatures in the heat distribution systems. This leads to higher efficiencies of heat pumps, which strongly depends on the temperature difference between the source and the target temperature to be provided. This finding implies that energy efficiency measures continue to make sense when combined with renewable energy systems, at least as much as previously with fossil fuel-based systems.

The findings are also significant because, due to the economies of scale of district heating systems and because they partially have costs that are rather fixed and vary little by size, it might be assumed that energy efficiency measures on building envelopes are less cost-effective in the case of district heating systems than in the case of decentralised energy systems. However, assessment results suggest that this is not the case, meaning that energy efficiency measures make sense regardless of whether a decentralised energy system or a district heating system is chosen.

There are indications that synergies between energy efficiency and renewable energy measures are even more significant for district heating systems than individual heating systems. An important factor concerning synergies between energy efficiency measures on building envelopes and renewable energy systems is the possibility of lowering the temperature of the grid and the energy systems due to energy efficiency measures on the building envelopes. In the case of centralised heat pumps for a district heating system, they strongly benefit from this reduction in the grid temperature, as the heat pump's efficiency heavily depends on the temperature difference between the heat source and the target temperature to be provided by the heat pump. In centralized and decentralized systems, energy efficiency measures reduce the temperatures required by the heating systems, increasing the efficiency of the heat pumps. But, in the case of a centralized solution, the centralized heat pump has to achieve higher temperatures, as the required temperature level is determined by the buildings connected to the grid with the highest temperature needs and also because energy losses through grid distribution have to be taken into account. Lowering these high-temperature levels has a stronger effect on increasing the efficiency of heat generation through a heat pump than lowering the temperature in buildings with decentralized heat pumps, as they already require lower temperatures on average to start. In addition, lowering the required grid temperature also reduces grid-related heat losses and increases overall system efficiency. The finding is remarkable because it was found that for district heating systems, there are economies of scale concerning investment costs. In

contrast, for decentralised heat pumps, sometimes the investment costs increase rather linearly with size since larger decentralised heat pump systems entail additional costs for ensuring compliance with noise protection regulations or for regenerating heat in the ground, compensating for economies of scale in the heat pump units themselves. The finding is also remarkable as energy efficiency measures on the building envelope will reduce the buildings' energy need, thereby also the district's linear heat density. Although this has a negative impact on the cost-effectiveness of a centralised system, energy efficiency measures reduce the required peak capacity and might also allow for lower supply and return temperature for the central system, resulting in higher heat production efficiency and lower distribution losses. The results suggest that the latter effects dominate the former, even to a greater extent than at a decentralised level and that energy efficiency measures are accordingly cost-effective for new central district heating systems, particularly for heat pumps. Lowering the temperature in the grid requires a solution to generate hot water while maintaining its safety from a health perspective, even at lower temperatures. Such solutions exist yet require careful examination. Overall, this implies that energy efficiency measures tend to play an even greater role in making renewable energy-based district solutions cost-effective than in the case of decentralised renewable energy systems.

Another finding is that significant energy efficiency measures are usually especially cost-effective for building envelopes in poor condition from an energy efficiency perspective. For buildings that have previously undergone energy efficiency measures or where options for interventions are limited due to particular characteristics of the façade, e.g., historic or protected buildings, energy efficiency measures on building envelopes are often less attractive.

In addition, it was recognized that the costs that would occur anyway in case a building element had to be renovated just to restore its functionality play an important role in making energy efficiency measures in the building envelope cost-effective compared to the reference case. Therefore, it is recommended to take the opportunity to apply energy efficiency measures in the building envelopes, especially when renovations are necessary anyway.

3.5 Strategy Recommendations

For the strategy development within IEA EBC Annex 75, three different types of starting conditions in the urban districts were distinguished:

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

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

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

Various strategies were distinguished and assessed based on these starting conditions, and related recommendations were provided and shown next.

The process of strategy development is illustrated in Figure 1. For each of the starting conditions, possible strategies are distinguished concerning two levels:

- Thermal energy production and distribution concept (centralised or decentralised).
- Heating and cooling production technology.

The level of energy efficiency measures and the installation of local heat production from renewable energy sources (RES) are considered ambition levels within each strategy.

The lines connecting the boxes in Figure 1 show the possible strategy pathways. The dashed lines are feasible options but were not investigated within IEA EBC Annex 75. The same is for individual solutions (dashed boxes).

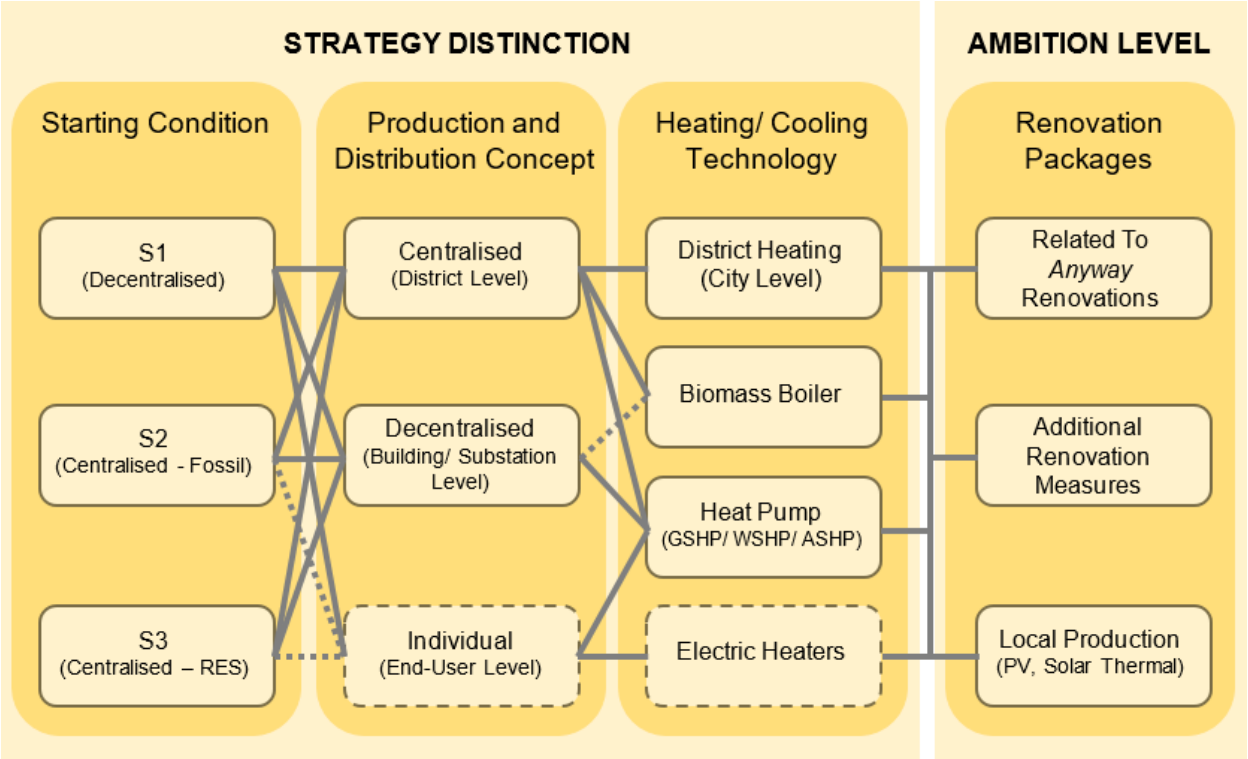

Figure 1. Strategy definition diagram (source: WALNUM ET AL. 2022).

The strategies presented next are those found cost-effective through the calculations performed in the case studies and generic districts analysed in this project. Recommendations are formulated at a general level based on the results from these calculations. In general, the IEA EBC Annex 75 methodology and the developed strategies are based on the concept that energy efficiency measures are performed first or at least at the same time as investments in heating/cooling systems so that the thermal energy supply system can be sized and designed based on the expected future energy needs. This is important as demand (both in amount and temperature level) influences the design and cost of the energy supply system. However, in practice, measures are often planned and executed in reverse order, which is challenging for cost-effective building renovation at the district scale.

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 (see also figure 1)

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, likely, 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 pumps5

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

5 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 will have ownership of the grid. Nevertheless, it is a very relevant option for some scenarios.

	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
	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, alternatively, 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

The previous tables illustrated relevant strategy recommendations. The following table provides target-group-oriented operational recommendations for policymakers and investors/decision-makers based on the most important findings of this chapter.

OPERATIONAL RECOMMENDATIONS FOR UPSCALING BUILDING RENOVATION TO THE DISTRICT LEVEL

FOR POLICYMAKERS	Create an in-depth and accessible database and source of information for analysing the starting conditions of building renovation projects at the district level as a basis for informed and integrated decision-making while guaranteeing the security and privacy of data, especially personal sensitive data
	Explore local renewable energy potentials, including those that can only be accessed at the district scale, to facilitate the development of related projects
	Be transparent about the potential effects of specific local preconditions, such as energy and building materials prices, as well as regulatory frameworks and user behaviour
	Take into account synergies between energy efficiency measures and the use **of** renewable energy when developing or supporting projects for building renovation at the district level
	Maintain regulations and incentives concerning energy efficiency measures in buildings within the scope of district solutions based on renewable energy since synergies between energy efficiency and the use of renewables can be as high at the district level as at the decentralised level
	Analyse each case individually according to an integrated approach that not only reflects the techno-economic assessments but also considers socio-economic effects, overarching policy and urban development goals and plans
	Plan any district intervention in such a way that it integrates well with the external energy system
	Take into account that if an existing thermal grid is in good shape in the district, it is usually more cost-effective to continue using it
	Explore or encourage the reduction of temperature in the heat grids while ensuring the necessary hygienic conditions
	Inform and encourage the use of energy efficiency measures in building envelopes whenever renovations are required anyway
	Develop city-wide, regional, or national strategies and align district solutions with them. Do not hinder the implementation and development of cost-effective decarbonisation technologies through overarching frameworks and strategies

	Promote and support training programs for the skilled workforce to implement building renovation
	Promote and support standardization and prefab solutions
	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
FOR INVESTORS/ DECISION-MAKERS	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 individual 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 standardization 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

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

This chapter provides information on business models that can support building renovation at the district level, targeting various stakeholders. In addition, recommendations related to business models and different categories of key stakeholders are derived, considering that the actions of each category are not independent of the others, as the influence of actors in the district is intertwined. Many of the recommendations regarding business models already emphasize the importance of stakeholder dialogue, an essential subject of this guidebook, which will be further elaborated on in chapter 6. The results and recommendations on how business models can support upscaling of building renovation are mostly derived from the IEA EBC Annex 75 report on business models (KONSTANTINOU ET AL., 2023), which provides a comprehensive analysis of the topic.

4.1 Energy Companies as Key Actors

Energy companies have a key role in upscaling building renovation to the district level and harness synergies between energy efficiency measures and the use of renewable energy.

First, there is a need for a combination of energy efficiency and renewable energy measures in business models. Economic assessments show that significant synergies are available when combining these two measures. However, so far, business models focus either on energy efficiency or renewable energy measures, which are hardly linked. It is essential that energy companies set up or use existing innovation clusters to discover business models that allow them to access the economic benefits of related combinations. Such business models can offer energy efficiency measures to building envelopes and heating or cooling solutions to buildings. Partnerships of energy companies with renovation solution suppliers will coordinate the conversion of overarching plans into concrete actions.

In addition, it is important for energy companies that provide heating or cooling to their customers to structure their tariffs to encourage building owners to carry out energy efficiency measures in their envelopes while connected to a district heating system. Tariffs may be strongly based on the energy used and barely have fixed components to maximize incentives for building owners to reduce their buildings' energy needs (if they are also the users). As tariffs continue to contain a fixed component, it is at least important that regular fixed costs can be adapted and, especially, reduced if a building improves its energy performance and, in consequence, requires less capacity from the grid.

However, incentives to implement energy efficiency measures can have very different effects depending on whether owners occupy their buildings themselves or whether they rent them out. In the latter case, the structure of tenancy and contract law, the possible apportionment of investment costs to tenants (such as in the case of equity financing) or the basic market situation in the local housing market are important

determinants of incentives for energy efficiency measures. Thus, it is essential that tariff structures are implemented considering the respective local context. Using synergies between energy efficiency measures and renewable energy measures requires that energy companies consider options to reduce the temperature in the grid, provided that building owners collectively carry out energy efficiency measures on their building envelopes. Coordination and synchronization of planning and decision-making is the main challenge that needs to be approached.

To take advantage of the synergies between energy efficiency measures and renewable energy measures, it is important that the cost savings associated with a higher efficiency of a district heating system when the temperature in the network is reduced can be passed on to building owners or other energy actors funding energy efficiency measures. To make the most of the synergies between energy efficiency and renewable energy measures, it can be beneficial to offer customers connected to district heating systems lower rates per kWh when they insulate their buildings and thus reduce energy consumption, even if that means less energy consumption.

A suitable target for business models can also be to expand the territory covered by a district heating system over time, as energy efficiency measures reduce the energy consumption within the part of the district already connected to a district heating system. Connection fees may have an important function in this context, to benefit companies as they expand the grid, when energy efficiency measures reduce energy consumption to the point that allows for such network extension. However, in the case of heating systems that depend on high shares of fossil fuels, decarbonisation and preservation of existing energy capacities might be a more pressing issue to overcome first.

An important element of business models for building renovation at the district level is also to provide a specific offer to building owners who need an interim solution between when the heating system has to be replaced and when a district heating system becomes operational. These interim solutions could be, for example, offering mobile heating systems or specifically offering to temporarily install decentralised air-source heat pumps. Again, it is very important to coordinate and synchronise renovation and investment decisions.

4.2 Policymakers as Enablers

Policymakers are responsible for encouraging the development of integrated district renovation plans and ensuring they are aligned with overarching heat master plans or other energy planning activities at the municipal level. Furthermore, they have an essential role in coordinating various energy actors. Finally, being part of the process supports communication and trust, which are key elements of the stakeholders' dialogue.

A comprehensive Heat Master Plan guides potential new business models. For existing large areas, the planning process is complex. It includes consideration of future heat demand and costs, existing infrastructure maintenance and operation, and new infrastructure development (see also chapter 5). Heat and energy system implementation plans cover many years of actions to increase efficiency, resilience, and reliability. These plans are essential to provide the scope, schedule, and security to projects funded directly or using a third-party financing body. Thus, district energy/ heat planning is important for renovation/ efficiency measures decision-making at the single-building level. Against this background, these master

plans must be "translated" to a building level and linked to respective renovation options. This should prevent lock-in effects due to investments for building renovation that do not fit the broader energy supply plan and do not pay tribute to long-term decarbonisation goals. As a result, the energy master plan needs to be combined with a district renovation plan. This is essential in combining renovation and energy interventions and supporting the dialogue between the respective actors. In this regard, it is also important to facilitate partnerships of energy companies with building renovation solutions suppliers and integrated home renovation services that can coordinate the translation from overarching plans to specific actions in districts.

Regulations, support schemes, communication programmes or organisational services defined by policymakers, such as minimum energy standards, financial incentives to renovate and subsidies, are instruments for mobilising renovations at a large scale. The policy instruments catalogue prepared in the IEA EBC Annex 75 project (MLECNIK ET AL., 2023) gives an extensive overview of such instruments. Policy instruments can incite new business models that support the decarbonisation of the building stock, e.g., through financial guarantees and direct funding or regulation. However, it is also important to analyse the local situation individually. For example, it will always be necessary to investigate whether the local labour market (which also includes the staffing of local authorities) can respond to a significant increase in building renovation works or if, in parallel, training programs can be initiated. This should always be done in coordination with local actors with practical knowledge.

Building efficient and sustainable communities requires careful coordination between all stakeholders, including policymakers, master planners, energy planners, building designers, investors, and decision-makers. These stakeholders work at differing levels of detail and use different planning horizons, which may lead to suboptimal decisions for the community as a whole. Coordinating the myriad of stakeholders and organizations, often based on the co-participation form, can be challenging. An effective governance model with clear roles and actions is needed. These governance models should take into account the business model(s) that will be developed.

4.3 Investors' Role

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 the 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 the policy instruments, such as subsidies, and innovative financial schemes, such as EPCs, prosumers' revenue, 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 and renovation process guidance, utilizing financing options and developing new business models around these tasks. A long-term planning perspective can be achieved with coordination between policymakers and investors/decision-makers, with the help of knowledgeable and experienced advisors and other market intermediaries, to facilitate the investors' decision-making and the development of integrated home renovation services.

District renovation requires both top-down and bottom-up approaches. Owners, as well as practical actors in the implementation of building renovation, need to present to policymakers their requirements for process improvements and framework conditions, but they also need to participate in initiatives that provide renovation solutions.

4.4 Market Characteristics

Upscaling building renovation to the district level can lead to new levels and scopes of building stock renovation and energy supply strategies. Building stock renovation scenarios can include measures as broad as renovation of the whole building stock, including an analysis of different energy efficiency levels with possible multiple benefits. Various supply strategies will provide different energy and cost scenarios, such as decentralised energy supply, renewable energy sources, short-term and seasonal thermal energy storage, batteries, and distribution strategies. Most importantly, decarbonisation can be offered as a new value proposition that aligns with the policymakers' local, national, and international goals and is expressed in the energy planning. Further improvement of the district's living quality and infrastructure, including the buildings, needs to be offered as part of the integral values of the interventions in coordination with the urban planning of the policymakers. In a context like this, innovation clusters should be set up to ensure that innovative business environments will grow with the potential for upscaling and replicating district decarbonisation solutions in energy communities.

Partnerships of energy companies with building renovation solution suppliers will be more important to coordinate the translation between overarching plans and concrete measures and handle the manifold interests and needs. Innovative solutions, e.g., in construction systems, serial refurbishments, energy-saving services, communication and mobilization methods, need to be part of the key business model activities around upscaling building renovation to the district level. The flexibility of the energy distribution grid, the implementation of digitised solutions that can lead to more efficient processes, and the consideration of user behaviour are examples of innovations that must be considered.

OPERATIONAL RECOMMENDATIONS ON BUSINESS MODELS SUPPORTING UPSCALING OF BUILDING RENOVATION TO THE DISTRICT LEVEL	
FOR POLICYMAKERS	Setup of a comprehensive Energy Master Plan and a city-wide decarbonisation strategy, including building renovation, which guarantees energy security and gives guidance to private actors (e.g., investors and decision-makers)
	Create a national policy framework (e.g., through regulation, financial incentives, and subsidies) and local action plans (e.g., for communication and organization in districts) to promote large-scale renovations and allow new business models to evolve in this regard
	Take the role of careful coordination between stakeholders, including master planners, energy planners, building designers and potential investors and decision-makers, and

	enable an easier linking of practical, concrete business activities to overarching goals and strategies
	Create effective governance models with clear roles and actions that must consider new business models but not neglect local specificities regarding the labour market and business structure. Encouraging upscaling of building renovation must be accompanied by co-developed information and training campaigns for the skilled workforce, as well as potential investors and decision-makers
	Facilitate partnerships between energy companies, prosumers, building renovation solutions suppliers and integrated home renovation services that can coordinate the translation from overarching plans to specific actions in districts
FOR INVESTORS/ DECISION-MAKERS	Combine energy efficiency measures and the use of 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 policymakers, investors and implementing actors e.g., with the help of advisors and other market intermediaries
	Present to policymakers the requirements for innovative energy improvements in districts
	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 policymakers' goals 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 replicating 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 encourage energy efficiency measures in building envelopes, in particular, if applied throughout the district, allowing the temperature to be lowered accordingly

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 building renovation solution suppliers and further practitioners in the implementation of building renovation

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

Actions by local authorities (including regions, provinces, municipalities, and cities) to promote energy-efficient building renovation at the district level include implementing regulations or incentives, facilitating stakeholder dialogue (see chapter 6), and urban planning processes, among other fields of action. Multiple pathways for planning and implementing actions at the district level are the norm. Yet, many local authorities, especially small to middle-sized ones, often "do not have the needed specialized and diverse capacities required to cover the entire process" (VALLEJO ET AL, 2019, p. 24). Usually, the best time for a city to intervene in renovation projects at the district level is as early as possible. In many countries, once zoning, building plans, and building permits are formally and legally defined, local authorities often have a limited say in changes if the building stock (as well as land) of a district is not publicly or semi-publicly owned (i.e., municipalities, limited profit real estate companies). Thus, the concept phase is highly important for district renovation efforts. Yet, action by policymakers is not limited to influencing ongoing district renovation projects. Policy instruments are also suitable to trigger district renovation projects in the first place. The possibilities that local authorities have, for example, in energy planning or energy spatial planning, but also other fields of action, are strongly related to the existing structure of multi-level governance. In an integrated action space, many levels communicate and influence each other (see **Figure 2**). In this guidebook, municipalities and cities, with their flexible connections to other levels, are the local levels of interest and offer some national, regional or neighbourhood-level examples.

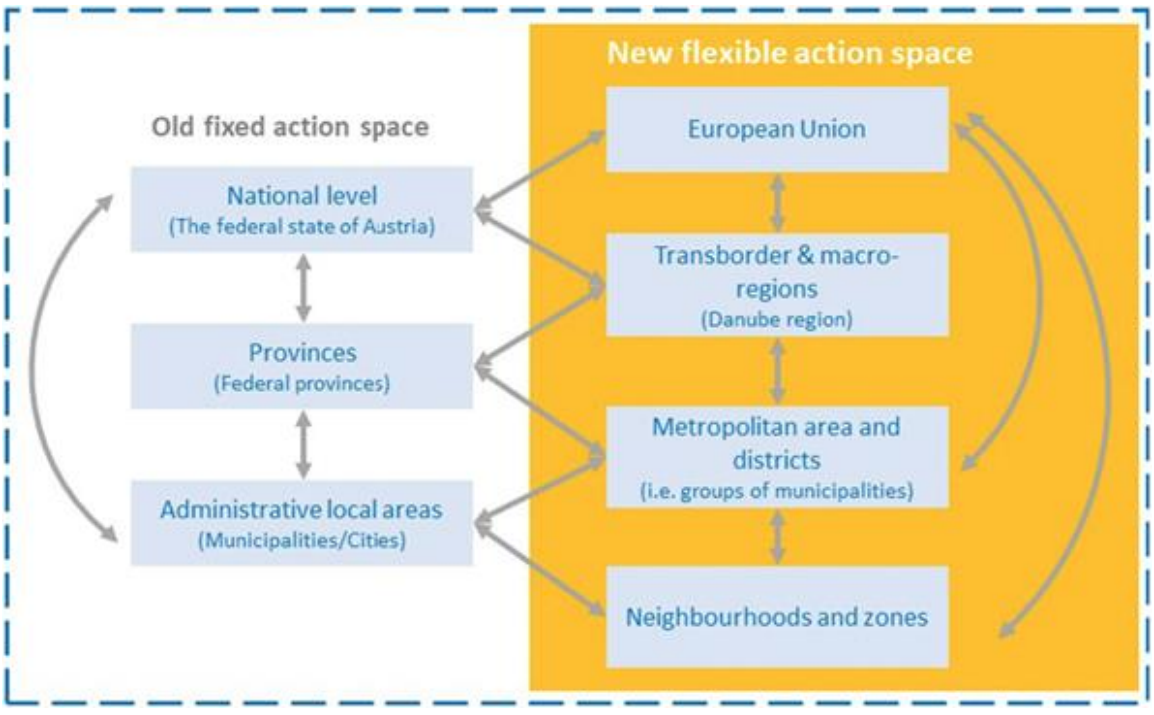

Figure 2. Modification of a new integrated, flexible action space for governance (DOBRAVEC ET AL., 2021)

5.1 Overview of potential instruments at the local level

For district-level actions, policy instruments at the local level are of high relevance. Local authorities are key in encouraging building renovation at the district level. Local authorities may assume various functions, such as mediators, coordinators, motivators, or funding institutions. They can also be facilitators to obtain funding, communicators, and act as information hubs. Local authorities may also be initiators, providing an initial impetus for building renovation projects at the district level. From a strategic planning view, the municipality (or another local authority) is a potential decision-maker, legislator, or regulator. It is also up to the municipality to start concepts and planning procedures related to district-level renovation efforts to connect existing concepts, procedures, strategies, and tools. Municipalities can also be role models, for example, in model renovations and pilot projects regarding their buildings or in connection with the land they sell (BUNDESMINISTERIUM FÜR VERKEHR, INNOVATION UND TECHNOLOGIE, 2017). Local authorities represent the level of government closer to citizens and districts. They have the best knowledge about local conditions and can interact with citizens and stakeholders at the local level. They can also be producers or suppliers of heat, for example, through public companies they own. In addition, local authorities already have the task of carrying out urban planning and authorizing 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.

Within IEA EBC Annex 75, a separate report was elaborated on policy instruments for cost-effective building renovation at the district level combining energy efficiency & renewables (MLECNIK ET AL, 2023). The following recommendations build to a large extent on this Policy Instruments report. Local policy instruments for building renovation at the district level, combining energy efficiency & renewables, include:

Target setting

An important element to stimulate building renovation at the district level is to define targets at the local level, for instance, the municipal level. Such targets include, for example, "net zero emissions" goals, “Smart City” goals, "Covenant of Mayors" targets, the goal of a “Climate Neutral City” or “2000-Watt-Society” targets, as well as targets defined in local climate and energy strategies or targets in regulations at a local level. It makes sense if they are aligned with overarching goals set by the Paris Agreement, the EU, or at the national level, but adapted to the local context. These targets can be of purely informal declaratory nature, or they can be binding commitments in case of regulations by law. The more binding related target definitions are, the higher their importance and effect. A powerful effect can be achieved if the population endorses such targets through consultation rounds or voting. Targets can refer to action on municipal buildings and infrastructure, all buildings within a municipality, energy supply and distribution, and mobility and framework conditions regarding municipal efforts to enhance urban development. They refer to specific topics such as the share of heat provided by renewable energy, the renovation rate or sector-coupling. For example, the city of Salzburg, in Austria, currently has a Smart City Masterplan 2025 (STADT SALZBURG, 2019). Other examples are Zürich or Luzern, in Switzerland, where a popular vote endorsed binding regulations to achieve climate neutrality by 2040. Also in Switzerland, the commune of Mettmenstetten, in its strategic energy plan, set the goal of reaching 100% renewable energy sources for heating by 2030. Target setting may also include defining a certain number of districts (or buildings) to be renovated within a specific timeframe or determining how many district certifications should be achieved within a given timeframe. Target definitions may overlap in “new flexible action spaces” (see Figure 2), for instance, when targets at the local level derive from or expand targets set at higher levels.

Energy planning

Spatial energy planning and energy strategies in general, including planning, designing, or tendering the planning of renovation of a district, can be an effective policy instrument to initiate and facilitate the development of building renovation projects. Key aspects that can be addressed through energy planning are, for example, the identification of suitable renewable energy-based heat sources, possibilities for seasonal thermal storage, distribution of already installed heating systems and their construction year by heating type, and information on the age of building envelopes or their energy properties. For example, in the Netherlands, all municipalities must provide plans for districts to disconnect from the gas supply. Such plans must state where they plan to include heat distribution via heat grids. In Mechelen, Belgium, such plans were developed as a result of an EU-project. In Switzerland, energy planning is mandatory for many municipalities. In the canton of Luzern, for example, it is required by law. In the canton of Zürich, the availability of energy planning is a pre-condition for receiving the European Energy Award for local authorities. Energy planning can be an effective communication tool to give building owners and energy companies knowledge about their options and to facilitate the development of integrated district renovation plans. In addition, energy planning can also be helpful in introducing mandatory regulations for specific areas, for example, to enforce connection to renewable energy-based district heating systems.

Energy planning plays a key role in enabling district projects, allowing the identification of related potentialities and the coordination, spatially and temporally, of replacing existing fossil fuel boilers. This planning allows for a step-by-step switch to a centralized heating system and avoids potential connection limitations to the district network for those replacing their boilers at a later stage.

Energy planning can be implemented at various levels. It can be pre-defined at higher policy levels, and it may define, for instance, specific target development areas within such plans. There are multiple names for such plans, e.g., “Master plans”, “Smart City plans”, “Framework plans”, or simply "Energy plans". Based on an initial selection of development areas, these plans often determine a site's fundamental characteristics and potential energy sources, providing information to project developers, including energy planning options for urban areas and districts.

Leading by example

Local authorities have an important role to play as change facilitators. Not only do they often own buildings (i.e., housing stock) or land, but action by local authorities on their building stock also encourages residents and stakeholders to undertake similar actions on their own. Local authorities may therefore initiate building renovation projects at the district level by taking their buildings as starting points and promoting similar efforts to other stakeholders, building owners or citizens. Furthermore, local authorities are often owners or majority shareholders of local energy companies. As such, they are responsible for ensuring that such energy companies proactively promote building renovation at the district level. They can ensure, for example, that public energy companies engage in exploring business models designed to encourage combinations of both energy efficiency measures and renewable energy measures in building renovation at the district level. They can also ensure that public companies that sell natural gas refrain from undertaking promotional activity for selling natural gas and instead give resources to the cause of advancing building renovation projects at the district level. Action by publicly owned municipal companies often benefits from an increased trust by citizens and vice versa.

Regulations by policy actors

Regulations and contractual arrangements can be powerful tools to facilitate or ensure change at a sufficient speed. If local authorities are allowed to go beyond national standards, they can, for example, enforce minimum building performance standards for the worst performing buildings, make a switch to renewable energy-based heating systems mandatory, oblige building owners to connect to renewable energy-based district heating systems, or use inspections and audits in districts to ensure the compliance with energy standards. However, such regulatory competencies are not found in many countries at a local level. Even if such competencies exist, policy actors often hesitate to resort to this instrument due to a lack of knowledge or fear of opposition by residents – and ultimately voters – if strict regulations are introduced. A facilitating approach can be if the introduction of binding regulations is coupled with something local authorities can give building owners affected by the regulation in return. For example, higher energy standards can be required in districts "in exchange" for granting the possibility to build an additional floor within a district or on top of a building to be renovated. This can occur either at a city-wide level or through specific contracts. Ultimately, contractual agreements (i.e., between the municipality and one or more building owners) should always be embedded in existing local policy (as sovereign law and private law should not contradict each other, which can be the case when contractual agreements are set up in urban planning).

- Examples of related suitable policy instruments at the district level are the following: Use of local codes as enforcement. Building codes and related standards are often defined at the national or regional level. In some countries, municipalities can introduce their local codes provided that they are more and not less ambitious than national or regional energy standards. For example, the commune of Hochdorf, in Switzerland, decided by popular vote to make a switch to renewable energy mandatory when heating systems are replaced. In Luzern and Zürich, and also in Switzerland, similar local regulations are planned to be introduced in certain areas of the city. Given the urgency of reducing carbon emissions to meet the Paris Agreement targets, local authorities, as far as possible, should ensure that whenever a heating system is replaced, a switch to renewable energy sources would be mandatory. Furthermore, it would also make sense to set an end date for the use of fossil fuels for heating purposes at the local level until related regulations are adopted at the national level.

- Zoning and building plans. The influence of zoning changes is more significant for new construction areas but can also play a role in the renovation of districts. A building plan (“development plan”), has a more direct impact on a specific project, as it directly influences the buildings in a district. Depending on the design of the planning laws, statements on energy are possible. In the province of Salzburg, in Austria, for example, it is possible to enforce the exclusion of fossil fuel energy sources in the building plan (SIR, 2021, p.15).

- Energy in quality agreements. The so-called quality agreements are usually a soft instrument, as they are often not anchored in planning laws. Nevertheless, municipalities can push for a quality agreement, especially if they are part of a planning consortium or can exert influence on publicly or semi-publicly owned urban housing or energy companies. This contains essential agreements on which qualities are to be implemented, whereby the contents are open and can potentially include all energy-related topics (SIR, 2021, p.13).

- Contractual land use agreements. In the framework of contractual agreements with private parties, for instance, when local authorities sell their land or public buildings, local authorities can impose minimum energy standards for buildings and renovations. For example, the city of Antwerp, in Belgium, requires and stimulates high energy efficiency through such an approach. In practice, local authorities can organize contracts in the format of sales under conditions or collaboration agreements with developers for areas of high social significance (PassREg, 2016).

- Conditions for obtaining concessions. When an entity intends to operate a district heating system, it may require authorization from a local authority to do so. An example is when the district heating system depends on pipes below the streets or restrictions on using a specific energy source such as groundwater. This requirement to obtain authorization can be linked to conditions that can stimulate building renovation at the district level or specifically promote the combination of energy efficiency and renewable energy measures. In the city of Zürich, for example, there is a requirement that groundwater in district heating can only be installed if all neighbours in a given area are invited to participate in the district heating project.

- Qualified concessions. If authorization from a local authority is required to develop a district heating system, the local authority may require specific quality standards. Ideally, public or semi-public companies offering district heating have the best structural abilities to comply with such standards to maximize synergies and flexibility in energy supply throughout their territory.

- Quality improvement of rented housing. Local authorities can undertake action when the quality of a dwelling endangers health or safety. Some local authorities are smart in coupling energy issues with such issues. For example, regions like Flanders or Brussels capital region have similarly implemented the “energy efficiency first" principle. However, it must be taken into account that the opposite combination, i.e., requirements to comply with fire protection standards or obligations to renovate the sewage connection in case of a building renovation, may be an obstacle to undertaking building renovation for energy purposes.

- Mandatory energy performance checks. Such checks are usually implemented at the national level or regional level. However, some municipalities have already used additional energy certificates based on performance checks, for example, as a condition to obtain local subsidies. This offers the opportunity to encourage the combination of energy efficiency measures and renewable energy measures. If an energy performance check is mandatory for subsidies for a renewable energy-based heating system, this encourages combining energy efficiency measures with renewables. Such energy checks can also be promoted as “do-it-yourself" home energy audits. Municipalities can promote voluntary checks through self-assessment websites.

- End customer involvement. Policymakers can make it mandatory for district heating companies to give customers a say in the choice of energy sources. This can boost demand for renewable energy sources, as people will likely support such systems.

- Mandatory tariff rules. Local authorities can ensure through regulation that tariffs set by district heating companies provide incentives to carry out energy efficiency measures, even after connection to a district heating system.

Financial incentives

There are many potential financial incentives, including subsidies, local tax reductions, and revolving funds. Financial incentives supporting district planning, connections to district systems or building renovation by groups of homeowners can have an impact and are useful in some countries. Furthermore, funds might be needed for stakeholder collaboration and cooperatives and for covering innovation and process risks. To the extent that local authorities have access to funding to promote building renovation, they can make use of this possibility, for example, as follows:

- Financial incentives created at the local level. An example at the municipal level is the climate protection fund “proKlima”, run by the municipality of Hannover, Germany, together with surrounding municipalities. Local subsidy programmes can foresee an additional bonus if buildings are renovated at the district level and if efficiency measures and renewable energy measures are combined. In this context, it is appropriate that subsidies for heating systems are not awarded simply based on the capacity of the heating system. They must be granted by heated floor area or by applying a defined funding threshold per heated floor area to ensure some level of energy efficiency for obtaining subsidies for renewable energy systems.

- Financial support for developing Integrated District Renovation Plans. As the development of suitable strategies for building renovation at the district level combining energy efficiency and renewables is a complex task, local authorities should provide subsidies for such purposes.

- Financial support for project development. As building renovation projects at the district level are accompanied by high risks of not being implemented at the stage of seeking interest from building owners, local authorities should provide a specific amount of funding for developing such projects up to the point where building owners sign contracts and the economic viability of the process is assured.

- Offering zero-interest loans. As an example, the Brussels capital region uses a zero-interest social loan for vulnerable households to insulate their homes and links it to energy standards. Such standards could comprise the mandatory combination of energy efficiency measures and renewable energy measures and contain specific benefits for action at the district level.

- Tax incentives. Local authorities can foresee tax incentives for building renovation at the district level, particularly if energy efficiency measures and renewable energy are combined.

- Energy demand side management in districts. The local energy market or an aggregator penalizes high energy use and rewards low energy use or renewable energy production. Overall, this policy option is still barely explored at the district level.

- Facilitation of trading certificates. Not all districts or cities can easily achieve a high level of energy efficiency or renewable heat production. Theoretically, a well-performing district or city could trade green, white or black certificates to compensate for other districts or cities with low performance. Certificates currently set (and traded) on a (pan) national level might be traded at a local level. Overall, this policy option is still barely explored at the district level.

Organizational policy instruments

Building renovation projects at the district level are complex. This is due to technical aspects and the challenge of leveraging synergies between energy efficiency and renewable energy measures. Also, various buildings in a district may have substantial differences in their characteristics and renovation cycles. Furthermore, building renovation projects at the district level involve a large number of building owners and other energy actors. Due to a lack of support from building owners, there is a high risk that such projects are not implemented. Therefore, far-reaching organizational support by local authorities is essential to make such projects happen. Policy instruments may include, for example, the following:

- Renovation services in districts. Local authorities can organize the planning or execution of renovation measures at the district level, offer related services themselves or through companies they own, or provide mandates to other energy actors. Energy advisors can, for example, be mandated to coach building owners in preparing initial studies on district projects or to accompany them throughout the process. Local authorities may aggregate related services in one-stop-shops by qualified actors. For example, in Hauts-de-France / Pacardie (France), public service can be requested by homeowners to help renovate their homes, acting as a special assistant, facilitating tenders and contractor engagement, and unburdening the homeowners from such things. In another example, the city of Zürich, Switzerland, provides comprehensive support by city staff to building owners interested in developing a district heating system, from initiating contacts between building owners, carrying out networking events, mandating a company to carry out feasibility studies, up to the point of assisting them in finding a suitable legal structure or contractor for operating the district heating system. The city of Zürich also offers energy coaching through building renovation experts, including special services for building owners in planning small grids connecting only two or three buildings.

- Energy advice services for citizens. The local authority sets up a physical location, such as a local energy desk, a similar virtual contact point, or another consultancy offering, to inform and advise citizens locally on energy efficiency and renewable energy and their combinations. Places can also be mobile. For instance, the city of Aachen, in Germany, initiated the building renovation NGO “Altbau plus” to inform and give advice about possibilities in building renovation.

- Process-steering group. A process-steering group with the participation of all relevant stakeholders (policy, administration, project development, energy service providers, etc.) should be defined and constituted at an early stage of the project. Such a group supports ongoing decision-making and communication in the process. Especially for district redevelopments above a certain size, such a group and regular meetings are recommended. It also ensures that previously defined measures are adhered to, especially if there are well-documented and shared minutes of the meetings (SIR, 2021, p. 11).

- Citizen energy cooperatives. District residents organize themselves in a cooperative to produce renewable heat or renewable electricity locally, to implement energy efficiency measures, or to jointly buy technical solutions. Local authorities may support the creation of such cooperatives and encourage them to combine energy efficiency measures and renewables.

Communication instruments

A policy instrument of crucial importance for advancing building renovation at the district level is establishing a set of communication measures. Policy instruments may include, for example, the following:

- Development of Integrated District Renovation Plans. A key instrument to facilitate the implementation of building renovation projects at the district level is to support the development of district assessments, such as those carried out in the IEA EBC Annex 75 project. These assessments make it possible to analyse various building renovation options at the district level, including improvements in energy efficiency and a transition to renewable energy and the development of the most appropriate renovation strategies.

- Local web tools. The local authority develops or procures media and web tools to support citizens' renovation journeys. For instance, cities like Rotterdam, the Netherlands, tried to use videos and digital testimonials. The city of Zürich, Switzerland, provides a GIS tool on its website, allowing all interested parties to explore the available renewable energy options at any given building in the city. The commune of Mettmenstetten, Switzerland, offers viewable examples of building renovation projects in an interactive map to encourage others to take action.

- Energy benchmarking in districts and contests. Comparison of energy data by local authorities or intermediaries allows building owners to compare their energy use, which might motivate them to undertake changes. A play factor can encourage citizens to take action. Similar benchmarking may also be carried out among local authorities.

- Education and training for building professionals. Through education and training, local authorities may increase the competencies of various professional actors such as building professionals, energy companies, housing associations, architects, heating installers, city staff, and also experienced building owners interested in the topics of building renovation in districts, including combinations of energy efficiency and renewables.

- Labels for low-energy/low-emission districts. Awarding specific labels for low-energy/low-emission districts incentivises project developers or groups of homeowners to reach related standards. Some EU Member States already have certification systems that go beyond individual buildings. In Austria, for example, a so-called settlement certification is offered. It considers all sub-aspects of comprehensive redevelopment (energy, mobility, communication, urban planning, etc.). If municipalities or project developers want to successfully complete certification, they must decide whether a standard will be applied prior to the planning phase. Indicators must be complied with in the subsequent planning phase. In the end, there is an assessment. Upon completion, it must be proven once again that the claimed qualities have been implemented (SIR, 2021, p. 14) to obtain the certification. In Switzerland, there has been a label for districts which comply with the 2000-Watt standard, meaning that the energy consumption on a yearly average is intended not to exceed 2000 Watt. The label was introduced for newly built districts, but a separate category was introduced to make the label applicable to districts, and it has subsequently been linked to the Minergie standard. In Austria, the “klimaaktiv district standard” was developed in the last couple of years and is now used for district renovation and new buildings.

- Local events for building owners. It is essential to raise awareness and increase the capacity of citizens, particularly building owners, with training, visits, events, and activities to encourage building owners to renovate their buildings and participate in district projects. The city of Zürich, in Switzerland, regularly organizes events for groups of homeowners in a district to allow them to get to know each other better and to elaborate a common vision as a basis for common renovation projects at the district level.

Overarching strategies

Of key importance is that all the various policy instruments that are available to local authorities to promote building renovation at the district level, combining energy efficiency and renewables, are placed in a common strategic framework that guides the city's activities in this field. Communes and cities must develop strategies of how they think the building stock in their entire territory is best decarbonised and what the roles of district solutions and energy efficiency measures are in such a vision. Energy planning is an important element of such a strategic overview to show in which area the city intends to see district solutions being implemented, in which areas decentralised solutions, and with which energy carriers. Prior to such overarching energy planning, cities must make strategic considerations about the extent to which they would like to have district solutions implemented based on the advantages and disadvantages, risks, and opportunities of various strategies. Such a strategic overview provides a framework within which different energy actors can position themselves and building owners can take decisions. It is also a good basis for determining which policy instruments are suitable to achieve the vision.

Urban planning processes

Urban planning processes are usually more helpful at the local level when new areas are being planned and developed. Municipalities often have the most formal and informal leverage over private owners, investors, and other land stakeholders by using zoning regulations and subsequent building or building development regulations. But urban planning processes can also impact building renovation at a district level. Depending on local circumstances, the municipality and the private or limited-profit housing developer might be interested in densification or the implementation of other aspects that need to be embedded in a local decision-making process by the municipality, using urban planning regulation, urban planning contracts, as well as informal urban planning methods, such as participation or stakeholder engagement. **Figure 3** shows examples (brown) of the potential use of urban planning processes for building renovation at a district level:

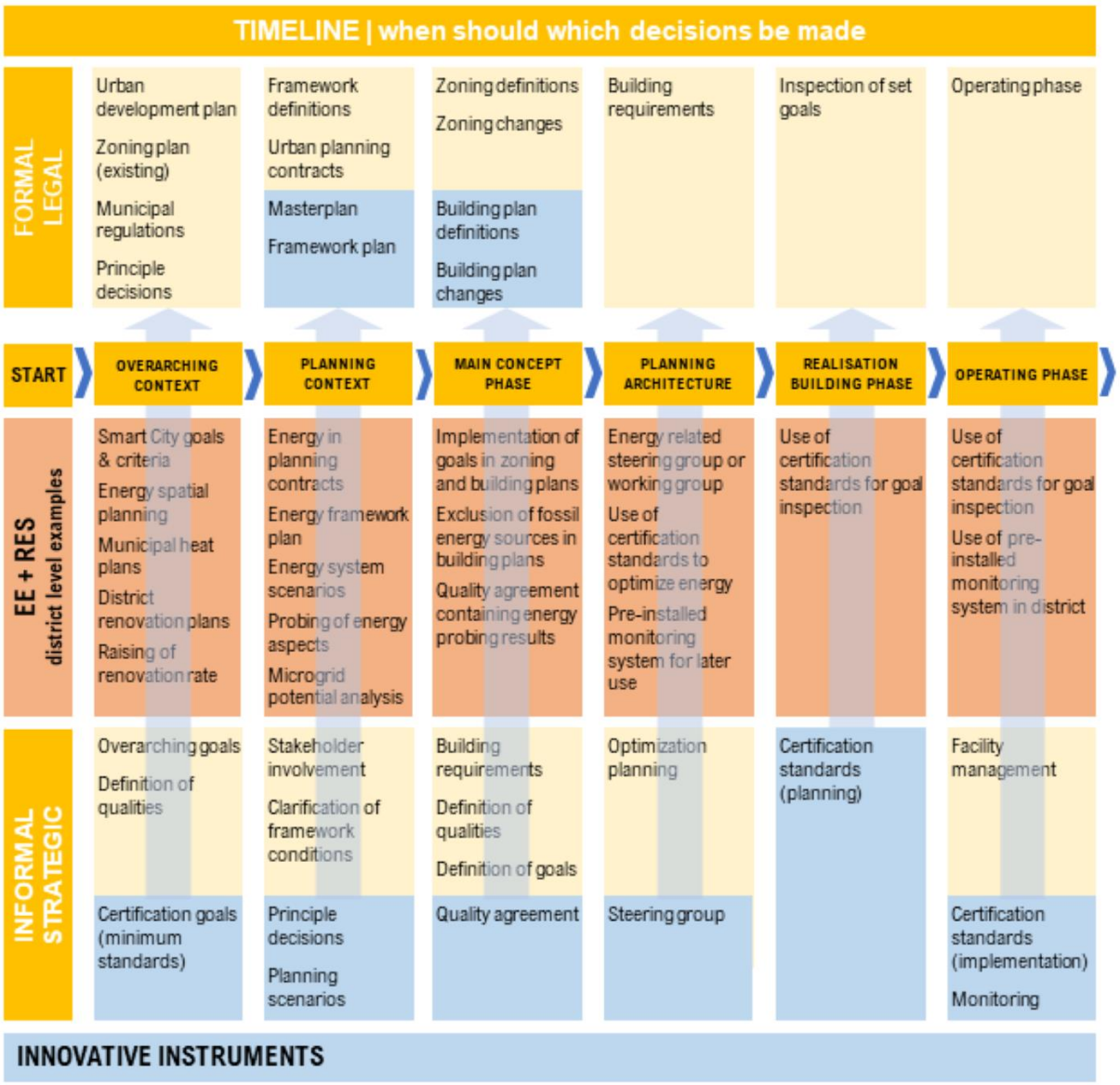

Figure 3. Example of a (planning) process combining various instruments (adapted from SIR, 2021, p. 17).

5.2 Support by policy instruments at the regional, national, European, or international level

Local authorities are a type of government institution suitable for promoting building renovation projects at the local level. However, their capacities to undertake related efforts are limited. Therefore, authorities at regional, national, European, or international levels must strengthen local authorities to support them in building renovation activities at the district level. In addition, it would be very important that at regional, national, European, or international levels, decisions are taken to ensure that whenever a heating system is replaced, a switch is made to renewable energy. In this way, an adequate framework could be created for local authorities to further develop building renovation projects at the district level.

Furthermore, it would be important to set appropriate financial incentives at the regional, national, European, or international levels to encourage building renovation projects, particularly at the district level.

Social distortions must be avoided, and transformations of the heat supply and the building sector must consider regional disparities. Decarbonising the building sector is always one of several legitimate social and political goals that need to be considered together in an integrated way - at the local level and all higher administrative levels.

5.3 Make use of the Instruments

In the selection and development of policy instruments, it is essential to address the following general guiding questions for cities, municipalities, and other local-level entities:

- Establish the state of play. What is the current policy context? What is the current overarching context regarding energy planning in my municipality? What instruments are available? What funds? Does a municipal heat plan exist, or is it in the making? Does a municipal renovation strategy exist, or is it in the making? What are future potentials? What are current and foreseen building renovation projects concerning energy efficiency or renewable energy? Is the planning carried out so far at a district level or the level of individual buildings?

- Determine the scope of action. Where can the municipality make a difference? Where can it influence the development of building renovation projects at the district level? How can a process structure be established? What influence can the municipality have on a specific renovation project? Can the municipality initiate building renovation projects at a district level combining energy efficiency and renewables? Does the municipality influence public or semi-public energy providers or housing associations?

- Select the policy instruments. Which city-internal actors and stakeholders are essential to be involved in and consulted? Which set of policy instruments is most suitable for my municipality? How can these policy instruments be ensured to live up to the challenge? Which policy instruments are endorsed by the local government and the population?

- Plan for long-term success. How can the implementation of policy measures be ensured? How can goals and qualities on a district level be achieved and guaranteed? How can the results of a renovation project influence future projects in the municipality? How can the results of a renovation project influence policy and instrument development in the future?

For implementing any selection of policy instruments, stakeholder dialogue is an overarching key element which is vital to consider.

OPERATIONAL RECOMMENDATIONS ON POLICY INSTRUMENTS FOR UPSCALING BUILDING RENOVATION TO THE DISTRICT LEVEL

FOR POLICYMAKERS	Support building renovation at the district level, specifically supporting combinations of energy efficiency measures and renewables
	Map building renovation efforts at a district scale and establish multi-level-processes that result in instruments and policy decisions at many institutional and geographical levels
	Raise awareness of the role of the municipal level in such processes. Engage a myriad of actors in the use and development of instruments through good stakeholder dialogue
	Scan existing instruments for their potential use in building renovation efforts. If not already established, create a municipal energy plan and municipal renovation goals, and expand them to city-wide decarbonisation plans
	Ensure energy efficiency measures are combined with district heating
	Define recommendations for district heating companies to cover additional territory, as energy efficiency measures reduce overall consumption
	Create financial incentives for connecting to district heating and ensure that efficiency measures in building envelopes remain attractive after the connection
	Ensure honest communication, recognizing that district heating is not always the most cost-effective solution, and its main advantages may be of another kind
	Make use of large renewable energy sources, if suitable and possible
	Enforce mandatory installation of heating solutions with renewable energy sources
	Use urban planning tools where possible. If there are regulatory restrictions, try to lobby for changes in laws at higher levels to be able to tackle building renovation issues
	Strengthen strategies and planning procedures, and, in particular, encourage the development of Integrated District Renovation Plans to combine both energy efficiency measures and renewable energy measures at the district level
	Define holistic & integrated approaches linking energy efficiency to urban design

	Design municipal subsidies, loans, and tax benefits to target district renovations
	Ensure appropriate incentives for landlords, but also correctly weigh tenants' needs
	Offer comprehensive organizational and advisory support for districts interested in developing district projects
	Do not stop engaging in a project after its realization. The results of a monitoring system could directly influence current and future local-level decisions and plans
	Communicate about the progress being made
	Spread information about successful building renovation examples at the district level
FOR INVESTORS/ DECISION-MAKERS	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 and use your practical knowledge of policymaking processes in your own business model whenever possible
	Look at building renovation at the district level from the point of view of your (future) tenants. What is the best way for them to have a secure, safe, affordable, long-term energy solution for their households? How can you help avoid energy poverty?
	Do not stop engaging in a project after its realization. The results of a monitoring system could directly influence investors' current and future decisions and plans

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

The previous chapters already discussed some aspects of stakeholder dialogue and process organization. This chapter will examine these aspects more comprehensively since stakeholder dialogue and process organization are highly important in upscaling building renovation to a district level and combining energy efficiency and renewable energy measures. A focus is placed on stakeholder dialogue from the perspective of local policymakers, including local administration and decision-makers in building renovation processes at the district level, with multiple stakeholders involved.

6.1 The Importance of Dialogue

Definitions of stakeholders and stakeholder dialogue for administrative actions vary in economic theory and practice. We refer here to the original definition of the term “stakeholder”:

In a corporation, a stakeholder is a member of "groups without whose support the organization would cease to exist", as defined the first time the word was used in a 1963 internal memorandum at the Stanford Research Institute. The theory was later developed and championed by R. Edward Freeman in the 1980s. Since then, it has gained wide acceptance in business practice and theorizing relating to strategic management, corporate governance, business purpose and corporate social responsibility (CSR).

When governments, intergovernmental organizations or regional organizations make certain stakeholder consultation part of their regulatory procedures, implementation procedures or planning procedures, the stakeholder dialogue becomes an institutionalized feature. The institutionalized stakeholder consultation procedure can be the result of positive experiences in preceding stakeholder consultation processes, such as stakeholder forums for the ongoing review of strategic planning processes. It can also be a provision in the constitution or societal pressure groups which force a public sector actor to ask for and integrate different stakeholder views.

As institutionalized stakeholder dialogues are convened following a regulatory procedure, the convening and participating stakeholders may lose the sense of urgency typical in other stakeholder dialogues. The challenge lies in breathing life into this stakeholder dialogue and keeping the purpose and the need for stakeholder consultation at the top of the decision-makers' agenda.

Institutionalized stakeholder dialogue on building renovation at the district level needs to be based on a clear vision/picture of local energy and climate objectives.

Many studies show that stakeholder engagement and involvement are essential for successfully implementing community energy strategies. The benefits of positive stakeholder involvement are clear. Engaging diverse and interested parties to integrate an energy and urban planning process may present

an organizational challenge but provides benefits essential to successful implementation (BURBY, 2003). 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.

This is particularly important for district-level building renovation projects that combine energy efficiency and renewables. Sharing a heating system or engaging in coordinated activities to increase the efficiency of building envelopes requires a high level of trust between building owners and building owners, and other stakeholders involved. This high level of confidence is necessary as high costs are involved, there are uncertainties about future energy markets, renovations are associated with the personal living environment, and the reliability of a heating system or other common energy systems is extremely important to building owners and tenants.

Identified stakeholders must be engaged early, given time to understand key issues, and become invested in a process and position to contribute meaningfully. In addition to stakeholders, technical and political champions can be developed. The specifically assigned role of a technical champion (e.g. energy manager) can be to care about large, dramatic initiatives such as introducing energy mapping or district energy. Political champions are highly visible to the public and the stakeholders and represent a practical way to move a project forward.

To optimize the results of the stakeholder process under limited resources (stakeholder schedule, etc.), stakeholder committees, such as advisory, technical or steering committees, can be created. To increase the cooperation between stakeholder groups, the inter-relationships between stakeholders should be understood and explicitly targeted.

Successful stakeholder engagement emphasizes a two-way exchange of information in an early, open, and ongoing process. To help build consensus, improve the results of planning efforts, and build support for the implementation of their projects, planners of all stripes can take the following engagement path:

- Identify the lead person/ organization for the plan or project initiative – who is responsible, and under what authority does that lead person operate? If that person/organization is from the "energy efficiency side", is there a similar role in the energy delivery sector, and vice versa? Is there a critical technical or political champion that should be engaged?

- What are the driving principles and goals of the plan or project in terms of energy / emission-related benefits for the community?

- What stakeholders share the project territory, have related expertise and interests, or have the power to influence the outcomes of the project or plan?

- What impact could the project bring to each stakeholder group, and where are the contact points?

- How can stakeholders and the public contribute with expertise, knowledge of the local context, and resources that can help enhance the plan or project?

- What role will the stakeholders play in your project; what are the possible ways to interact with them, and when should that interaction begin?

- How and when should ongoing interactions and results be documented and shared?

6.2 Implementing Stakeholder Dialogue

Good stakeholder dialogue is crucial for a successful building renovation at the district level. To organize a building renovation process combining energy efficiency measures and renewable energy measures and to establish a dialogue between the stakeholders involved, the following recommendations should be followed.

Municipalities have an essential role in communicating with different stakeholders. It is recommended that the municipality:

- Coordinates the process in terms of communication, consulting and financing
- Takes the role of both moderator and central actor to reach a large number of stakeholders
- Connects various building owners and helps them implement a district heating solution
- Engages actors for the dialogue and partnership: municipality, owners, investors, suppliers, inhabitants, users
- Provides long-term guarantees to support financing
- Combines building renovation with other measures on building and district
- Establishes a steering group
- Ensures that energy companies are part of the dialogue

Thematic workshops should be organised, including all district renovation issues and addressing all types of tenants. The renovation project group, consisting of district managers, citizen representatives, public administrators, public companies, neighbourhood institutions, etc., is recommended to meet regularly before and during the renovation process and after the renovation's completion. As pointed out earlier, homeowners are a group that can be difficult to reach. Consequently, communication with this group is important, and meetings bringing building owners together should be promoted. Individual building owners may play a key role in motivating others to participate in joining district projects. However, users/tenants should also be integrated into the dialogue process since user involvement will likely raise the building renovation's acceptance. Tenants will favour the whole renovation project more if they can influence some solutions. Therefore, it is recommended to encourage citizen involvement and user participation, e.g., through co-creation of the renovation concept together with residents. This approach may lead to a higher degree of acceptance, even for unpopular actions.

In general, public housing companies or public actors have the advantage that citizens may have more trust in such non-profit companies regarding their (not dominating) economic motives behind building renovation decisions. It is recommended to support bottom-up initiatives, e.g., by providing coaches for citizen groups, arranging inspirational meetings for the citizens in the district and person-to-person communication. Citizen involvement could also be in the form of thematic workshops or consultations where many different district renovation issues are treated, even the design of open spaces, and where all types of tenants participate. Moreover, it is important that the actors involved in the building renovation process at the district level are well-known to the citizens, as it helps create societal trust. Structured stakeholder

dialogue could follow the model of citizen conferences. These conferences aim to connect theory and practice, bringing together citizens and experts to discuss a particular topic. The entire process takes place publicly to ensure maximum transparency. A citizen conference consists of 10 to 30 citizens who receive information material a few weeks in advance to prepare questions and ideas to present and discuss with experts. The results are documented in a report by the participating citizens. Another format would be round tables. These meetings allow diverse participants with different interests and backgrounds to come together and openly discuss a topic. This approach can help minimise hierarchical structures and provides a good foundation for an even discussion of various feasible solutions. Especially for homeowners, this approach can help lower the threshold to engage in the renovation process.

OPERATIONAL RECOMMENDATIONS ON PROCESS ORGANIZATION & STAKEHOLDER DIALOGUE	
FOR POLICYMAKERS	Make stakeholder dialogue a core objective of your local policy, as it is an essential part of public participation
	Identify and address all relevant stakeholders involved in processes of change in your municipality (urban development, building renovation at the district level)
	Be clear and honest about the changes, the process and the goals, and address citizens' fears (costs, gentrification) to overcome them
	Organize a continuous process of a stakeholder dialogue with the administration, including building owners/investors and energy suppliers as an open table
FOR INVESTORS/ DECISION-MAKERS	Use existing formats and platforms for residents 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 make your vision visible and to engage all target groups in the communication
	Be available on-site. A one-stop-shop and regular provision of information about schedule and events will help gain residents' attention and acceptance

7. District-Oriented Mobilization for Building Renovation

Bringing energy efficiency and renewable energy measures into the districts, involving building owners, owners who live in the building, and tenants, is essential. They are crucial decision-makers regarding investments and, therefore, the key players in accepting policies and renovation measures. However, they are also a highly diverse target group. Appropriate measures to address them strongly depend on the housing market structure in the respective country, region, and district.

On average, the homeownership rate in Europe is 75,4%, with the highest values in Albania (96,5%) and Romania (96,1%), and the lowest values in Germany (50,4%) and Switzerland (41,6%) (STATISTA, 2021). It is challenging to deal with tenants' and landlords' different motivations and interests. While tenants are concerned with low rent, good thermal comfort, and absence of noise or other disturbance due to construction works, landlords are concerned with high rents, value retention or enhancement. Homeowners living in their building may be somewhere between these positions, and all actors aim for a conflict-free relationship with each other. Depending on the ownership structure, different constellations of interests and motives exist during building renovation processes. In addition, the age of the building stock varies by country, which is a good indicator of its average efficiency, determining suitable measures as well.

This guidebook shows that building renovation is a complex techno-economic and social process, especially when willing to combine energy efficiency and renewable energy systems and upscale it to the district level. Many aspects are hard to grasp in all their details and options for non-experts. Accordingly, diverse advisory support is needed to boost building renovation activity. Within the stakeholder dialogue processes explained above, establishing and maintaining structures within which such support is given should also be an objective. This chapter advises on how non-professional end-users of building renovation can be mobilized for broader action, improving the consultation landscape and creating networks among the many actors involved. With a common knowledge base, these networks allow for an end-user-friendly reference culture and a common language that should help dismantle barriers in complex renovation processes. Different approaches are presented, supported by practical examples from different European countries (7.1-7.4).

Theoretically, the building renovation consultation can be classified into five stages. However, these cannot always be clearly distinguished in practice since an extensive and differentiated consultation landscape often does not exist or is difficult to grasp for single homeowners and non-experts. During the “Initial Contact” stage, building owners get a first insight into the subject and possibly an overview of the scope of action of their buildings. During the following “Concept Orientated Consultation” stage, the state of the building is analysed, and actions or renovation packages, including costs and saving potentials, are evaluated. The third stage, “Planning and Tendering”, marks the transition to implementing the renovation measures. Building owners are supported in obtaining proposals and coordinating the following stage of “Realisation”, where experts ensure the quality of the performed measures. Finally, during the “Operation Management & Monitoring” stage, the end-users are instructed on how to use the new technologies and potential technological readjustments are made. During all these stages, diverse expertise is needed to ensure a coherent and well-balanced mix of building renovation measures, combining energy efficiency

measures and the use of renewable energy. These measures must be adapted to the respective building, the situation and personal needs of the homeowner and end-users, and the framework conditions for building renovation within the district.

Figure 4. Building Renovation Consultation Chain.

In this context, the German research project “Drei Prozent Projekt – energieeffizienter Sanierungsfahrplan für kommunale Quartiere 2050” (Three Percent Project – energy efficient renovation roadmap for municipal districts 2050) showed that the existence of a transparent, low-threshold and networked consultation chain that connects the described stages can decrease renovation barriers and increase trust, as well as the quality of building renovation measures.

While the vast expertise required during the planning, implementation and monitoring of a renovation process is mainly held by private service providers and actors, local policymakers can also contribute to an effective and user-friendly consultation landscape boosting the renovation activity. They can indirectly support the ideal renovation consultation process by providing grounds for investment decision-making through strategic long-term energy planning (see above in chapter 5), and directly by raising awareness, providing information, and connecting actors.

In a complex district renovation process, a well-established information and consultation landscape is a vital precondition to synchronise renovation and investment decisions if the implementation and cost-effective operation of new heat supply systems based on renewable energy (especially centralised) depend on individual investment decisions at the building level.

7.1 Provide Basic Information & Engage in Low-Threshold Mobilisation

The first step for public actors or public-private partnerships is to actively communicate and provide essential neutral information about various building renovation options. This means that the first stage of the consultation chain should include an introduction to the complex issues of energy efficiency and renewable energy. Here, end-users need access to reliable and neutral information. It is essential to provide an overview, preferably free of charge, of the different aspects to be considered, the technological options and possible financing for the renovation of buildings, in addition to hints and links to find more information. An online service is an important means of encouraging building owners to move forward with renovating their buildings. End-users can use it as a low-threshold initial information source. Providing essential information is not necessarily a local task. It is efficient and helpful to refer to information services of regional or national actors like ministries, research institutes or energy agencies. However, as soon as heterogeneous districts are addressed and aim for concrete renovation actions, building owners have to be approached and activated through different channels to inform them in the first place.

Next to cost-effective solutions that “pay off” and the basic need for building maintenance, the motivation of building owners to engage in building renovation measures is also dependent on competence and trust in technologies and advising and implementing actors. Therefore, the actors at each stage of the renovation process need to pick up the owners right where they are, consider and include their personal goals and capacities. The same applies to local public actors who engage in mobilization and information on building renovation. Situation and target-group-oriented approaches are essential to convince the most sceptical households or those less concerned about saving energy or reducing emissions. Providing objective and clear information on tangible saving potentials, renovation costs, economic effectiveness, and implementation options is equally important. In districts with very heterogeneous ownership structures, a lot of awareness, information and consultation are especially needed. If end-users have little interest in saving energy, action needs other than energy could be a starting point for building renovation, for instance, renovation according to the building age. Local public actors should use existing activities and contacts in the respective districts.

A suitable measure for very low-threshold, simple and small-scale mobilization could be outreach-counselling, where energy and climate consultants visit tenant-owner associations or tenants and owners directly to help them become more energy efficient and inform them about energy savings, existing support, and renewable energy options. Different actors, like the city energy service provider, energy agencies etc. could work together on this. It is most promising to address districts with old buildings that require building renovation and where a change of ownership is likely soon or has already taken place to a large extent. Outreach-counselling allows for spatially targeted mobilization, e.g., according to general building renovation and development plans or district-oriented energy and heat planning.

Further measures could be on-site contact persons, informal events, or individual consultations. Examples are permanent consultancy centres, mobile information centres of the municipality, or other actors that offer consultation from qualified energy coaches. If building owners initially require advice on a specific issue, this should be incorporated into a longer-term, step-by-step overall concept.

As another measure, one-stop-shops can accompany end users through all stages of the renovation process, thereby contributing to a network-building of the different actors involved (see also below). The municipality can support one-stop-shops. However, as it is the nature of such one-stop-shops to enable an uncomplicated link to private renovation services, the involvement of public bodies can be complex in some legal contexts due to the duty of neutrality of municipalities.

7.2 Networking Initiatives & Linking a User-friendly Renovation Process

Another way for local policymakers to support the building energy consultation scenario is to create multi-stakeholder networks to advise homeowners during the renovation process. Local energy and consultation networks can strengthen the trust between stakeholders and enable cooperation.

The quality of counselling and renovations can be increased by establishing a referral culture between different network partners. In the case of upscaling building renovation to the district level, these networks become especially important as the coordination of several stakeholders is necessary. Existing networks are an excellent advantage for activating building owners and ensuring the successful implementation of

building renovation measures. For such networks to succeed, a regular professional exchange is necessary.

Local policymakers as neutral and permanent entities could contribute to keeping up the exchange. Having implemented such a structure, this exchange could be activated quickly and used for several ad hoc issues like enforcing new funding and framework conditions, training, and education initiatives. However, these networking initiatives do not necessarily have to be district-oriented or provided at the city level to be effective.

The size of a city or municipality and the building and owner structure need to be considered. As size increases, so does the number of different stakeholders and their concerns, making coordination more essential. However, there is also a need for strong coordination in smaller municipalities or rural areas (and often less available capacities in the administrations). Here, overarching regional networks might be an efficient approach.

Local or regional energy and climate protection agencies are vital cooperation partners in these networking processes, as they usually have well-trained staff on energy topics and often already offer counselling. In addition, they are familiar with the stakeholder landscape in the respective city or region.

Using local umbrella brands for communication, which bundle together various climate action measures, can help engage residents in a way that makes them feel responsible for achieving climate goals by doing their own part in their homes. However, the quality of the measures and the content and information communicated are still important preconditions for the successful use of such umbrella brands. Developing such brands can be another way for local authorities to mobilize end-users and motivate them to undertake renovation measures.

At the same time, they can provide a reliable communication umbrella from which local providers of building renovation services could profit and thus be motivated to cooperate and network with the municipality.

Creating a mutual quality standard or information base (e.g., renovation guidelines) for networks to build trust and preserve neutrality may be helpful. Establishing such general standards for a city or municipality can also improve the quality of renovation measures. By bringing together stakeholders, especially craftspeople, the local expertise is pooled, and quality standards can be implemented. Furthermore, the chance to be part of well-recognized quality assurance initiatives could be (depending on the market situation) a motivation for implementing actors of building renovations to cooperate and exchange in local renovation networks and with public authorities.

More detailed instruments and practical examples of incentivizing, mobilization and consultation instruments at a local level are also elaborated in the IEA EBC Annex 75 report on policy instruments (MLECNIK ET AL. 2023, p. 38-45).

OPERATIONAL RECOMMENDATIONS ON DISTRICT-ORIENTED MOBILIZATION FOR BUILDING RENOVATION

FOR POLICYMAKERS	Support an interlinked "consultation chain" for building renovation to foster a local user-friendly "culture of referring"
	Provide neutral basic and low-threshold information on building renovation, available funding options and a general overarching framework
	Organize and support situation and target group-oriented approaches to mobilizing homeowners within the target district, such as through consultancy centres, local energy desks or pop-ups, outreach-counselling, or one-stop-shops
	Offer advice and organizational support to building owners in districts to carry out district projects from the beginning to the implementation. For example, by initiating contacts between building owners, mandating a company to develop an Integrated District Renovation Plan, assisting building owners in finding a suitable legal structure among themselves and a contractor or another type of company for implementing a district project
	Install or perpetuate local or regional networks of implementing and consulting building renovation actors as they are a link to practical knowledge and an interface to practical needs that can also be used to explain and communicate overarching strategies to the implementation level
	Bundle activities for building renovation (including energy efficiency and renewable energy systems) under an umbrella brand for better communication and recognition value
	Help to implement local or regional quality networks and standards by co-developing them with implementing actors in building renovation
FOR INVESTORS/ DECISION-MAKERS	Seek support along the whole renovation process, from initial information and planning to realisation and operation, to be able to make the best investment in building renovation
	For professional actors: engage in consultation networks and with different stages of the "consultation chain". Through these engagements, the holistic view of the building renovation process can help offer more tailored services and mobilize 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 mobilization 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

8. Conclusions

In the previous chapters, several topics were analysed and detailed to illustrate the potential of a district-oriented approach to building renovation. The general advantages of having the district as an action level for cost-effective building renovation, followed by overall recommendations to improve the potential of this strategy were presented in Chapter 2. Detailed relevant aspects to promote district renovation were organized and presented as follows: the techno-economic potentials and cost-effective renovation strategies and their interdependencies (Chapter 3), the business models to support building renovation at the district level (Chapter 4), the policy instruments to help a city in upscaling building renovation at the district level (Chapter 5), the renovation process organization and stakeholder dialogue (Chapter 6), and how to set up district-oriented mobilization and consultation for building renovation (Chapter 7). The specific challenges and opportunities for combining energy efficiency measures and renewables in this context were addressed in the respective chapters. Each chapter ends with a set of specific recommendations targeted to policymakers and investors/decision-makers.

This guidebook explores how the district, as the action level for building renovation, can offer several synergies and cost-effective solutions in addition to building renovation at the individual building level. It also provides recommendations concerning the combination of energy efficiency measures and renewable energy use for building renovation at the district level. However, complexity grows with upscaling, and tailored strategies and technology combinations and policy frameworks are needed. Integrated thinking and cooperation in each local context can help to develop these suitable, tailored solutions.

A major conclusion is that 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. Potential synergies between energy efficiency measures and renewable energy measures at the district level are worth exploring, especially if the initial condition of the building envelope has poor thermal performance. Sometimes certain measures will not be the most cost-effective, but their associated co-benefits will be the main reason for choosing them. This is why a holistic approach is needed when considering different renovation solutions. Finding a local optimum and balancing it with other interests requires an integrated approach to district-specific building renovation based on cooperation, the balance of needs, in-depth knowledge, information, and regulatory frameworks.

Looking also into public interests, social and urban aspects are essential, aiming at the general improvement of the indoor and outdoor spatial quality, comfort conditions and the residents’ quality of life, which also contributes to a greater acceptance and participation of the residents in the process. It is important that points of view and objectives of the different stakeholders involved in the process converge towards a common agreement with a view to the decarbonisation targets.

Nevertheless, the key factors for a successful building renovation at the district level are effective communication and coordination, without which the other aspects will not be applied to their full potential. In particular, the involvement and collaboration of residents in the definition of the renovation proposal and throughout the entire process help with its acceptance and understanding of the solutions, contributing to a successful renovation project. Local authorities, in turn, can have a key 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, at higher levels, action can be incited by 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, building codes and energy certificates to building renovation rather than only new buildings and to the district level as a complement to the single-building level. Therefore, 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.

References

BOLLIGER, R., Terés-Zubiaga, J., Almeida, M., Barbosa, R., Davidsson, H., Engelund Thomsen, K., Domingo Irigoyen, S., Ferrari, S., Johansson, E., Konstantinou, T., Limacher, R., Matuška, T., Mlecnik, E., Mørk, O. C., Ott, W., Romagnoni, P., Rose, J., Säwén, T., Walnum, H. T., Venus, D., & Winkels, Z. (2023). Methodology for investigating cost-effective building renovation at district level combining energy efficiency & renewables. Report prepared within IEA EBC Annex 75 on Cost-effective Building Renovation at District Level Combining Energy Efficiency & Renewables. ISBN: 978-989-35039-6-6. https://annex75.iea-ebc.org/publications

BPIE – DEEP RENOVATION (2021). Deep Renovation: Shifting from exception to standard practice in EU Policy. Retrieved 30/08, 2022. https://www.bpie.eu/ publication/deep-renovation-shifting-from-exception-to-standard-practice-in-eu-policy/

BPIE (2018) Policy Innovation for Building Renovation – How can policy innovation scale up the decarbonisation of the building stock in Europe? Retrieved 01/04, 2020. http://bpie.eu/wp-content/uploads/2019/01/BPIX-Briefing-_Final-1.pdf

BPIE (2016) Scaling up deep energy renovations. Unleashing the potential through innovation & industrialization. Retrieved 28/08/2022. https://www.bpie.eu/wp-content/uploads/2016/11/BPIE_i24c_deepretrofits.pdf

BUNDESMINISTERIUM FÜR VERKEHR, INNOVATION UND TECHNOLOGIE (2017) E_PROFIL: Quartiersprofile für optimierte energietechnische Transformationsprozesse. Retrieved 20/10/2022. https://nachhaltigwirtschaften.at/resources/sdz_pdf/schriftenreihe-2017-9-e-profil.pdf

DOBRAVEC, V., N. Matak, C. Sakulin & G. Krajacic (2021) Multilevel governance energy planning and policy: a view on local energy initiatives. https://www.researchgate.net/publication/348285921_Multilevel_governance_energy_planning_and_policy_a_view_on_local_energy_initiatives

DOMINGO-IRIGOYEN, S., Almeida, M., Barbosa, R., Bell Fernández, O. B., Bolliger, R., Davidsson, H., Dall'Ò, G., Dalla Mora, T., Engelund Thomsen, K., Ferrari, S., Grisaleña Rodríguez, D., Gugg, B., Hidalgo-Betanzos, J. M., Johansson, E., Monge-Barrio, A., Peron, F., Romagnoni, P., Rose, J., San Miguel-Bellod, J., Sánchez-Ortiz, A., Strassl, I., Teso, L., Venus, D., & Zagarella, F. (2023). Success Stories of Cost-effective Building Renovation at District Level Combining Energy Efficiency & Renewables. Report prepared within IEA EBC Annex 75 on Cost-effective Building Renovation at District Level Combining Energy Efficiency & Renewables. ISBN: 978-989-35039-7-3. https://annex75.iea-ebc.org/publications

EUROPEAN COMMISSION (2021) Proposal for a DIRECTIVE OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL on the energy performance of buildings (recast) COM/2021/802 final. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52021PC0802&qid=1641802763889

EUROPEAN COMMISSION (2018) DIRECTIVE (EU) 2018/844 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 30 May 2018 amending Directive 2010/31/EU on the energy performance of buildings and Directive 2012/27/EU on energy efficiency (Text with EEA relevance). https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32018L0844&from=EN

EUROPEAN COMMISSION DG ENERGY (2014) Financing the energy renovation of buildings with Cohesion Policy funding. Retrieved 01/04, 2020. https://ec.europa.eu/energy/sites/ener/files/documents/2014_guidance_energy_renovation_buildings.pdf

FIELT, E. (2014), Conceptualising Business Models: Definitions, Frameworks and Classifications, Journal of Business Models, Vol. 1, No. 1, pp. 85-105

HIDALGO-BETANZOS, J. M., Mlecnik, E., Konstantinou, T., Meyer, H., Bolliger, R., Almeida, M., Tan De Domenico, A., & Walnum, H. T. (2023). Definitions and Common Terminology on cost-effective building renovation at district level combining energy efficiency & renewables. Report prepared within IEA EBC Annex 75 on Cost-effective Building Renovation at District Level Combining Energy Efficiency & Renewables. ISBN: 978-989-35039-8-0. https://annex75.iea-ebc.org/publications

IEA (2013) Energy Efficient Communities. https://www.iea-ebc.org/projects/project?AnnexID=51

JOHANSSON, E., Davidsson, H., Mlecnik, E., Konstantinou, T., Meyer, H., Hidalgo-Betanzos, J. M., Bolliger, R., Domingo-Irigoyen, S., Haase, M., Gugg, B., Almeida, M., & Tan De Domenico, A. (2023). Barriers and drivers for energy efficient renovation at district level. Report prepared within IEA EBC Annex 75 on Cost-effective Building Renovation at District Level Combining Energy Efficiency & Renewables. ISBN: 978-989-35039-5-9. https://annex75.iea-ebc.org/publications

KONSTANTINOU, T., Haase, M., Hidalgo-Betanzos, J. M., Motoasca, E., Conci, M., Winkels, Z., Mlecnik, E., Meyer, H., & Johansson, E. (2023). Business Models for cost-effective building renovation at district level combining energy efficiency & renewables. Report prepared within IEA EBC Annex 75 on Cost-effective Building Renovation at District Level Combining Energy Efficiency & Renewables. ISBN: 978-989-35039-3-5. https://annex75.iea-ebc.org/publications

MLECNIK, E., Hidalgo-Betanzos, J. M., Meyer, H., Lynar, U., Konstantinou, T., Meijer, F., Bolliger, R., Haase, M., Johansson, E., Davidsson, H., Peters-Anders, J., Gugg, B., Almeida, M., & Tan De Domenico, A. (2023). Policy instruments for cost-effective building renovation at district level combining energy efficiency & renewables. Report prepared within IEA EBC Annex 75 on Cost-effective Building Renovation at District Level Combining Energy Efficiency & Renewables. ISBN: 978-989-35039-1-1. https://annex75.iea-ebc.org/publications

MØRK, O. C., Rose, J., Thomsen, K. E., Matuška, T., Sánchez, S. V., Venus, D., Peron, F., Romagnoni, P., Mlecnik, E., Walnum, H. T., Almeida, M., Barbosa, R., Hidalgo-Bertanzos, J. M., Terés-Zubiaga, J., Johansson, E., Davidsson, H., Bolliger, R., Domingo Irigoyen, S., Lynar, U., & Meyer, H. (2020). Overview of available and emerging technology for cost-effective building renovation at district level combining energy efficiency & renewables. Report prepared within IEA EBC Annex 75 on Cost-effective Building Renovation at District Level Combining Energy Efficiency & Renewables. ISBN: 978-989-35039-4-2. https://annex75.iea-ebc.org/publications

PASSREG (2016) PassREg – Solutions Open Source. Retrieved from: https://passregsos.passiv.de/wiki/PassREg-Solutions_Open_Source, accessed 13/05/2020.

ROSENOW, J., Fawcett, T., Eyre, N., Oikonomou, N. (2016) Energy efficiency and the policy mix. Building Research & Information. DOI 10.1080/09613218.2016.1138803

SÄWÉN, T., Kronvall, J., Venus, D., Rose, J., Engelund Thomsen, K., Balslev Olesen, O., Dalla Mora, T., Romagnoni, P., Teso, L., Blázquez, T., Ferrari, S., Zagarella, F., Almeida, M., Tan De Domenico, A., Hidalgo-Betanzos, J. M., Briones-Llorente, R., Davidsson, H., Johansson, E., Bolliger, R. & Domingo Irigoyen, S. (2023). Cost-effective building renovation strategies at the district level combining energy efficiency & renewables – investigation based on parametric calculations with generic districts. Report prepared within IEA EBC Annex 75 on Cost-effective Building Renovation at District Level Combining Energy Efficiency & Renewables. ISBN: 978-989-33-4464-4. https://annex75.iea-ebc.org/publications

SEDDON, P. B., G. P. Lewis, P. Freeman and G. G. Shanks (2004) The Case for Viewing Business Models as Abstractions of Strategy" CAIS 13: 25.

SIR (2021): Nachhaltige Siedlungsprojekte – Tipps, Instrumente, Beispiele. Retrieved: 10/22 from: https://www.salzburg.gv.at/bauenwohnen_/Documents/SIR_Nachh_Siedlungspro_10_2021_WEBopt.pdf. Salzburger Institut für Raumordnung und Wohnen GmbH.

STATISTA (2021) Wohneigentumsquote in ausgewählten europäischen Ländern im Jahr 2020. https://de.statista.com/statistik/daten/studie/155734/umfrage/wohneigentumsquoten-in-europa/

STUNNING (2019) Renovation hub business models. Retrieved 13/5, 2022. https://renovation-hub.eu/business-models/

E. VALLEJO, C. Criado, E. Arrizabalaga, G. Massa and A. Vasallo (2019) “The CITyFiED Methodology for city renovation at district level”. Building & Management, vol. 3(2), pp. 23-33.

VENUS, D., Romagnoni, P., Dalla Mora, T., Teso, L., Almeida, M., Tan De Domenico, A., Celador, A. C., Terés Zubiaga, J., Hidalgo-Betanzos, J. M., Davidsson, H., Johansson, E., Bolliger, R., Domingo-Irigoyen, S., Christen, C., Walnum, H. T., & van den Brom, P. (2023). Investigation of cost-effective building renovation strategies at the district level combining energy efficiency & renewables – a case studies-based assessment. Report prepared within IEA EBC Annex 75 on Cost-effective Building Renovation at District Level Combining Energy Efficiency & Renewables. ISBN: 978-989-33-4463-7. https://annex75.iea-ebc.org/publications

VENUS, D., Domingo-Irigoyen, S., Säwén, T., Kronvall, J., Davidsson, H., & Johansson, E. (2023). Good practices and lessons learned to transform existing districts into low-energy and low-emission districts. Report prepared within IEA EBC Annex 75 on Cost-effective Building Renovation at District Level Combining Energy Efficiency & Renewables. ISBN: 978-989-35039-9-7. https://annex75.iea-ebc.org/publications

WALNUM, H. T., Venus, D., Rose, J., Engelund Thomsen, K., Dalla Mora, T., Romagnoni, P., Teso, L., Almeida, M., Tan De Domenico, A., Davidsson, H., Johansson, E., Bolliger, R., & van den Brom, P. (2023). Strategies to transform existing districts into low-energy and low-emission districts. Report prepared within IEA EBC Annex 75 on Cost-effective Building Renovation at District Level Combining Energy Efficiency & Renewables. ISBN: 978-989-35039-0-4. https://annex75.iea-ebc.org/publications

ZHIVOV (2022) Energy Master Planning toward Net Zero Energy Resilient Public Communities Guide. Retrieved 19.10,2022. https://annex73.iea-ebc.org/publications

ANNEX 75

EBC

Energy in Building and Communities Programme

www.iea-ebc.org

Technology Collaboration Programme
by iea