PATH2LC

LEARNING MUNICIPALITY NETWORKS

D2.7 Guideline on long-term transition roadmaps for municipalities

04/08/2023

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This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 892560.

CONSORTIUM PARTNERS

LOGO	PARTICIPANT	COUNTRY	TYPE
IREES research for future.	Institute for Resource Efficiency and Energy Strategies (IREES)	Germany	Scientific
Fraunhofer ISI	Fraunhofer Institute for Systems and Innovation Research ISI (Fraunhofer)	Germany	Scientific
TU WIEN TECHNISCHE UNIVERSITÄT WIEN Vienna | Austria	Technische Universität Wien (TU Wien)	Austria	Scientific
e think ENERGY RESEARCH	Zentrum für Energiewirtschaft und Umwelt (e-think)	Austria	Scientific
ENERGY CITIES	Energy Cities (ENC)	France	Scientific
HESPUL	Hespul (HESP)	France	Communication
UCSA Ufficio Comune per la Sostenibilità Ambientale	Ufficio Comune per la Sostenibilità Ambientale (UCSA)	Italy	Local network
SUSTAINABLE CITY CITY NETWORK	Sustainable City Network (SCN)	Greece	Local network
OESTE SUSTENTÁVEL AGÊNCIA REGIONAL DE ENERGIA E AMBIENTE DO OESTE	Agência Regional de Energia e Ambiente do Oeste – OesteSustentavel (Oeste)	Portugal	Local network
CITIES NORTHERN NETHERLANDS	City Northern Netherlands represented by City of Leeuwarden (CNNL)	Netherlands	Local network
ALTE 69 Agence Locale de la Transition Énergétique du Rhône	Agence Locale de la Transition Énergétique du Rhône (ALTE69)	France	Local network

THE PATH2LC PROJECT

In the PATH2LC project public authorities are working together within the framework of a holistic network approach (so called learning municipality networks) with the aim to achieve low-carbon municipalities.

The core of the project activities are the SE(C)APs (Sustainable Energy (and Climate) Action Plans) or similar climate protection plans developed by the municipalities. The PATH2LC project will foster exchange of existing knowledge and experiences among municipalities, enhance coordination between different administrative bodies within the municipalities, improve cooperation with local stakeholders and civil society and will equip stakeholders in public authorities with required planning and monitoring tools to develop and implement transition roadmaps for achieving the targets set in the SE(C)APs.

The holistic network approach intends to link stakeholders in public authorities among municipalities enabling peer-to-peer learning and to increase the engagement for the energy and climate transition. Policy makers and public authorities at local level are supported with scientific analysis and expertise in order to understand and implement their SE(C)AP measures. Five existing networks of municipalities in Italy, Greece, Portugal, the Netherlands and France are participating in the project.

A special interest of the project is to invite other municipalities to replicate the learning municipality network approach and take advantage of the knowledge base collected in the project.

Further information on www.path2lc.eu

Project information

Proposal number: 892560

Acronym: PATH2LC

Title: Public Authorities together with a holistic network approach on the way to low-carbon municipalities

Years of implementation: September 2020 - August 2023

Client: CINEA

Acknowledgement

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 892560.

Legal Notice

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CONTEXT

The overarching objective of the PATH2LC project is to support policymakers and public authorities at the local level in the transition process towards a low-carbon society. Through a holistic network approach, stakeholders in public authorities are linked among municipalities to enable peer-to-peer learning and increase engagement in energy and climate transition. This holistic network approach is described as Learning Municipality Networks (LMN): Several municipalities of a region build a network, work on common topics and exchange experiences while doing so. In the present case, all topics deal with the transition towards a low-carbon society, more precisely, heating and cooling planning, energy in buildings, renewable energy, stakeholder engagement and financing.

Why is this relevant? Because cities and communities in the EU account for more than 80 % of the total energy demand and emit around 50 to 60 % of global greenhouse gases (UN-Habitat, n.d.). Instruments and incentives such as the European Energy Award, the Covenant of Mayors or the Climate Alliances were introduced as ways to reduce energy consumption. The Sustainable Energy (and Climate) Action Plans – SEAPs and SECAPS in short – are another instrument introduced by the EU. Climate actions are also initiated by the member states themselves, e.g. through research on how to foster the energy transition or by developing pathways to climate-neutral buildings, districts or municipalities. In this document, we present an introduction to transition roadmaps, what they consist of and how to integrate these roadmaps into the decision-making processes. In this context, it must be noted that situations in different municipalities may vastly differ: Numerous factors such as the size of the municipality, its current energy system, funding, societal acceptance of measures etc. are involved. This document, therefore, serves as a guideline on how to start the process. Therefore, we present vital elements of transition roadmaps, show concrete case studies from the PATH2LC project and list further resources at the end.

ENERGY TRANSITION ROADMAPS

Energy transition roadmaps for municipalities are an important tool for local governments to combat climate change and promote sustainability in their communities. Energy transition roadmaps for municipalities are comprehensive plans that outline the steps that a local government will take to transition from traditional energy sources to renewable and sustainable energy sources. These roadmaps typically include goals, timelines, and specific actions that the municipality will take to reduce its carbon footprint and become more environmentally friendly. Within the PATH2LC project, we assisted participating networks and their municipalities with the different steps. That means they received support in either setting their targets or when taking the first steps in reaching these targets.

How to set up your energy transition roadmap

There is no one-size-fits-all approach: Municipalities differ in size, existing or needed energy infrastructure and the overall energy challenges they are facing. However, there are common challenges. The following list presents seven points that could be used to kickstart your municipal transition roadmap. By following these steps, a municipality may develop and implement an effective energy transition roadmap, driving the shift towards a sustainable and low-carbon future. However, each municipality's situation may vary, so not not all steps may apply to your municipality.

1. **Set goals and targets:** At the very beginning of developing a transition roadmap, the foundation is typically laid by setting goals and targets for reducing greenhouse gas emissions and increasing the use of renewable energy sources. These goals and targets should be ambitious yet achievable and should be supported by a solid understanding of the current energy system in the municipality. Different stakeholders should be involved in this process, as e.g. (political) administrative bodies alone may not be sufficiently aware of the challenges and needs of different affected parties.
2. **Assess the current energy situation**: Municipalities should analyze their current energy use and identify areas

where they can make changes. Understand the existing energy systems, including electricity, heating, transportation, and waste management. Identify the main sources of energy and their environmental impact before developing a plan on how to use and integrate them into your existing system.

3. **Develop a plan for renewable energy sources:** Your municipalities should consider a variety of renewable energy sources and assess which ones (solar, wind, biomass, geothermal energy etc.) are most feasible in your local context. Create a detailed roadmap outlining the specific actions and projects required to achieve the energy transition goals. Identify key milestones, timelines and responsible parties for each action item. Prioritize initiatives based on their impact, feasibility, and cost-effectiveness. Consider aspects such as renewable energy installations, energy-efficient building retrofits, sustainable transportation measures, waste management strategies, and educational campaigns.
4. **Undertake feasibility studies:** Municipalities may implement policies and programs to encourage energy efficiency in buildings and transportation, such as incentivizing energy-efficient upgrades or implementing energy-saving practices in municipal operations. Another possibility is to assess the energy efficiency options that can be easily implemented in existing buildings. What may be needed first are feasibility or potential studies to evaluate possibilities.
5. **Engage the community:** Municipalities should involve community members and stakeholders in the planning process and gain input and feedback on the roadmap. This can be achieved by initial information campaigns about the plans, and through public meetings, surveys and workshops. Depending on the project – and if possible – it is important to involve the public at an early stage of a project. Failing to do so may result in resistance or even legal issues.
6. **Secure funding and resources:** Once the plan is set, municipalities should aim to identify potential funding sources, including government grants, private investments and partnerships. There are plenty of options available, like the *European Local ENergy Assistance* (ELENA), several funding options by the European Commission (financing opportunities) or national funding schemes. Seek collaborations with energy providers, research institutions and industry experts who can contribute knowledge, technical expertise, or financial support. Develop a budget for implementing the roadmap and explore opportunities for cost savings and revenue generation.
7. **Track progress, evaluate and adjust:** Municipalities should regularly monitor and report on their progress toward their energy transition goals, adjusting the roadmap as needed to ensure they are on track. It is important to periodically assess the effectiveness and impact of the energy transition initiatives, as well as assessing the progress made towards the defined goals and targets. Identify areas for improvement, lessons learned, and emerging technologies or policies that can further enhance the transition. Adjust the roadmap and action plan accordingly to ensure continued progress and alignment with evolving energy transition trends. Check if you need external assistance in doing so, as data availability and keeping track of progress achieved can be time-consuming and complex.

Integration of roadmaps into decision making

Integrating an energy transition roadmap into existing decision-making structures requires careful consideration and coordination with other existing and possibly conflicting structures. Since the spike in energy prices starting mid of 2022, most cities and municipalities are arguably aware of the need to integrate such matters into their strategic plans to mitigate increasing energy costs. However, support from either the mayor or other higher municipal staff is required to successfully coordinate the necessary integration. Energy transition is a dynamic process, influenced by evolving technologies, market conditions, and societal needs. The following steps may support decision-makers to effectively integrate an energy transition roadmap into existing decision-making structures. This integration ensures that energy transition goals are considered in decision-making processes and enables a coordinated and coherent approach towards a sustainable and low-carbon future in your respective municipality.

The integration should begin by thoroughly **understanding the current decision-making structures** in place. Identify the key stakeholders, decision-making processes, and the roles and responsibilities of different entities involved in energy and climate-related decisions. This understanding will help you determine how to align the energy transition roadmap with the existing framework. Understanding these structures may be easier in authorities with relatively strict hierarchies, and possibly more complex when hierarchies are not as obvious. Once an understanding is built, you need to **assess the implications of the energy transition roadmap** on existing decision-making structures: Consider how the roadmap's goals, targets and actions align with or impact the decision-making processes, regulations and policies already in place. In case there are potential synergies and especially conflicts, you need to identify and understand the adjustments required. Energy transition involves multiple sectors and areas of expertise, which is why **relevant stakeholders need to be engaged**, including policymakers, government agencies, industry representatives, experts, community organizations and civil society groups. Seek their input, expertise, and feedback throughout the integration process. Foster collaboration and create opportunities for inclusive decision-making, while ensuring diverse perspectives are considered and potential resistance mitigated.

Together with these stakeholders, you need to **identify the specific decision points** where the energy transition roadmap needs to be integrated. This could include policy formulation, investment decisions, regulatory changes, infrastructure planning, and project approvals. Determine how the roadmap's objectives and strategies can be incorporated at each decision point to steer actions towards the energy transition goals. This process is also a chance to review the existing decision-making criteria and frameworks and update them to reflect the priorities and objectives of the energy transition roadmap. Consider factors such as greenhouse gas emissions reduction targets, renewable energy deployment, energy efficiency standards, and the Sustainable Development Goals (SDGs). Ensure that these criteria are integrated into the decision-making processes and inform policy development and project evaluations. Ensure that decision-makers and relevant stakeholders have the necessary resources, knowledge, and capacity to understand and implement the energy transition roadmap. Providing trainings, workshops and educational materials, if available or possible to obtain, may enhance the stakeholders' understanding of the roadmap's objectives, technologies, and policy implications. Mechanisms to **monitor and evaluate the outcomes** of decisions made within the integrated framework should be established to measure its effectiveness and possibly identify areas for improvement. This feedback loop helps refine the integration process and adapt decision-making structures as needed.

CASE STUDIES FROM PATH2LC: LESSONS LEARNT

As part of the operation of the municipality networks, special support was provided to some municipalities that are on an advanced level in their transition roadmaps. To deepen their knowledge and capability to use the selected tools and methods for the development of energy transition roadmaps in this task, e-think and Energy Cities assisted the members of the networks in their application. It was planned to assist two to three municipalities in each network in the preparation of analyses that feed into ongoing energy transition roadmap developments to assure maximum synergy with ongoing activities and efficiency in the use of resources.

Table 1: Assistance portfolio for the networks and their respective municipalities

Network	Activities	Support	Municipality learns how to…
ALTE69 (FR)	1. Assess **excess heat potential** from local industries and recovery options - CMDL/COR 2. Explore **financing** options - CCSB	**1. e-think** 2. IREES	1. …assess excess heat potential and recovery options 2. …access new financing sources
SCN (GR)	1. Replicable **H&C solutions** on a few **building archetypes** 2. Learn what **data** is needed, where to find/ replace it, assess options and zoning	1.+2. **TUW**	1. …outline a custom strategy of available options. 2. …collect data or complement with proxies
UCSA (IT)	1. **Replicable solutions on a few building archetypes** w/ thermal renovation, PV, cooling + asses EH potentials (factories) 2. Viability of **small DH** (Palma Campania)	1.+2. **e-think** + TUW 2. IREES	1. …compare and select custom options and solutions + assess excess heat potential 2. …assess DHC system viability
OESTE (PT)	1. Start a **Stakeholder Mapping** in view of a future H&C planning workgroup 2. Identify **Policies and Measures** (renovation)	1.+2. **IREES**	1. …map and contact stakeholders to set up an H&C workgroup 2. …compare and select solutions

However, due to several challenges within the networks, the analyses focused on fewer municipalities rather than all networks. In the following, the idea and content of energy transition roadmaps will be explained, and how such roadmaps can be set up in a step-by-step approach. The experiences of assisting municipalities with their respective challenge within the PATH2LC project are described: Several municipalities were assisted in different areas to reach some of the targets set out in their respective SE(C)AP. The assistance focused on the topics of Financing/Funding of projects, Waste Heat Potential District Heating and Cooling assessment and Replicable efficiency solutions by building archetypes. Our expert Ms Giulia Conforto (e-think, Email: conforto@e-think.ac.at) coordinated this task and created the assistance portfolio. Municipalities in the French and Greek networks were assisted.

French network

The PATH2LC Rhône network includes 139 municipalities of four Inter-Municipalities of the French Rhône Department (69) and the ALTE 69 (Agence Locale de la Transition Énergétique du Rhône) is a local Agency, covering the whole Rhône area, that advises and supports local authorities throughout their policies and projects promoting the Energy transition. These four Inter-Municipalities are not members of the Covenant of Mayors (CoM) and gather around 30-40 municipalities each, making the PATH2LC French network a “network of networks”.

They are all located in a rural area in the Rhône Department, close to Lyon Metropole. Since 2019, setting up a SECAP is compulsory in France for local authorities with over 20,000 inhabitants (Inter-Municipalities included), most often produced by external consultants. During the late 2010s, the 4 inter-municipalities participating in the PATH2LC project decided to be more ambitious by planning to become ‘Positive Energy Territories’ by 2050: Namely, to halve their energy consumption by 2050 (compared to 2015 approx.), and to produce enough Renewable Energies to cover their remaining energy needs. Thus, at that time, there has been a convergent political commitment to plan local energy policies. However, and still nowadays, political consensus about conducting ambitious and concrete measures is still not clear (municipal elections in 2020).

The civil servants working on SECAP (for these 4 Inter-Municipalities) have been involved in energy topics for a few years now and have set up SECAPs that are regularly updated. They wish to receive an assessment of their SECAPs feasibility and effectivity, an overview of the other networks to learn from similar experiences, and training on how to tap funding. The PATH2LC technical expertise for energy planning is expected to contribute to this commitment and help to upscale what they are already doing.

Assistance offered within PATH2LC:

Our experts Mr Marcus Hummel (e-think, Email: hummel@e-think.ac.at), Ms Giulia Conforto (e-think, Email: hummel@e-think.ac.at) and Mr Aadit Malla (TU Vienna, Email: malla@eeg.tuwien.ac.at) assisted the French network on multiple technical levels: a) Showing the potential of using *Hotmaps* in their areas, b) How they could develop and use a waste heat cadastre c) Collecting the relevant data and assessing the potential of waste heat recovery to supply some local heat demand.

Developing a waste heat cadastre

The online open-source tool *Hotmaps* was used to identify potential waste heat sources and heat sinks in the region. The calculation module *excess heat transfer potential* calculates the flow and costs of heat transmission from potential excess heat sources located outside of potential district heating areas to the district heating area. The inputs are hourly load profiles of the excess heat flow and the district heating demand, the location of the excess heat source and the potential district heating system, investment costs for heat exchangers and transmission lines, and threshold values for distance and transmission costs.

The tool provided an overview of assessing waste heat potential locations concerning potential demand. The application of the tool and utilization of the results for the strategic planning process was discussed with the network. The demonstration of the tool already provided a clearer perspective on the potential utilization and geographic distribution of waste heat sources. The tool provided a better insight into important indicators such as energy supply potential (GWh/yr), energy demand potential (GWh/yr), load supply potential (MW), load demand potential (MW), distance (m), description of the match of demand/supply schedule. Over multiple exchanges, the usability of the tool for the network's/municipality's strategic heating and cooling planning process was discussed. Based on the requirements of the network, tailor-made training sessions were conducted on the network to accommodate the knowledge transfer.

For COR, the industrial sites with the biggest energy consumption were identified. These included the Gerflor in Tarare, the wastewater treatment plant, and Agis in Le Cantubas. These locations were then added to the *Hotmaps* database. Utilizing the calculation module, the transport potential of these locations in relation to the demand points was assessed. The network further envisions using the tool for the assessment of the potential of waste heat sources in other regions in the future. The tool is expected to provide a quantitative basis for their strategic planning for decarbonizing their heating and cooling sector.

Waste heat to cover thermal demand

Application of the *THERMOS* Tool

THERMOS is a tool that makes District Heating and Cooling (DHC) planning processes easier, faster, and more cost-effective. The tool therefore supports energy planners in the evaluation of the expansion of an existing system, the planning of an entirely new system, or in comparing the performance of a potential energy network with the deployment of individual solutions on buildings. The tool facilitates the rollout of energy-efficient networks and supports the decarbonization and refurbishment of existing systems, allowing users to prioritize renewable energy sources and climate targets.

The tool was applied for the two inter municipalities of the “Communauté d'agglomération de l'Ouest Rhodanien” (COR, 31 municipalities) and “Communauté de Communes des Monts du Lyonnais” (CCMDL, 32 municipalities) to identify the supply potential and estimate the network size to use the waste heat sources available in the region. The tool optimized the network to obtain the highest Net Present Value i.e. maximum revenues resulting from the highest building connection rates. The following paragraphs present the financial estimates and preliminary results from the *THERMOS* tool. Default data available in the tool was used for the assessment for a first-level overview of the potential. However, with real measured data, the accuracy of the results is expected to improve.

Municipality 1: COR- Tarare

Figure 1 shows a simple network calculation done with the *THERMOS* tool for the case of two potential supply sources in the Eastern part of Tarare. The two supply sources are a biomass (wood chip) heat-only boiler of 8 MW_{th} and a heat pump using the outflow of the wastewater treatment plant with a supply power of 2 MW_{th}. Both plants would be located in the red circle. In the calculation, very rough estimations were used for the heat demand in the buildings, the investment and operating costs for the district heating pipes, and the two supply facilities. The orange lines show the city's potentially feasible district heating network routes. These lines indicate the pipe length and diameter connected to the individual buildings (demand points). Pink and yellow lines represent uneconomical connections. The summary of the demonstrative calculation is as follows:

- Total Heat Demand covered by the network: 8.9GWh/yr
- Total Pipe Length: 4.84km
- Total investments: 6.77 Mio EUR
- Heat supply costs (Levelised costs of heat): 8.29 cents/kWh

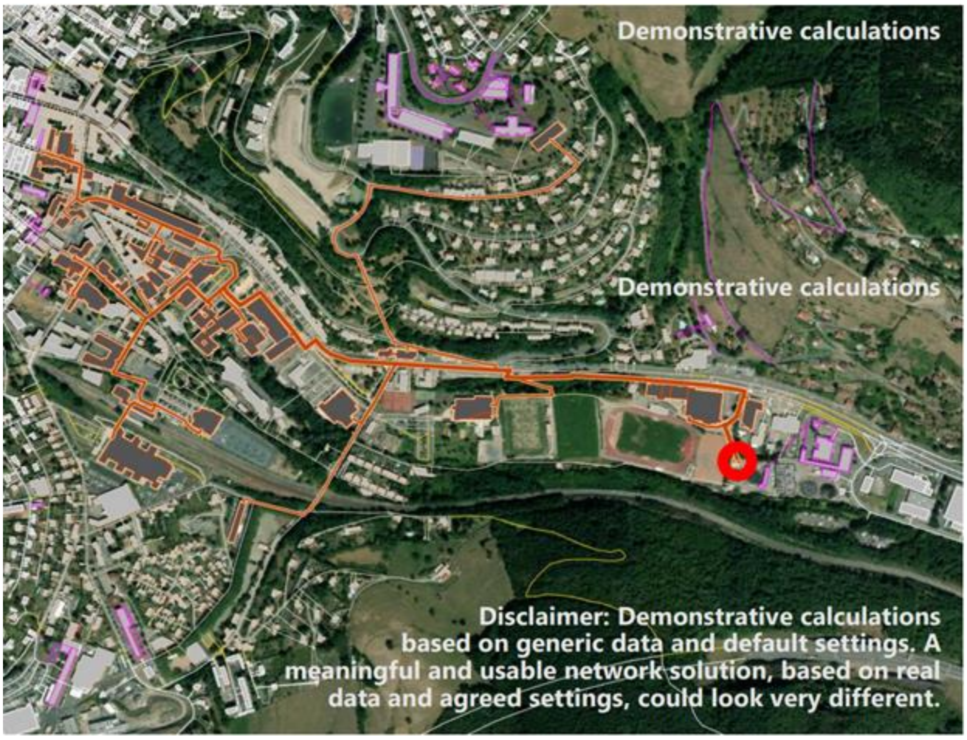

Figure 1 Demonstrative District Heating Network Tarare

Municipality 2: CCMDL-Ediliens

Figure 2 shows a simple network calculation with *THERMOS* for the case of using the available excess heat in the Ediliens plants in Sainte-Foy-l'Argentière. It is assumed that excess heat is available at both plants, 1/3 (2.5 MWth) in the Southern plant and 2/3 (5 MWth) in the Northern plant (marked with the red circles). For the calculation, rough estimations are used for the heat demand in the buildings, the investment and running costs for the district heating pipes, and the equipment to retrieve and feed the excess heat into the district heating network. The orange lines show the potentially feasible district heating network routes. The lines indicate the pipe length and diameter connected to the individual buildings (demand points). Pink and yellow lines show no feasible connections.

The summary of the demonstrative calculation is as follows:

- Total Heat Demand covered by the network: 19.2GWh/yr
- Total Pipe Length: 7.86 km
- Investments into the network: 6.95 Mio EUR
- Costs to retrieve and feed the excess heat into the network: 1.5 cents/kWh
- Heat supply costs (Levelised costs of heat): 3.15 cents/kWh

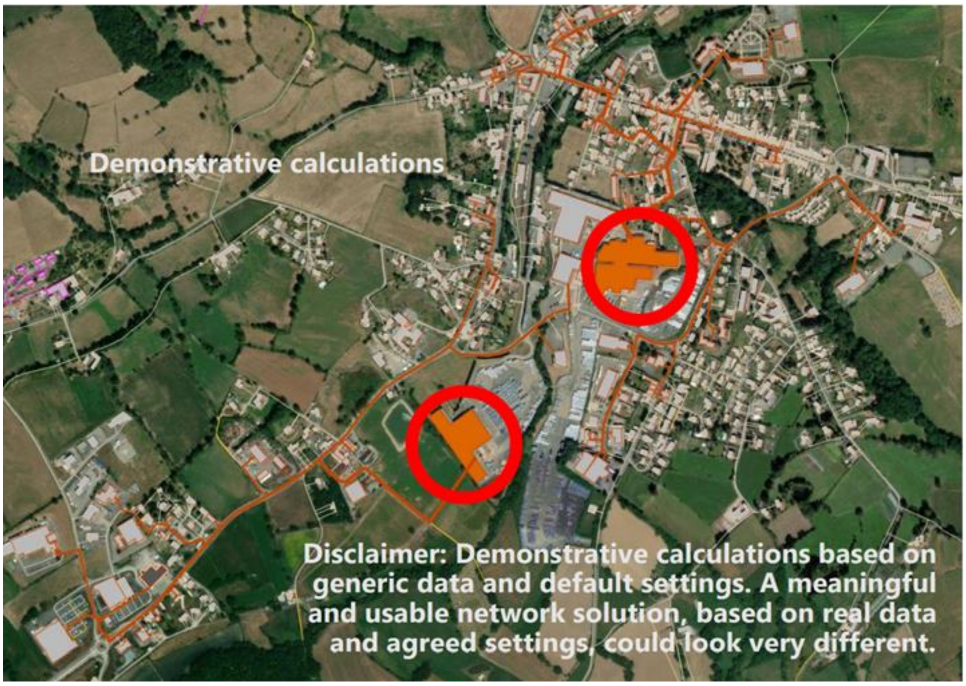

Figure 2 Demonstrative District Heating Network Ediliens

Please note that these demonstrative calculations were done based on generic data and default tool settings. The results are expected to change with the use of data better fitting the local and case-specific conditions. A meaningful and usable network solution should be based on real data, and agreed settings and objectives could look very different.

Application of the *Embers* Tool

Embers is a platform/tool for matching heat and cold sources and sinks. Similar to *THERMOS*, the tool was also used to estimate the network's potential size, which showed similar results. The *Embers* tool allows further detail to the assessment as the impact of supply temperature and profiles can be integrated into the assessment.

Application for a European Funding Scheme (ELENA)

Our expert Mr Eftim Popovski (IREES, Email: e.popovski@irees.de) supported Belleville-en-Beaujolais, a municipality located around 40km North of Lyon with a population of around 13.000 inhabitants, in their plan to:

- Reconstruct the local Aquatic centre (Supplied by geothermal energy and district heating)
- District heating network (Biomass, Industrial excess heat, solar thermal, and gas)
- Photovoltaics covering the total electrical consumption
- Supply residential buildings with district heating

Figure 3 presents the location of the aquatic centre and the industrial excess heat site at the local paper company. Additional to the Aquatic Centre, the foreseen district heating network would supply heat to public buildings with approximately 40,000 m² floor area and residential buildings with approximately 80,000 m² of total floor area.

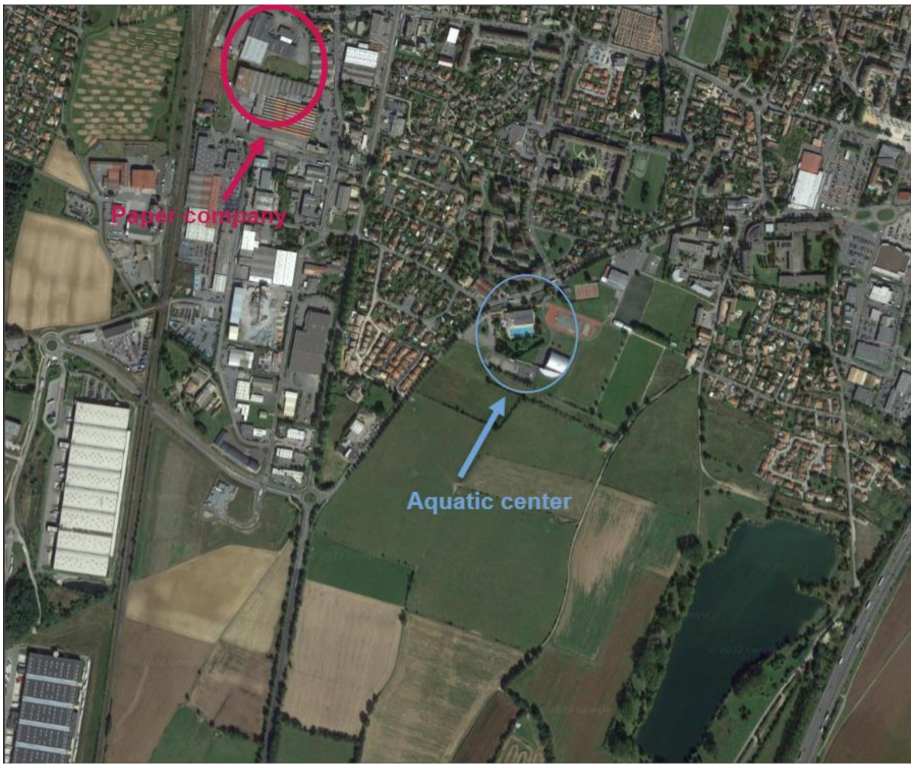

Figure 3 Aquatic Centre and paper company location in Belleville-en-Beaujolais municipality

The municipality was assisted in applying for funds at the European Local Energy Assistance (ELENA). ELENA supports investment programmes above 30 M€ with a three to four-year implementation period depending on the type of project. The application process at ELENA consists of two phases filling in the pre-application form (includes a brief description of the investment program as well as expected impacts) and the application form (in case the pre-application form was successful – detailed presentation of the investment program, estimated Project Development Services and milestones for measuring leverage factor).

The total expected investment for the Aquatic Centre (25M€), the residential buildings (10M€) and the district heating network (10M€) was 45 Million Euros. The expected impacts of the project are listed below:

- Renewable heat: 11,1 GWh/y
- Renewable electricity: 0,7 GWh/y
- Energy savings: 0,9 GWh/y
- Avoided CO_2 emissions: 3.515 t $CO2_{eq}$/y
- Jobs created/ maintained: 30 Full-time equivalents

Lessons learned

The pre-application form for the ELENA program was rejected. The total sum of 25 M€ for the expansion of the Aquatic Centre is not eligible for funding since only the geothermal plant and the photovoltaics are eligible for funding. Potential re-submission for the program is possible 6 months after the rejection of the pre-application form. Nevertheless, reducing the amount of 25 M€ and focusing only on the renewable heat and electricity production plants would most likely not be enough to reach the investment program's minimum value of 30 M€. To reach this amount, additional projects that focus on renewable energy and energy efficiency in residential and non-residential buildings would be necessary for the total project sum to reach the 30 M€ benchmark.

Greek network

Eight municipalities from a country-wide network participate in the PATH2LC project. They aim at implementing planned SEAP measures, which have been developed jointly by five of the eight municipalities. A special emphasis on the network approach in PATH2LC is put on capacity building for networking processes and capacity building for heating and cooling planning, as well as on updating the SECAPs and making them attractive to investors. Prioritising measures based on available data and expert input was planned to be a first step.

The network is managed by the organization Sustainable City Network (SCN). Few municipalities published SEAP/SECAPs, some were updated, but not published nor shared on the CoM website. Lack of funding and human resources are behind the missing two-year monitoring. SECAPs have been mostly written by external consultants and municipalities do not have a deep understanding of their content, nor own their data. They wish to receive training to enable the network members to better understand the SECAPs' content, how to implement their measures, tap funding, and achieve their targets, as well as technical assistance on analysis and implementation.

Objective

Develop a methodology that provides first-level results to understand opportunities for energy and emission reduction in different building archetypes. This can be done via changes to the building envelope or integration of renewable energy-powered supply technology in an overall vision to contribute towards achieving the SECAP targets. The results identified from this approach are envisioned to provide a first-level overview of possibilities for municipalities to include in their roadmap, which can further be integrated into their strategic decision-making process. This methodology provides an exemplary approach for developing an implementation plan and finding external service providers to concretize the decarbonization projects further.

Identifying the working archetype

Based on the discussions with the Sustainable City Network and the municipalities, school buildings were identified as the working archetype for the development of the methodology. The selection of the archetype was based on the following reasons:

- The current highly energy-intensive nature of the buildings
- Potential to provide higher savings and impact for the same investment levels
- Ease of data acquisition considering that the school buildings are directly under the control of the municipality

Developed Methodology

The methodology section includes the approach developed for the techno-economic assessment of potential measures for developing the roadmap element. This approach applies to any building archetype and is not geographically restricted. Based on statistical and literature-based data, open-source tools were used to estimate energy demand in specific building archetypes. Once validated to consumption patterns from real measured data, it is then used to develop and analyze scenarios that can be further used to identify the most favourable options for demand and emission reductions. The methodology follows the following series of steps to assess the key performance indicators of the different scenarios:

- Status Quo of building archetypes
- Scenario definition
- Estimated Demand
- Defining Key Performance Indicators

Status Quo of Building Archetypes

The first step of the methodology was to understand the existing status of the building archetype. This required the collection and assessment of data covering the following aspects:

- Building Geometry (floor area, height)
- Building Envelope (construction material of wall, window)
- Energy Demand (Heating and cooling)

- Occupancy levels
- Supply technology

In addition, the national or regional policy targets were analyzed better to replicate the status quo during the absence of data.

Scenario Definition: Analyzing the renovation opportunities

Based on the literature [1, 2] , the following have been identified as potential energy reduction opportunities in Greece's buildings. Based on this, the scenario has been developed.

- Increasing wall insulation thickness
- Improving widows glazing level
- Adding shading measures
- Improving the ventilation in buildings

The renovation/retrofitting costs are based on German building cost values, which are scaled based on the European cost index [3].

Identifying carbon-neutral supply solutions

Four different decarbonization options, the most relevant for the Greek building stock, were assessed in this study. These supply options are selected due to their high overall impact on building decarbonization but also considering their ease of application within the Casanova tool. These include:

- Biomass boilers
- Heat pumps
- Solar PV
- Solar Thermal

Also, these technologies, especially heat pump applications, allow technology changes with minimal or no structural changes to the building envelope, which is especially important in dealing with old, historically significant buildings.

Demand Estimation

The average heating and cooling demand estimation for specific building archetypes was done with the open-source model of the *CASANOVA* tool based on the building geometry and status quo of the envelope and temperature profiles. The generated monthly resolution demand values are then scaled down based on the occupancy status of the buildings based on the status quo.

Analyzing key performance indicators

The scenarios developed based on the combination of the passive and active measures were assessed and analyzed based on the following key performance indicators. The Excel sheet developed during this methodology's development permits the calculation and comparison of these KPIs.

[1] Gaitani et al., "Paving the Way to Nearly Zero Energy Schools in Mediterranean Region- ZEMedS Project," *Energy Procedia* 78 (November 2015): 3348–53, https://doi.org/10.1016/j.egypro.2015.11.749.
[2] Centre for Renewable Energy Sources and Savings (CRES) (2020)
[3] M. Hummel et al., "The costs and potentials for heat savings in buildings: Refurbishment costs and heat saving cost curves for 6 countries in Europe," Energy and Buildings, vol. 231, p. 110454, Jan. 2021, doi: https://doi.org/10.1016/j.enbuild.2020.110454

- Total costs (Passive and active measures)
- CO_2 emissions/savings
- Levelized cost of energy (Thermal)
- % Energy savings

With this, the cost-effectiveness and energy-saving potential of the different scenarios were identified. Thus suitable carbon-neutral roadmaps for the building archetype are identified.

Case Study for Schools in Corinthos

Status Quo of Building Archetypes: National Targets and Policies

- All public buildings (including school buildings) by 2015 need to cover the heating and cooling supply with RES (CHP, DHC, heat pumps).
- New buildings and existing buildings with major renovation must be able to obtain a class B energy certificate upon completion.

Energy Consumption

Electricity consumption – 16 kWh/(m2*yr) [4]
Space Heating oil – 68 kWh/(m2*yr) [ranging from 49-90 kWh/(m2*yr)[5]
These values are used as a reference to compare the values generated in Casanova, which is used for further analysis.

Building Envelope (based on discussion with SCN)

Walls	No or minimal insulation
Windows	Single Glazing
Ventilation	Natural
Heating System	Low-Temperature Boiler
Fuel Oil	Diesel
Cooling System	Electric Fans
Cooling energy source	Electricity

Scenario Definition

The final analyzed scenario is based on a combination of all the assessed passive measures to ensure the highest demand reduction at minimum cost. Also, the measures selected take into consideration the logistic restrictions concerning the possibility of immediate implementation. The combined measures referred to as 'Retro_1_EFF_base' was developed with the inputs of the network.

The combined renovation scenario includes the minimal renovation of the following building envelopes:

- Window
- Shading

[4] Niki Gaitani et al., "Paving the Way to Nearly Zero Energy Schools in Mediterranean Region- ZEMedS Project," *Energy Procedia* 78 (November 2015): 3348–53, https://doi.org/10.1016/j.egypro.2015.11.749
[5] E.G. Dascalaki et al., "Energy Performance of Buildings—EPBD in Greece," Energy Policy 45 (June 2012): 469–77, https://doi.org/10.1016/j.enpol.2012.02.058

- Roof
- Ventilation
- Set temperature

Further, for these renovation measures, different supply technology interventions are performed to analyze the economic impact of low-carbon supply solutions.

For the supply scenario, the following technologies were assessed:
- Biomass Boiler
- Heat pumps
- Direct Electric Heating
- Solar PV
- Solar Thermal

Demand Estimation

Figure 44 shows the fluctuation in the demand calculation of the sample school building under different passive measures calculated by the CASANOVA tool.

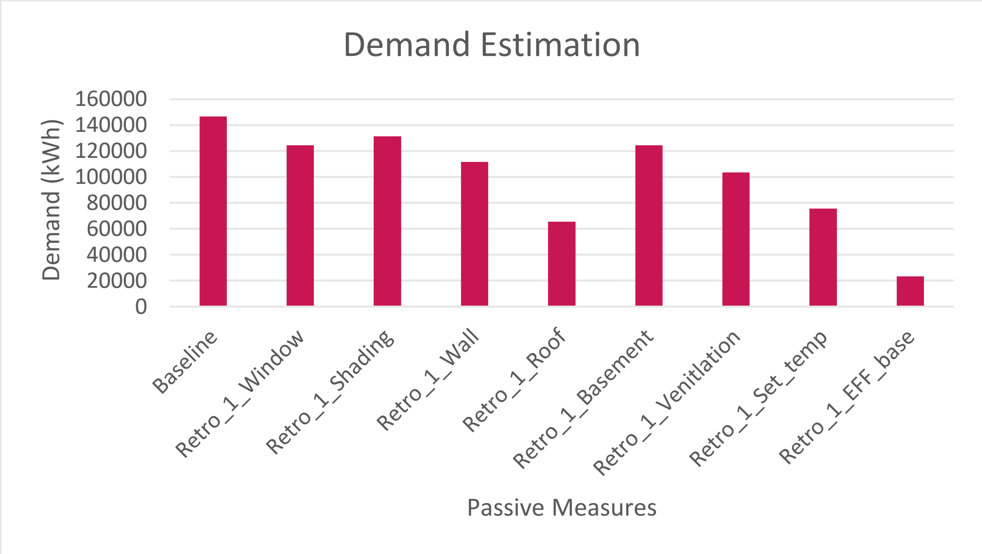

Figure 4: Demand Estimation under different passive measures

Analysing key performance indicators
Based on the discussions with the network the so-called 'Retro_1_EFF_base' was developed which combines the highest ratio of Energy savings to cost and is implementable with minimal effort. The results presented below are for these combined measures compared against individual options.

The combined measures showed the highest potential for energy savings as seen in Figure 5 primarily because multiple interventions of measures are put in place in this compared against the individual options.

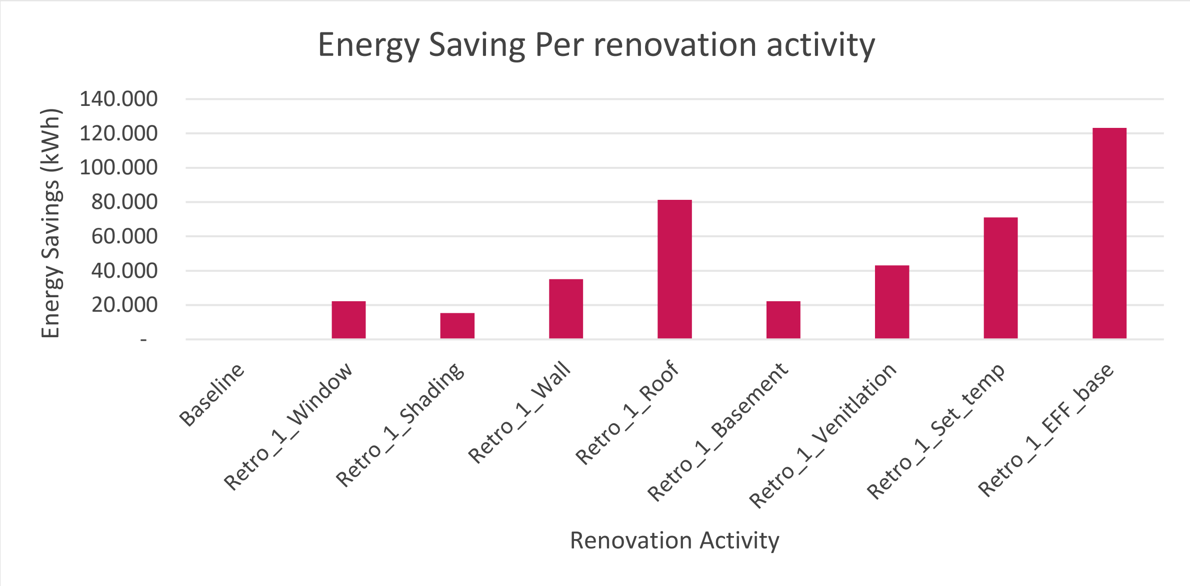

Figure 5: Energy savings achieved from different renovation activities

Figure 66 indicates the levelized cost of energy savings for the different measures. This is the ratio of the annual energy saving due to the renovation intervention and the annualized investment for these interventions. This is then compared against the average fuel price to estimate the economic feasibility of the measure. Nevertheless, the levelized cost energy savings are highly sensitive to the underlying interest rates and other financial assumptions. The investment in the combined measures is deemed justifiable at interest rates of 2 %.

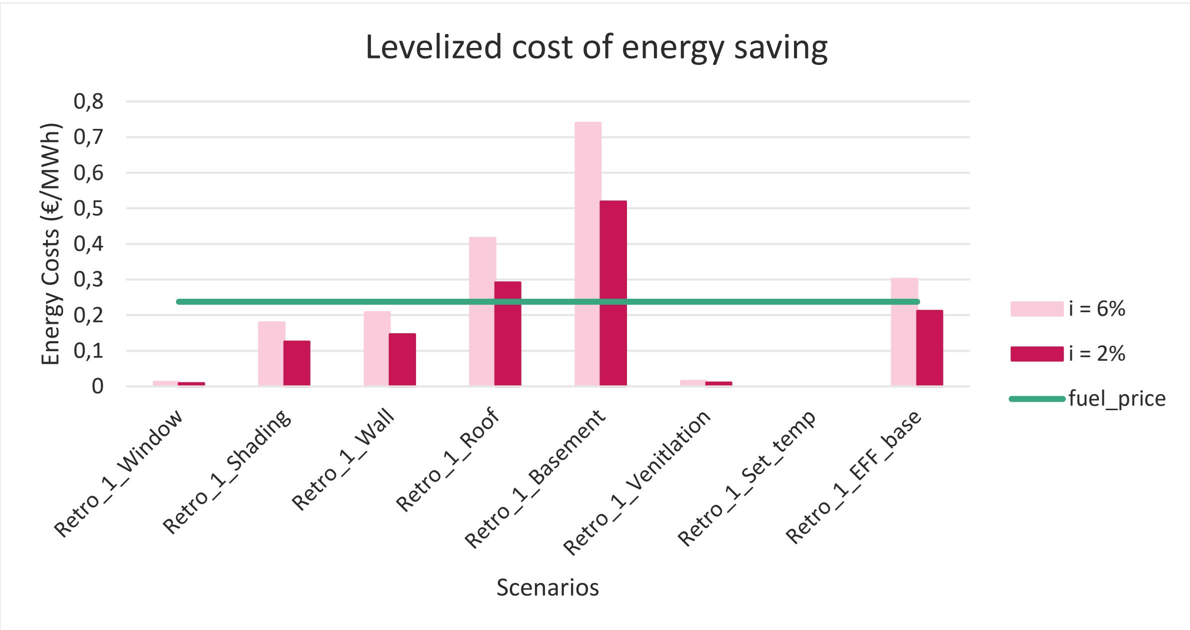

Figure 6: Levelized cost of energy savings

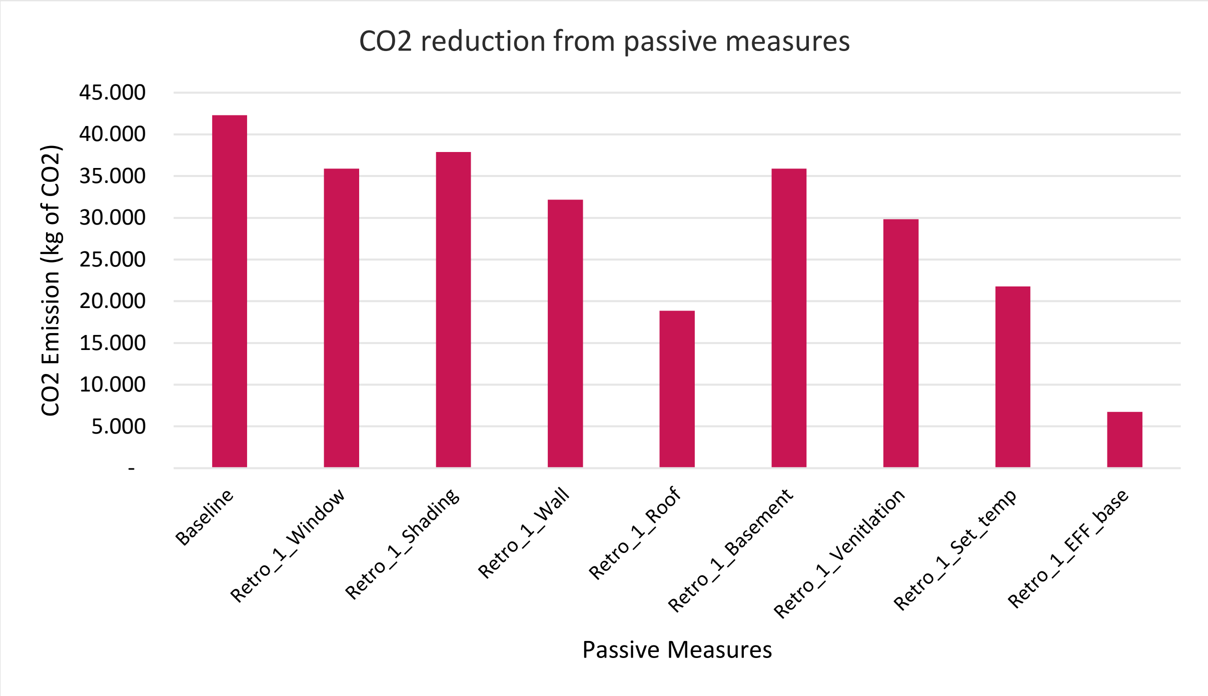

Figure 7: CO_2 Reduction from the passive measures

As shown in Figure 7, the CO_2 emission of the combined measure is compared against individual options. In alignment with Figure 5, the reduced energy consumption in the combined measures scenario results in lower CO_2 emissions. However, the emissions are not completely omitted as only passive measures are changed and the heating technology (low-temperature diesel boiler) is unchanged. Figure 8 on the next page further shows the reduction in CO_2 for the combined measure scenario with changes to the supply technology. Heat pumps and electric heaters have high emissions due to the large share of fossil-based generation sources in the Greek energy mix.

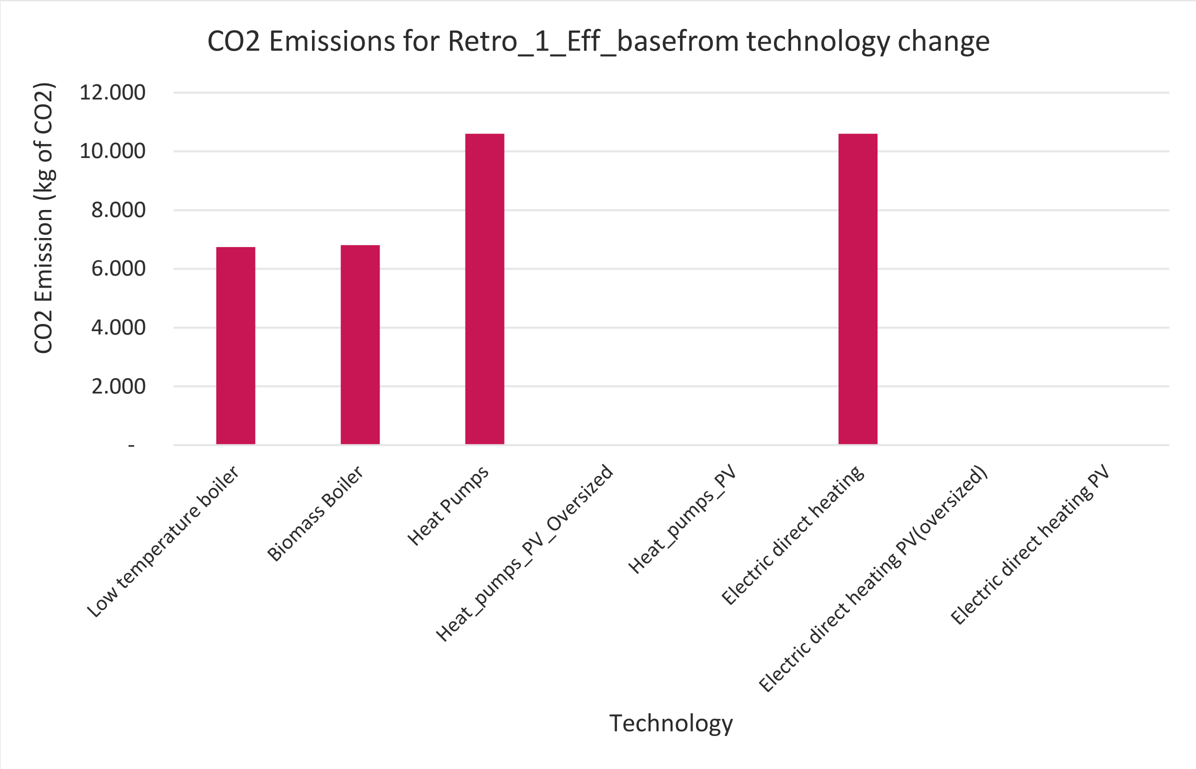

Figure 8: CO_2 emissions with changes in the supply technology

Figure 99 on the next page shows the changes in the levelized cost of heating with the changes in the heating technology compared to the status quo. The renovation in combination with the integration of the RE supply technologies shows improved economic performance.

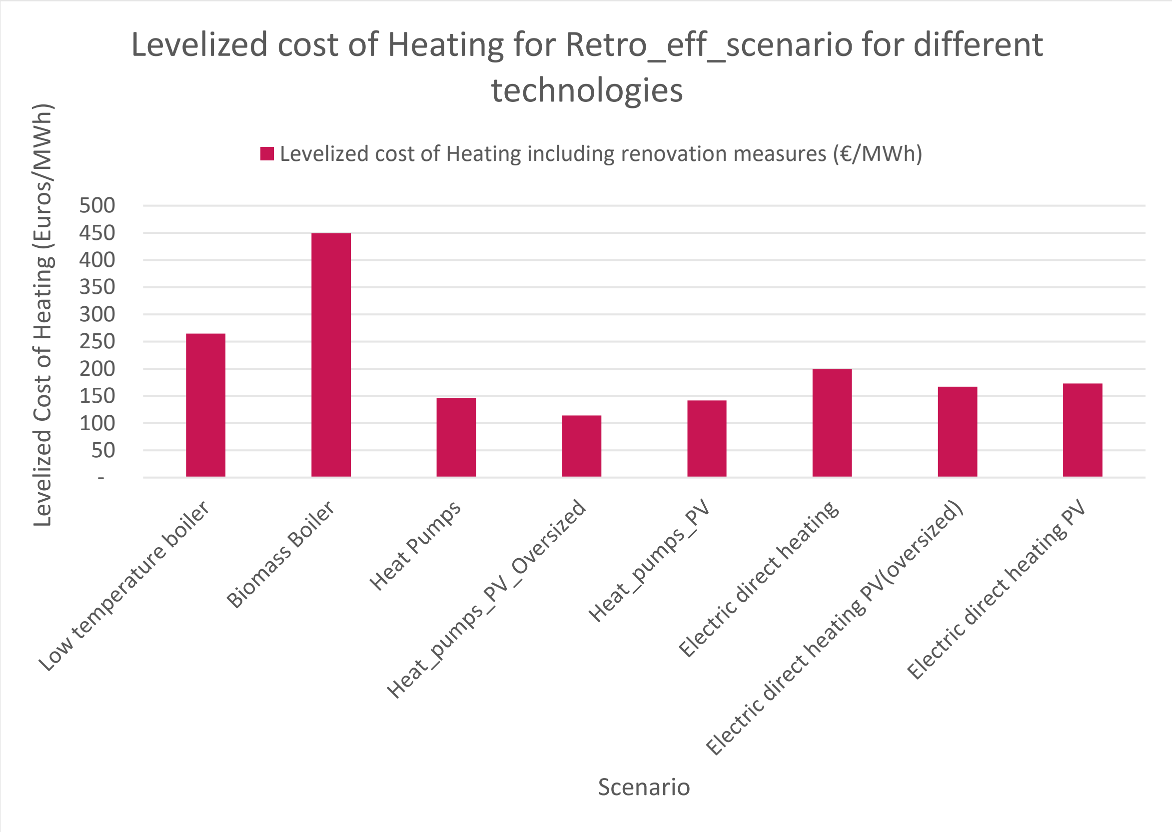

Figure 9: Changes in the Levelized cost of heating

Technical Conclusions

- Demand reduction ranging from 10% to 80% compared to the baseline can be achieved from the implementation of different renovation activities (individual and combination)
- The feasibility of these renovation options is dependent on different factors including the conventional fuel price, interest rate, and the energy saving per unit cost for each measure
- Some CO2 reduction is achieved from the implementation of the passive measures but noticeable differences are only observed with the implementation of the active measures
- Switching to Heat pumps heating provides the possibility of RE integration thus reducing the overall CO2 emissions
- Compared to the baseline lower levelized costs of heat are observed for the Solar PV integrated system. However, due to the intermittent nature of solar energy and the seasonal nature of the heating load, PV solely for thermal needs is not recommended. Solar PV in combination with electric load and grid integration is seen as a viable option. Also, the establishment of renewable energy communities with schools participating should be examined.
- The assessment of solar thermal showed its feasibility with a design aimed at both Space heating and warm water demand. However, the lack of warm water demands prevented detailed assessment.

Summarizing all key performance parameters, applying a heat pump as a supply technology along with a low envelope retrofitting scenario showed good techno-economic feasibility. This can be used for the development of the immediate next steps and strategic heating and cooling planning in the municipality.

Note: The conclusions drawn here are based on basic data from literature and assumptions literature and generated with the anticipation of providing an overview of the opportunities. Hence, these conclusions are to be taken only as starting point for the pathway development and not as a concluding result of a detailed feasibility study of a concrete case study.

Next steps

Based on the preliminary results developed from the simplistic techno-economical assessment, the next step is considered to be the integration of the developed roadmap into the strategic planning process of the network/municipality. An overview of the potential next steps for the municipality is provided below:

Identify and engage key stakeholders

The next step is to identify the involved stakeholders for implementing the measures or assessed scenarios in the schools. Considering that all schools are under the municipality's ownership, their involvement is the priority considering both administrative and financial support. The results and conclusions of this report should be shared with the respective authority to raise their interest in the implementation of energy-saving measures in their building stock. In addition, it is recommended to involve different players from different areas (economic, social, environmental) and across departments (buildings, urban planning, finance) for the early stage. This will further increase the success rate during the implementation stage[6].

Identify the pilot schools

Based on the inputs of all relevant stakeholders, the identification of a school as a pilot case is to be defined. On the one hand, this gives a real-world demonstration of the energy-saving potential and validates the potential calculated in the above techno-economic assessment. On the other hand, pilot testing would also help identify practical barriers which might have been overlooked in the theoretical assumptions. The pilot study is seen as a real-world testing phase. A lack of resources, if any, is identified at this stage. This would further improve planning for the actual implementation on a larger scale to the entire building stock.

Define milestones

The milestones should include both administrative and technical targets. The first milestones would involve the respective stakeholders from an early stage so they would have an overview of the ongoings in the entire process. In addition, the timeline can be set up for the detailed assessment based on measured data to obtain detailed results. The future milestone could be defining the annual building renovation targets and aiming for certain cost savings. Aligning the milestones with the SECAP targets could be the easiest approach to ensure implementation.

[6] https://www.bpie.eu/wp-content/uploads/2020/05/How-can-Member-States-implement-iBRoad.pdf

Identify measurable progress indicators

Define the levels of improvement in the energy performance:

- The change of windows provides tangible energy savings, is easier to implement and has low costs compared to other building envelope components. This could be the first intervention that will allow the assessment of a demand reduction.
- To assess the impact of cost intensive measures on the building stock, a certain percentage of buildings to be renovated for such a measure are to be defined. For example, 10-30% of the building stock to implement improvements in the walls within a pre-defined time period.
- Compare the energy bills of the buildings before and after the intervention.

Understanding Barriers and Drivers

Rate of acceptance with regards to high upfront costs and identification of funding and financing opportunities: Based on other similar case studies, two groups of users need to be identified, those who can self-finance and those who cannot. The first group is harder to reach and requires marketing/communication campaigns and value-added consultancy. For the second group, the cost of developing the roadmaps can be included in the overall implementation costs. Thus, a detailed roadmap would add value to convince banks to provide the required credit.

European success stories from both public and private financing have been observed. However, in the case of Corinth, public financing would be recommended considering the public status of the school buildings. Secondly, public financing gives a push to obtain the desired volume and push needed to impact the market. There are financing opportunities as over 500 million euros have been allocated for upgrading public buildings with a focus on decommissioning oil-powered technology and installing hot water systems using RES and installation of PV[7].

In addition to the technological costs, the following additional cost components need consideration and should be included in the budget estimation:

- Costs of the operational phase (e.g. Energy auditor training cost)
- Cost for renovation work and subsidies

The different costs borne by different shareholders under different conditions should be clear and well-defined before the project's initiation. (e.g., financing instruments like energy efficiency loans- is it repaid by the building owner, public fund, or another program that enables access to the loan).
Other identified financing opportunities in Greece include:

- 'PV in the roofs' Programmed
- PV Net-metering policy
- 'Exoikonomo' Programme: Improve energy efficiency at the local level, to promote energy savings

Renewable energy supply security: The scenario assessment showed the use of heat pumps as the best option for supply. But policy-level interventions on increasing the RE share of the electricity mix would be needed to ensure environmental performances are met.

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7 https://www.businessdaily.gr/english-edition/24195_greece-launch-13-bln-euro-scheme-upgrading-energy-performance-buildings

Existing resources and expertise, availability, and outsourcing: Capacity building in local human resources for the implementation of the deep measures as well as production of scenario-based building stock envelope materials locally. In cases of need for outsourcing, a procurement process will need to be initiated with the tender document in line with the goals of the overall replicability study.

Drivers: A combination of public or private leadership, competition and collaboration provides a new market instrument that, if well nurtured, provides a strong market push. e.g., in Germany and Flanders initiatives are driven by regional governments, in Denmark and France the initiators are private investors. Competition aids in the development of competitive tools, as does the collaboration across different administrations and stakeholders to exchange views and ideas.

Design and implementation stage

There needs to be a development in legislation to support the improvement of the buildings in the specific building archetype (schools). This regulation needs to include aspects like changing or inclusion of the minimum requirements of deep renovation to improve step-by-step renovation. Once legal, technical, and economic factors are taken care of, strategic planning ought to be developed to recruit more buildings to be renovated. Communication or recruitment campaigns led by private or public actors or even energy auditors could positively influence the uptake of the building energy renovation measures[8].

Evaluation

Continuous evaluation is needed to observe whether the results deviate from the baseline, as expected. This also permits the adaptation of the methodology as per the feedback acquired.

Conclusions

The overall building-stock energy reduction replicability study combines different components, technical assessment, legislative actions and policy interventions. Based on the chosen scenario from the technical study, the implementation of a pilot case study is envisioned. Once satisfactory results are obtained from the pilot building, this can be replicated in other buildings in the archetype. For this, a push for public financing is envisioned. A detail of the financing opportunities is defined by the stance of the individual municipality/ regional authority. For the success of the overall process, a close interaction between all stakeholders is recommended along with campaigns to positively influence the uptake of the building energy renovation measures.

Though the approach only provides a first-level overview of cost-saving measures, the replicability aspect is envisioned to have large-scale applications and contribute toward decarbonizing the heating and cooling in the different building stocks.

[8] https://www.businessdaily.gr/english-edition/24195_greece-launch-13-bln-euro-scheme-upgrading-energy-performance-buildings

FURTHER RESOURCES

The following resources allow interested readers to delve deeper into the topic of energy transition roadmaps.

TOMORROW Project

Designing participatory transformative processes for just and climate-neutral cities. Deliverable report. Brussels: TOMORROW, Link.

Covenant of mayors

There are plenty of helpful resources on the homepage of the Covenant of Mayors for Climate and Energy, from posters, webinars and several case studies. The Covenant of Mayors is a joint voluntary initiative of European local governments that aims to implement EU climate and energy objectives. As such, the initiative is supported by the European Commission

PATH2LC knowledge base

Within PATH2LC, we created a knowledge base with different resources regarding Climate Action, Energy Efficiency and Energy Production. See our dedicated PATH2LC homepage for further information on these resources.

C40 knowledge base

The C40 network consists of « mayors of nearly 100 world-leading cities collaborating to deliver the urgent action needed right now to confront the climate crisis can create a future where everyone, everywhere can thrive. In their guideline to *create a roadmap for your city's energy transition*, you'll find further useful information.

ACKNOWLEDGEMENT

This work has been performed in the course of the Horizon 2020 project PATH2LC (project number 892560) funded by the European Commission, to which we convey our deepest appreciation for providing the funding to carry out the present investigation. We would like to express our sincere thanks to the scientific partners for their valuable work in the respective assistance as well as the writing process of this document. This work has greatly benefited from review of Fraunhofer ISI (Sven Alsheimer and Markus Fritz) and IREES (Jacqueline Raterink).

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