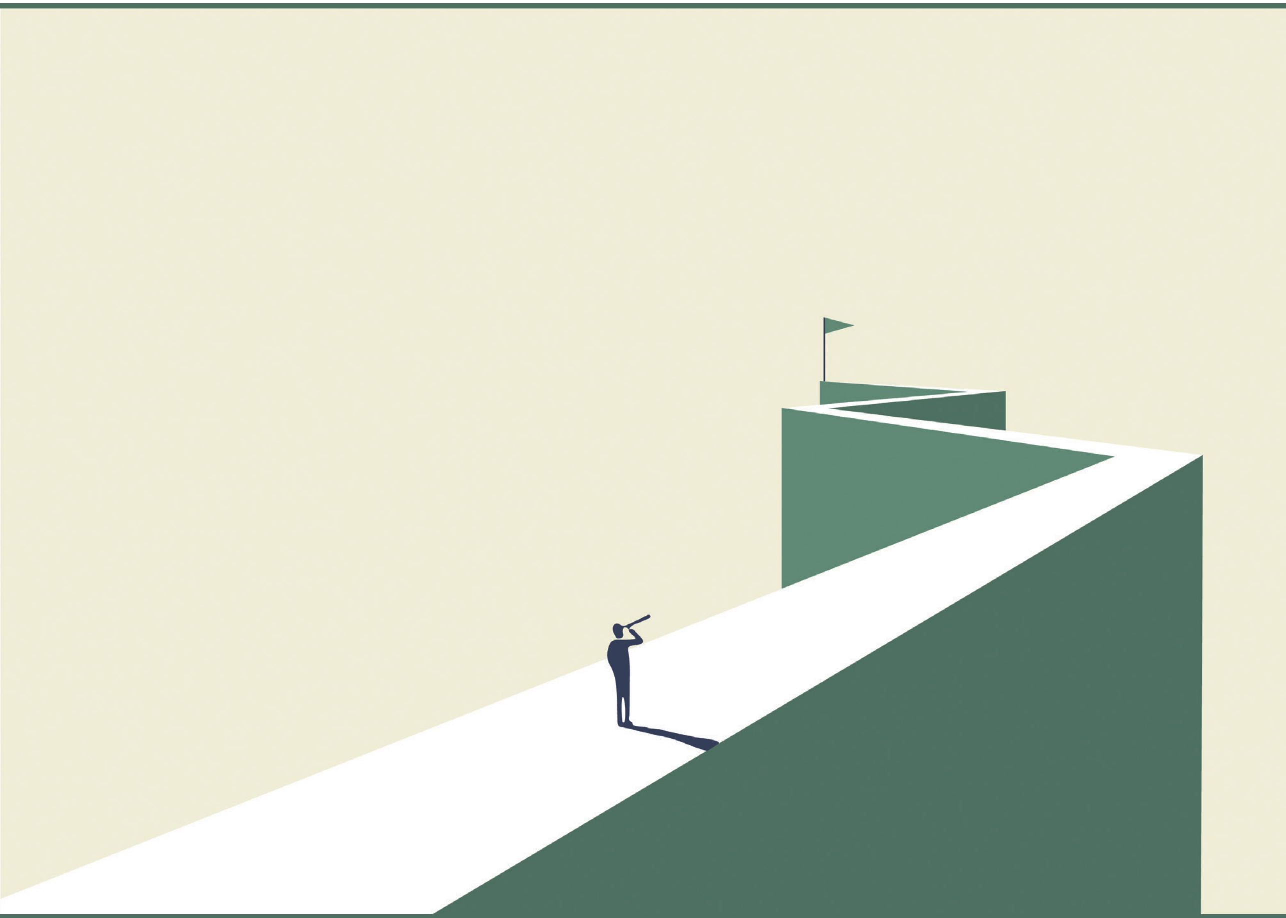
RIGA TECHNICAL UNIVERSITY

Anda Jēkabsone

THE ROLE OF ENERGY MANAGEMENT IN ACHIEVING CLIMATE NEUTRALITY IN MUNICIPALITIES IN EUROPE

Summary of the Doctoral Thesis



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RIGA TECHNICAL UNIVERSITY
Faculty of Electrical and Environmental Engineering
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Summary of the Doctoral Thesis

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DOCTORAL THESIS PROPOSED TO RIGA TECHNICAL UNIVERSITY FOR THE PROMOTION TO THE SCIENTIFIC DEGREE OF DOCTOR OF SCIENCE

To be granted the scientific degree of Doctor of Science (Ph. D.), the present Doctoral Thesis has been submitted for the defence at the open meeting of RTU Promotion Council on 26th June 2023 at 14.00 at the Faculty of Electrical and Environmental Engineering of Riga Technical University, Āzenes iela 12/1, Room 115.

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DECLARATION OF ACADEMIC INTEGRITY

I hereby declare that the Doctoral Thesis submitted for the review to Riga Technical University for the promotion to the scientific degree of Doctor of Science (Ph. D.) is my own. I confirm that this Doctoral Thesis had not been submitted to any other university for the promotion to a scientific degree.

Anda Jēkabsone ……………………………. (signature)
Date: ………………………

The Doctoral Thesis has been written in Latvian. It consists of Introduction, 3 chapters; Conclusions, 31 figures, 16 tables, 6 appendices; the total number of pages is 81, not including appendices. The Bibliography contains 134 titles.

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Introduction

Over the past decade, the European Union has made it clear that mitigating climate change is a top priority. As a party to the Paris Agreement, the EU's goal is to limit global warming to below 1.5 °C, or at the very least, below 2 °C compared to pre-industrial levels [1]. This commitment demonstrates the EU's dedication to reducing greenhouse gas emissions and preventing the most catastrophic effects of climate change. However, the latest Assessment Report (AR6) by the UN Intergovernmental Panel on Climate Change (IPCC) warns that current policies for mitigating and adapting to climate change are inadequate, and that we could surpass the 1.5 °C global warming threshold as soon as this century [2]. The world has already experienced a significant increase in global warming, with the average air temperature rising by 1.1 °C during the decade spanning 2011 to 2020 when compared to the average level of 1850–1900. This rise in temperature has led to a marked increase in the frequency of extreme climate phenomena, posing significant threats to both humans and the natural world alike [2]. Urban areas, where the majority of the world's population resides, are particularly vulnerable to the risks posed by climate change [3], [4]. As such, sustainable planning initiatives implemented by municipalities are critical for mitigating economic, social, and environmental risks, and for achieving global goals. However, it is essential that the shift towards climate neutrality is fair and proportionate for all societal groups, and that it does not contribute to energy poverty or further vulnerability to climate risks [5].

Climate change adaptation is a relatively new concept in municipal planning, particularly in countries that have not yet experienced serious climate disasters. Nevertheless, given that climate change is inevitable, adaptation must be integrated into planning at all levels. Since 2015, the Covenant of Mayors has expanded its methodical approach to include three main directions for the Sustainable Energy and Climate Action Plans of municipalities: climate change mitigation, climate change adaptation, and mitigation of energy poverty. This approach recognizes the crucial importance of preparing for the impacts of climate change and highlights the need for a comprehensive and integrated approach to addressing these challenges [6]. As a result, to develop a plan that addresses all three aspects in a municipality, a wide range of competencies is required. This includes the ability to involve a broad range of stakeholders throughout the development and implementation process, as well as the capacity to work systematically on implementing the plan.

Numerous municipalities across Europe have developed action plans or strategies to achieve climate neutrality and resilience. However, the implementation of these plans is often not as successful as intended, as documented in existing research [7]–[10]. Literature identifies various external and internal barriers to plan implementation, yet effective solutions are still being sought. Despite significant progress in climate action planning, effective implementation remains a critical challenge for municipalities.

The ISO 50001 standard, also known as the "Energy Management System," provides guidelines on how to systematically improve energy efficiency, reduce energy consumption and costs, and minimize an organization's environmental impact. The standard outlines the requirements for creating, implementing, maintaining, and continuously improving the system

[11]. The ISO 50001 standard emphasizes the importance of regularly setting short-term energy reduction goals, implementing energy efficiency measures that require minimal or no investment, and continuously monitoring energy consumption. While the standard is widely adopted by industrial companies [12], it is also suitable for any type of organization and easily applicable to municipal infrastructure [13].

The Doctoral Thesis focuses on developing and approving a methodology that demonstrates how the implementation of an Energy Management System (EMS) in municipalities can help institutionalize systematic actions for improving energy efficiency and achieving the goals of energy climate neutrality and climate resilience. The Thesis proposes integrating a systematic approach, a clear division of responsibilities, and precise procedures in managing municipal energy and adapting to climate change. By doing so, municipalities can establish a framework for achieving their energy management goals, reducing energy consumption, and minimizing their environmental impact, thus contributing to the fight against climate change.

The Relevance of the Doctoral Thesis

The European Green Deal (EU Green Deal) is a vital policy for the European Union aimed at making the EU economy sustainable. It is currently one of the most important EU policies, encompassing targets such as reducing GHG gas emissions, increasing the share of renewable energy, improving energy efficiency, and transitioning to a circular economy. These targets are critical not only for addressing climate change, but also for promoting economic, social, and environmental sustainability. Similarly, in Latvia, the National Energy and Climate Plan of Latvia for 2021–2030 (NEKP2030) has been developed to ensure a fair and equitable transition towards climate neutrality. Achieving these objectives requires an integrated and systematic approach, which can be facilitated by sustainable energy and climate action plans with energy management systems. In addition to promoting environmental sustainability, these goals also contribute to economic and social sustainability.

To meet the targets set by the EU and national climate goals, municipalities need to adopt an integrated and systematic approach. Sustainable energy and climate action plans with an energy management system can provide such an approach. By achieving good energy efficiency indicators in their infrastructure, municipalities can set an example of best practices for both the public and private sectors, thereby promoting the move towards climate neutrality. This can be achieved not only within the municipality's jurisdiction, but also beyond it, inspiring other sectors to follow suit.

When commencing the development of the Doctoral Thesis, it was noted that while sustainable energy and climate action plans have been established in several European municipalities, their implementation is often chaotic or incomplete [8], [9]. Local government employees lack the necessary competence and understanding [14], [15] and issues related to climate and energy are often deemed less pressing and given lower priority due to the volume of problems and issues that need to be resolved within municipalities [16]. Municipalities, being large organizations with extensive infrastructure and numerous employees, present a challenge for employees to take personal interest in potential financial savings resulting from energy efficiency measures, which in turn reduces motivation to act [17]. These barriers necessitate the development of a methodology and approach for municipalities to plan and implement systematic actions in the field of climate and energy.

Objective and Tasks of the Thesis

The objective of the Doctoral Thesis is to create a methodology and provide recommendations for municipalities to implement a systematic approach in managing their energy and climate sectors, with a focus on ensuring tangible progress towards achieving climate neutrality goals. Special emphasis will be given to the energy management system, which can initiate specific actions and measures towards this end.

To achieve the overall goal, several specific tasks have been outlined for the Thesis:

1. Conduct an analysis of existing sustainable energy action plans to study the climate goals set by municipalities and identify the main barriers hindering their achievement.
2. Develop an approach to integrate climate change adaptation aspects into sustainable energy action plans for municipalities with the goal of achieving climate resilience and approbating in European municipalities.
3. Research and analyse the development, implementation, maintenance, and outcomes of the energy management system in Daugavpils municipality, the first Latvian municipality to obtain ISO 50001 certification, to determine the advantages of implementing the standard in achieving the municipality's climate neutrality goals and to identify any implementation or maintenance challenges.
4. Evaluate the impact of implementing systematic behaviour change measures on energy consumption in municipal buildings in European Union countries and the broader achievement of energy efficiency and climate neutrality goals in municipalities.
5. Analyse energy consumption data from Latvian municipal buildings during the COVID-19 pandemic to identify trends in energy consumption changes and the potential impact on municipalities' progress towards climate neutrality during crisis situations.
6. Carry out the approval of the energy management system in European Union municipalities according to the ISO 50001 standard to determine the key benefits and challenges of implementing the standard for achieving municipal energy goals.

Hypothesis of the Thesis

The transition towards climate neutrality and resilience requires a structured and cyclical approach to managing energy and climate adaptation sectors in European municipalities, as outlined in the European Green Deal. This involves analysing the current situation and progress, as well as action planning. The use of an energy management system helps to institutionalize these cyclical and systematic actions in the municipality's daily processes, promoting a culture of sustainability and ensuring progress towards climate and energy goals.

Scientific Novelty

Throughout the development of the Thesis, extensive collaboration has been established with multiple municipalities in Latvia and other European Union countries to explore mechanisms that can support and accelerate progress towards achieving climate neutrality and other environmental and climate goals. Through research, various authors have identified issues with the implementation of sustainable energy action plans, such as a lack of systematic implementation of planned activities and inadequate monitoring mechanisms to track progress towards the goals set out in these plans [8], [9], [14]. As the implementation of a standardized energy management system in municipalities is not well-researched, the Thesis experimented with different approaches and methods for implementing the ISO 50001 standard in municipalities. The conceptual framework of the Thesis, illustrated in Fig. 1, outlines the key components of the methodology developed to support municipalities in achieving their energy and climate goals.

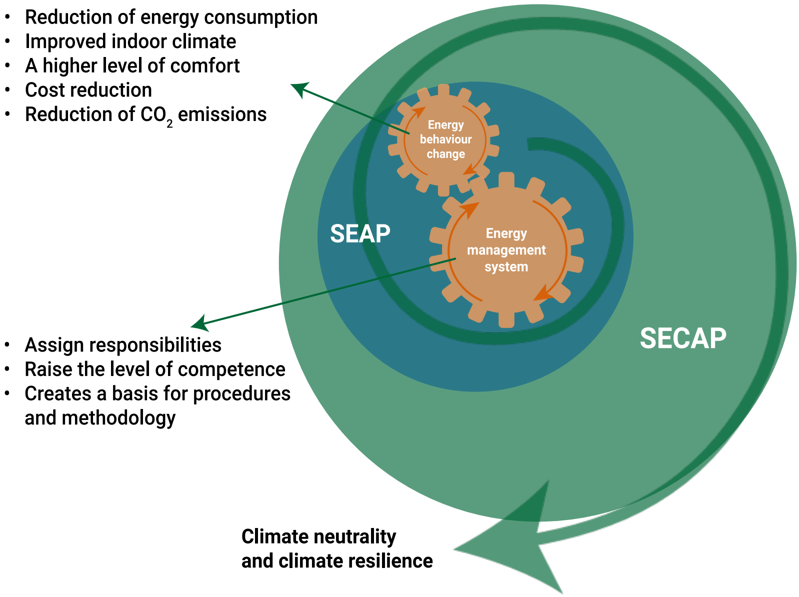

Fig. 1. Theoretical framework of the Thesis.

The creation of a working group and management structure during the implementation of the ISO 50001 standard "Energy Management System" is a significant step towards achieving sustainable energy and climate action plans and setting municipal climate goals. As part of the methodological framework developed for the Doctoral Thesis, Fig. 2 illustrates the proposed approach.

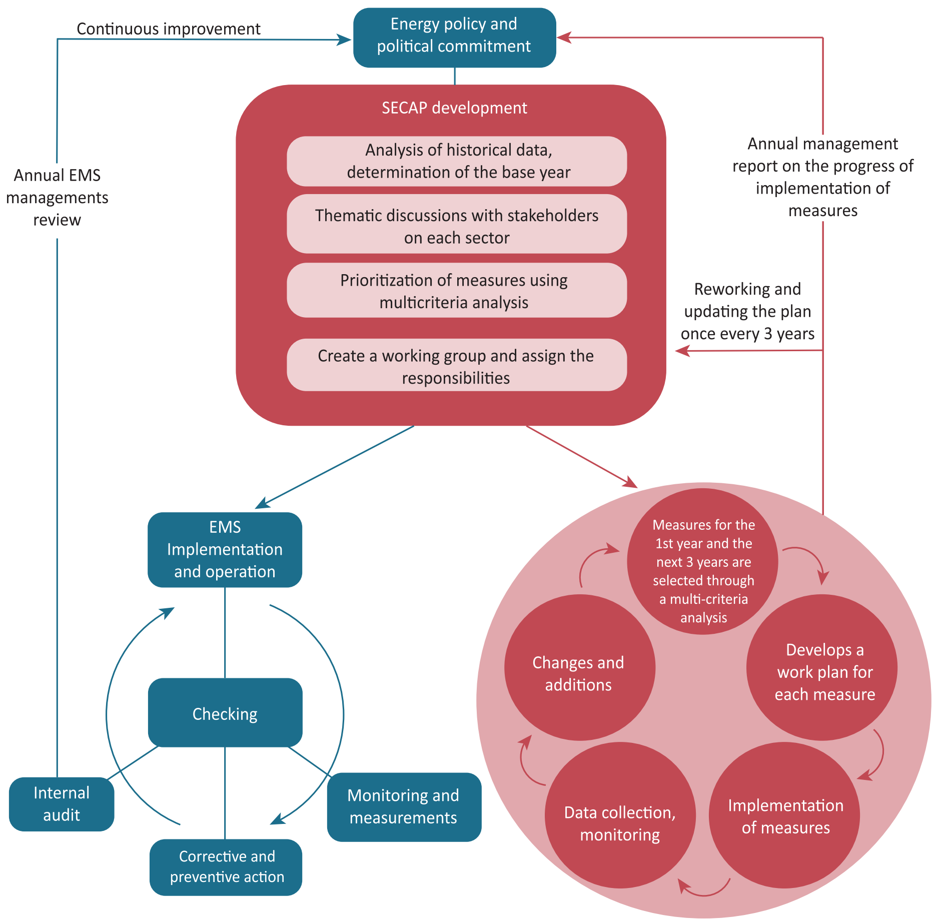

Fig. 2. The methodology developed in the Thesis.

The Doctoral Thesis has developed a methodology for implementing an integrated energy management system [18] and Sustainable Energy and Climate Action Plans (SECAPs) (see Fig. 2). Political support from the municipality's management and members is crucial to initiate the development of both EMS and SECAP. Therefore, the decision to develop them must be taken by the municipal council through a vote. The analysis of the existing situation can be carried out either by the municipality or by external experts. In both cases, it is important to involve responsible specialists from each sector through working group meetings. During the development of SECAPs, a working group should be created to implement the plan and determine responsibilities, similar to the creation of an energy management system.

Once the municipality has developed the SECAP and implemented the energy management system, cyclical work on the implementation and monitoring of measures should commence. For EMS, the cycle is one year long, where goals must be set and actions must be planned for municipal infrastructure objects included in the EMS. Throughout the year, data must be monitored and an annual report submitted to the municipal management at the end of the year.

For SECAP, an annual cycle is introduced, including creating an action plan, monitoring and reporting for each year, and a 3-year cycle to update and adjust the plan. It is important to note that the SECAP is a medium-term planning document.

Practical Significance of the Research

The practical implications of the Doctoral Thesis are significant for municipalities across Europe, as they provide a knowledge and competence base necessary to achieve climate neutrality and resilience. The approaches and methods developed in the Thesis have been refined and improved based on the obstacles identified in the research, which municipalities face when developing and implementing sustainable energy action plans. By integrating the energy management system into the management of the energy sector and aligning with European Union policy, the methodology of sustainable energy plans includes aspects of adaptation to climate change. The methodology and recommendations developed in the study have been approved by municipalities in Europe and can also be integrated into policy planning at the EU, national, and regional level. The energy management system is an effective tool for reducing energy consumption and moving towards climate neutrality, which makes the developed methodology a valuable contribution to the efforts towards a more sustainable future.

Research Framework

The Doctoral Thesis presents a comprehensive approach to energy management in municipalities, which has been developed and validated through six scientific publications. The studies cover various aspects of the energy and climate sector management system, providing a solid foundation for municipalities to achieve their climate and energy goals. Figure 2 illustrates the interrelated studies and their results, which are presented in detail in the Thesis. Overall, this research offers a valuable contribution to the field of energy management and provides practical tools and methods for municipalities to create functioning and sustainable energy systems.

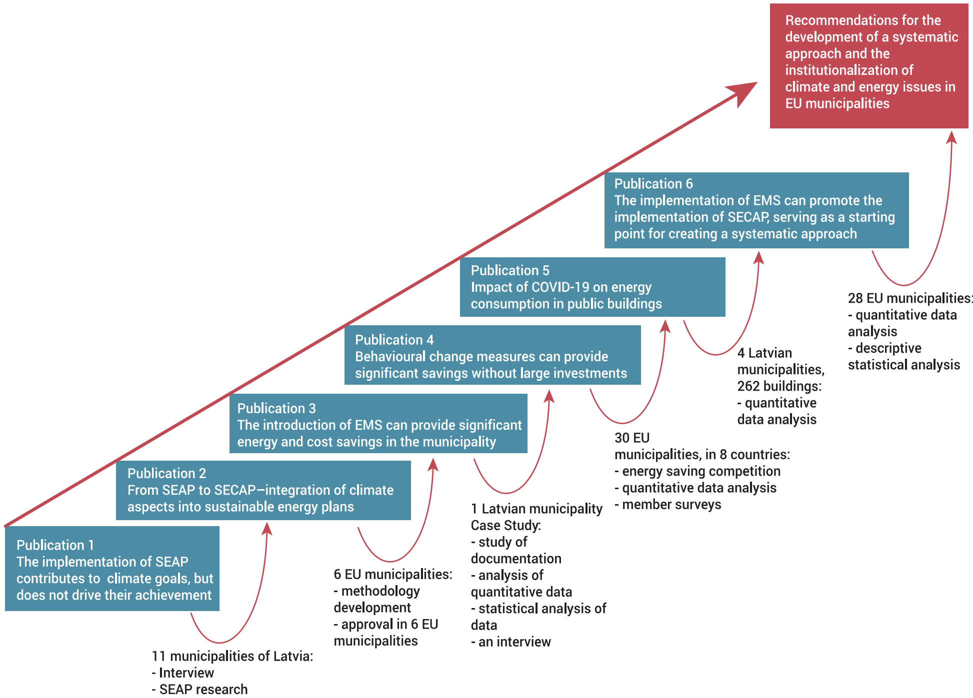

Fig. 2. Structure of the Doctoral Thesis.

The research undertaken in the Thesis covers various aspects of sustainable energy and climate management in municipalities. Firstly, an analysis was conducted on the progress and content of sustainable energy action plans, as well as their implementation and monitoring. The study then focused on integrating climate adaptation aspects into municipal sustainable energy and climate action plans, which were tested in six EU municipalities accross three countries.

The following section analyses the implementation progress, system boundaries, procedures, obstacles, and challenges faced by Daugavpils municipality in establishing and maintaining the energy management system, including the analysis of real energy savings achieved after implementing EMS.

In addition to the previous studies, the Thesis analysed the progress and results of energy saving competitions in 30 EU municipalities accross eight countries. These competitions included measures to change user behaviour towards energy consumption. Furthermore, the impact of the COVID-19 pandemic on energy consumption in four Latvian municipalities was analysed, providing insights into the effects of external factors on energy management in municipalities. The study also examined the implementation of EMS according to the ISO 50001 standard in 28 EU municipalities, identifying obstacles and challenges in municipal climate and energy management.

The research outcomes provided valuable recommendations and methodologies for municipalities to establish sustainable energy and climate management systems. These recommendations and methodologies are currently being tested in 44 EU municipalities to further validate their effectiveness. Overall, this work presents a comprehensive and practical approach to achieving sustainable energy and climate management in municipalities.

Approbation

Scientific publications included in the Thesis

1. Jēkabsone, A., Kamenders, A., Rošā, M., Kaselofsky, J., Schule, R. Assessment of the Implementation of Sustainable Energy Action Plans at Local Level. Case Study of Latvia. *Environmental and Climate Technologies*, 2019, Vol. 23, No. 2, pp. 36–46. ISSN 1691-5208. e-ISSN 2255-8837. Available: doi:10.2478/rtuect-2019-0053
2. Jēkabsone, A., Kamenders, A., Rošā, M. Implementation of Certified Energy Management System in Municipality. Case Study. *Environmental and Climate Technologies*, 2020, Vol. 24, No. 2, pp. 41–56. ISSN 1691-5208. e-ISSN 2255-8837. Available: doi:10.2478/rtuect-2020-0053
3. Kaselofsky, J., Schule, R., Rošā, M., Prodaņuks, T., Jēkabsone, A., Vadovics, E., Vadovics, K., Heinel, T. Top Energy Saver of the Year: Results of an Energy Saving Competition in Public Buildings. *Environmental and Climate Technologies*, 2020, Vol. 24, No. 3, pp. 278–293. ISSN 1691-5208. e-ISSN 2255-8837. Available: doi:10.2478/rtuect-2020-0103
4. Kaselofsky, J., Rošā, M., Jēkabsone, A., Favre, S., Loustalot, G., Toma, M., Marín, J., Nicolás, M., Cosenza, E. Getting Municipal Energy Management Systems ISO 50001 Certified: A Study with 28 European Municipalities. *Sustainability*, 2021, Vol. 13, No. 7, Article number 3638. ISSN 2071-1050. Available: doi:10.3390/su13073638
5. Jēkabsone, A., Delgado Marin, J., Martins, S., Rošā, M., Kamenders, A. Upgrade from SEAP to SECAP: Experience of 6 European Municipalities. *Environmental and Climate Technologies*, 2021, Vol. 25, No. 1, pp. 254–264. ISSN 1691-5208. e-ISSN 2255-8837. Available: doi:10.2478/rtuect-2021-0018
6. Jēkabsone, A., Rošā, M., Kamenders, A. Impact of COVID-19 on Energy Consumption in Public Buildings. *Environmental and Climate Technologies*, 2022, Vol. 26, No. 1, pp. 306–318. e-ISSN 2255-8837. Available: doi:10.2478/rtuect-2022-0023

Participation in conferences

1. Jēkabsone, A., Kamenders, A., Rošā, M., Kaselofsky, J., Schule, R. Assessment of the Implementation of Sustainable Energy Action Plans at Local Level. Case Study of Latvia. Conference of Environmental and Climate technologies, CONECT 2019, 15–17 May 2019.
2. Jēkabsone, A., Kamenders, A., Rošā, M. Implementation of Certified Energy Management System in Municipality. Case Study. Conference of Environmental and Climate technologies, CONECT 2020, 13–5 May 2020.
3. Kaselofsky, J., Schule, R., Rošā, M., Prodaņuks, T., Jēkabsone, A., Vadovics, E., Vadovics, K., Heinel, T. Top Energy Saver of the Year: Results of an Energy Saving

Competition in Public Buildings. Conference of Environmental and Climate technologies, CONECT 2020, 13–15 May 2020.

4. Jēkabsone, A., Delgado Marin, J., Martins, S., Rošā, M., Kamenders, A. Upgrade from SEAP to SECAP: Experience of 6 European Municipalities. Conference of Environmental and Climate technologies, CONECT 2021, 12–4 May 2021.
5. Jēkabsone, A., Rošā, M., Kamenders, A. Impact of COVID-19 on Energy Consumption in Public Buildings. Conference of Environmental and Climate technologies, CONECT 2022, 11–13 May 2022.

1. METHODOLOGY

1.1. An In-depth Survey

As part of this research, a comprehensive analysis of documents (SECAP, EMS documentation) was carried out and an in-depth survey was developed to study Sustainable Energy Action Plans. This study was conducted as part of the *Compete4SECAP* project, which was funded by the European Union's Horizon 2020 program.

At the time of the study, 42 municipalities in Latvia had developed SECAPS, of which 11 agreed to participate in the survey. The study provided valuable insights into the progress and content of sustainable energy action plans in these municipalities.

The survey comprised six sections, which covered basic information about the municipality (municipality profile), the purpose of the SECAP, data availability, the implementation process of the SECAP, monitoring and supervision, and the energy management system. It included a total of 43 questions, and the information obtained was further supplemented and clarified based on publicly available sustainable energy action plans of the municipalities.

The collected data underwent qualitative analysis, which enabled the drawing of relevant conclusions regarding the progress and implementation of the SECAPs in the surveyed municipalities.

1.2. Application of a Multi-criteria Analysis Method for Measure Selection

Within the *Life Adaptate* project an approach was developed for planning and implementing climate change adaptation measures, which involved three primary steps: the development of the SECAP, adaptation of local-level policies, and implementation of climate change adaptation measures. To test the approach, six European municipalities (Lorca, Aguilas, and Cartagena in Spain, Alfandega da Fe and Mertola in Portugal, and Smiltene in Latvia) were selected. Each municipality followed the proposed methodology by the project partners and developed a sustainable energy and climate action plan. Additionally, they implemented one measure to showcase the significance of adaptation measures to the public.

During the development of sustainable energy and climate action plans, significant innovations were introduced, such as the utilization of multi-criteria analysis in evaluating and selecting adaptation measures, as well as targeted stakeholder involvement (see Fig. 1.1). To create a list of potential adaptation measures, workshop discussions were organized to identify climate change risks and possible mitigation measures. Given that the benefits of adaptation measures can be diverse and not always easily quantifiable, unlike in the case of climate change mitigation, a multi-criteria analysis was employed to evaluate and prioritize measures. The analysis considered the following criteria:

- Effectiveness: the level at which the proposed solution is able to solve the problem.
- Efficiency: the extent to which benefits exceed costs/losses.
- Equity: the extent to which the action adversely affects other areas or population groups.
- Flexibility: the activity allows for adjustments or gradual implementation.

− Legitimacy: the action is politically, legally and socially acceptable.
− Urgency: deadline for solving the problem.
− Synergy: degree of coherence with other goals or measures.
− Costs: investment amount.
− Funding: availability of internal or external funding for the implementation of the event.

To perform the multi-criteria analysis, all members of the working group and parties involved in the meeting were asked to evaluate and score the potential adaptation measures based on the criteria mentioned above. Municipalities were given the option to assign weights to each criterion or to consider all criteria equally important [19].

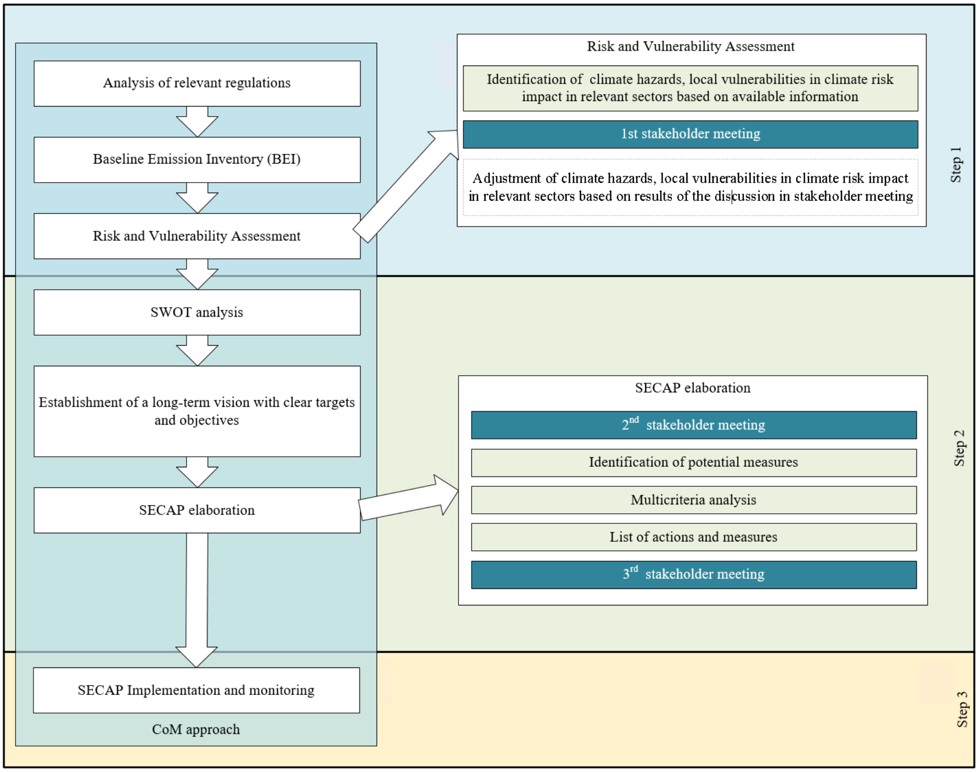

Fig.1.1. The approach of the Covenant of Mayors and the developed additional steps in the development of the SECAP [19], [20].

1.3. Research on the Implementation of the Energy Management System

The theoretical framework used to analyse the implementation and operation of energy management systems is based on the methodological scheme developed by Kamenders et al. (see Fig. 1.2.) [18]. This framework comprises four main stages. The first stage is to secure political support from municipal leaders and their commitment to achieving medium- and long-term climate and energy goals. The second stage is the planning phase, which involves analysing the existing situation, determining base values, and setting quantitative and qualitative goals and measures to achieve them. The third stage is the implementation and maintenance of the energy management system, which includes implementing measures and procedures, such as the monthly data collection and processing procedure, and the deviation detection procedure. The last stage is monitoring, which involves conducting internal audits, analysing quantitative results, and identifying strengths and weaknesses in the system process.

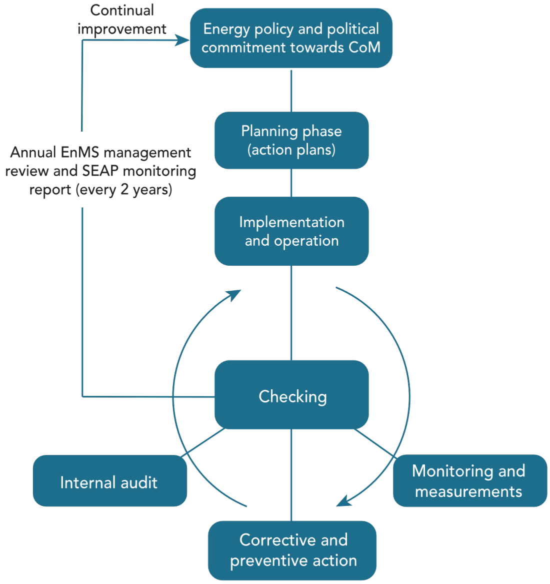

Fig. 1.2. Integrated approach of EMS and SECAP [18].

The principles of the theoretical framework served as the foundation for the research conducted in the context of the Doctoral Thesis. The study encompassed both quantitative and qualitative data analysis, including a qualitative interview with the municipal energy manager. The primary documents analysed were the Sustainable Energy Action Plan of the City of Daugavpils and the Manual of the Daugavpils Energy Management System, as well as the results of the annual audits performed under the ISO 50001 certification framework. The energy manager's survey focused mainly on the EMS implementation process and the obstacles encountered by the municipality. All the quantitative data used in this study were collected through the municipal energy management system, which requires those responsible for specific facilities or buildings to submit monthly energy consumption data to an online monitoring platform in accordance with established protocols and procedures.

Examining the Process of EMS Implementation Across 28 European Municipalities

As a key activity of the *Compete4SECAP* initiative, an energy management system was implemented across 28 municipalities in Europe. To identify the primary advantages and difficulties of the EMS implementation process, we carried out interviews with municipal energy managers and participating experts, in addition to analysing energy consumption data.

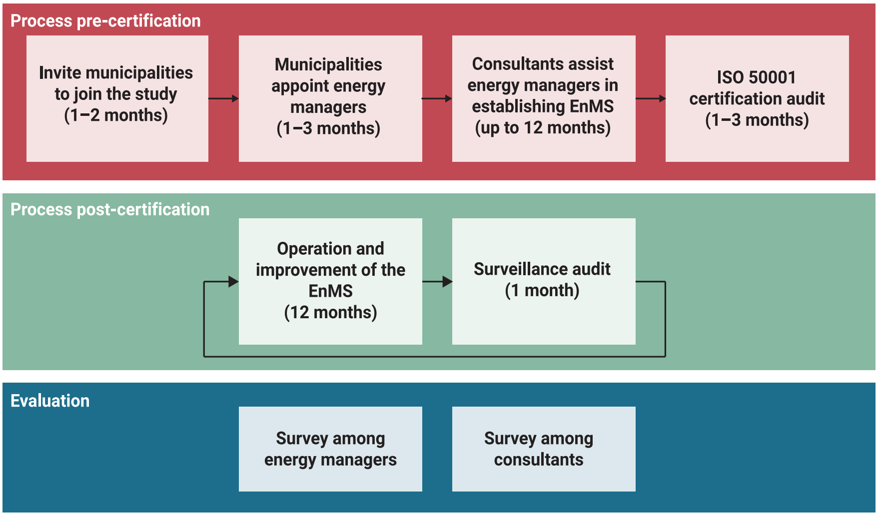

Fig. 1.3. Activities during the study.

Figure 1.3 illustrates the primary phases of the conducted research, including pre-certification, post-certification, and evaluation stages. Municipalities were encouraged to designate energy managers and working groups for implementing the EMS. The expert support was available throughout the EMS implementation process via the *Compete4SECAP* project. The pre-certification stage culminated in a certification audit, resulting in the municipality's receipt of an ISO 50001 certificate. From that point, the EMS is continually maintained and improved via regular monitoring audits, with specialists providing assistance only when necessary. Continuous improvement is a key tenet of the ISO 50001 standard [11], [21], and prior research has also underscored the importance of this aspect [22], [23].

To assess the EMS creation process, two surveys were conducted. The first survey targeted municipal energy managers, while the second survey focused on specialists who offered support to those involved in the municipality.

Between May and October 2020, online interviews were conducted with energy managers who were responsible for the EMS implementation in their respective municipalities. To promote candid responses, the interviews were conducted anonymously, without any identification of the represented municipality.

The respondents' assessments were quantified based on a scale as given in Table 2.5. To evaluate the quantified results, the arithmetic mean ($\overline{x}$) and standard deviation (s) were calculated for each question. The findings are presented in the results section. Due to the limited dataset, an extensive statistical factor analysis like the one carried out by Marimon and Casadesús [24] was not conducted.

Table 1.1

Scales Used in the Survey and Respective Numerical Values

Quantitative values	Motivation	Challenge	Statement	Change
1	Not important	Not at all	Strongly disagree	Much lower
2	Slightly important	Slightly	Disagree	Lower
3	Moderately important	Moderately	Undecided	About the same
4	Important	Very	Agree	Higher
5	Very Important	Extremely	Strongly agree	Much higher

1.4. Statistical Analysis of Behaviour Change Measures Data

One way to enhance the energy efficiency of buildings and conserve energy is by promoting changes in the energy consumption habits of building users. To assess the potential impact of behaviour change measures on energy consumption, energy-saving competitions were organized in 30 different municipalities across eight European countries as part of the *Compete4SECAP* project. A total of 91 public buildings participated in these competitions. The success of the energy-saving competitions was primarily evaluated using data from two sources. First, during the competition, energy consumption data for all participating public buildings were continually collected. Second, surveys of energy team members were conducted before and after the competition to further evaluate the impact of the energy-saving measures.

Between January and December 2019 (competition period), representatives from local governments recorded monthly heat and electricity consumption ($Q_{competition}$) as well as outdoor air temperature data for each month. This information was then entered into an energy monitoring system. Using a calculation methodology created during the analysis of historical (reference) data, baseline consumption ($Q_{baseline}$) was determined after all the monthly data had been entered.

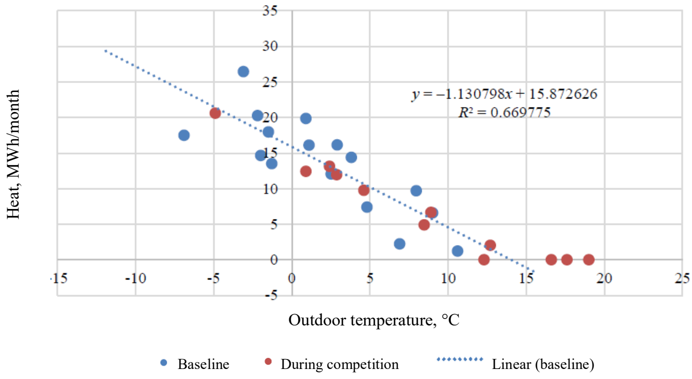

Fig. 1.4. An example of heat energy baseline determination.

The baseline consumption ($Q_{baseline}$) was determined by applying the equation shown in Fig. 1.4, where x represents the outside air temperature. Once $Q_{baseline}$ had been established, the absolute monthly and annual energy savings ($Q_{savings}$) were calculated using Formula (1), based on the energy consumption data collected during the competition period.

$$Q_{\text{savings}} = Q_{\text{baseline}} - Q_{\text{competition}}, \text{ MWh/month} \quad (1)$$

To estimate the total energy savings achieved during the competition period, accumulated energy savings were calculated. This provided participants with a way to monitor their progress and adjust their strategies accordingly. The savings calculation was performed monthly, and the individual monthly energy savings results were summed to determine the cumulative or total savings ($Q_{total\ savings}$) over the entire competition period.

In order to determine the winner of the energy saving competition, $Q_{savings}$ was expressed as a percentage (q_{saving}) using Formula (2):

$$q_{\text{savings}} = \frac{Q_{\text{savings}}}{Q_{\text{baseline}}} \cdot 100, \%. \quad (2)$$

Energy savings expressed as a percentage were used to compare the performance of different buildings, irrespective of their size and type. This approach allowed for fair and accurate comparisons between buildings and ultimately enabled the identification of the winner of the energy-saving competition.

Team representatives from each building were requested to participate in two surveys – one prior to the competition and one after the competition. The primary objective of these surveys was to evaluate the extent to which variations in qualitative variables could account for the discrepancies in performance observed during energy conservation competitions.

The Spearman's rank correlation coefficient (ρs), also known as Pearson's correlation coefficient for rank values, was utilized to evaluate the correlation. The calculation of ρs and testing whether the correlation was significantly different from zero were performed using a function integrated into software R [25].

1.5. Quantitative Data Analysis and Climate Correction

In this study, we analyse the impact of the COVID-19 pandemic on the energy consumption of municipal public buildings in four Latvian municipalities.

To conduct this analysis, we collected and analysed monthly thermal energy and electricity consumption data from a total of 262 buildings (electricity data from 240 buildings). All four municipalities had implemented an energy management system in accordance with ISO 50001:2018, ensuring the systematic collection and compilation of energy consumption data. The data set underwent rigorous quality control procedures, and the results are presented in Table 1.2.

Table 1.2

Summary of Data Set

Building groups	**No. of buildings for heat consumption analysis**	**No. of buildings for electricity consumption analysis**
Administration and office buildings	46	45
Buildings of the cultural establishment	53	49
Schools and educational institutions	47	46
Kindergartens and pre-schools	25	26
Total	262	240

To ensure accurate comparison of heat energy consumption data, a climate correction was applied by normalizing the data against the standard heating season, as indicated by the heating degree days (HDD) indicator. Formulas (3) and (4) show how the climate correction was calculated. In contrast, electricity consumption was not normalized, as it was assumed to be independent of the outside air temperature. The analysis covered a four-year period, comprising data from 2018 and 2019 as the baseline (representing consumption unaffected by the COVID-19 pandemic), and data from 2020–2021.

$$K = \frac{L_{\mathrm{st}} \cdot (t_{\mathrm{ind}} \cdot t_{\mathrm{out.reg}})}{L_{\mathrm{act}} \cdot (t_{\mathrm{ind}} \cdot t_{\mathrm{out.act}})}, \qquad (3)$$

where

K – climate correction coefficient;

L_{st} – standard monthly heating duration, days;

L_{act} – actual monthly heating duration, days;

t_{ind} – average indoor temperature during the heating season, °C;

$t_{\mathrm{out.reg}}$ – standard monthly average outdoor air temperature, °C;

$t_{\mathrm{out.act}}$ – actual monthly average outdoor air temperature, °C.

$$H_K = K \cdot H_a, \qquad (4)$$

where

H_k – climate corrected monthly heat energy consumption, MWh;

K – climate correction coefficient;

H_a – actual monthly heat energy consumption of the building, MWh;

To assess the impact of the COVID-19 pandemic on energy consumption, deviations from a baseline value were analysed by comparing energy consumption in 2020 and 2021 with the baseline value. The baseline value was determined by calculating the average energy consumption of the years 2018 and 2019. As various restrictions were introduced during 2020 and 2021 as a result of the pandemic, these years were used for analysis.

To calculate the deviation from the baseline consumption, Formula (5) was used. This was done by taking the difference between the energy consumption value in the analysed year (2020 or 2021) and the base value, and dividing it by the base value [26]. The result was expressed as a percentage deviation from the baseline consumption. Positive deviations indicated an increase in energy consumption compared to the baseline, while negative deviations indicated a decrease.

$$D = \sum_{i=1}^{n} \left(\frac{\left[E_y - \left(\frac{E_{2018} + E_{2019}}{2} \right) \right]}{\frac{E_{2018} + E_{2019}}{2}} \right), \quad (5)$$

where

D – deviation of the energy consumption during pandemic, %;

E_y – energy consumption in 2020 or 2021, MWh;

E_{2019} – energy consumption in 2019, MWh;

E_{2018} – energy consumption in 2018, MWh;

n – number of buildings.

2. RESULTS

2.1. Sustainable Energy Action Plans in Municipalities

In Latvia, there were a total of 119 municipalities in 2019, out of which 40 had developed sustainable energy action plans (SEAPs). However, it is worth noting that the majority of these plans were created with the assistance of external specialists, primarily as part of EU-funded projects such as *Conurbant, SEAP+, Meshartility*, and *50000&1 SEAP*. These projects provided substantial support for the development of the plans. To gain a deeper understanding of the impact of the SEAPs, an extensive survey was conducted on the municipalities that had developed SEAPs. All 40 municipalities with SEAPs were approached to participate in the survey, but only 11 municipal energy managers or responsible specialists agreed to take part. The goal of the survey was to assess the effectiveness of the SEAPs in achieving their energy efficiency and climate goals.

The survey findings indicate that all municipalities that were surveyed have established CO_2 reduction targets. In addition, most municipalities have also established sector-specific targets. Our analysis shows that the size of a municipality does not seem to have a significant impact on the level of ambition demonstrated in its targets. Furthermore, among the municipalities that have set additional targets, there is a predominant focus on reducing energy consumption in sectors that are directly managed by municipal authorities. For other sectors, information campaigns are planned to motivate individuals to reduce their energy consumption, but without any specific quantitative goals being set.

Upon analysing the availability of data in municipalities, our findings reveal that six out of the eleven surveyed municipalities have conducted assessments of CO_2 or GHG emissions within their jurisdiction. Furthermore, of these, five municipalities state that they renew such assessments regularly. Participants were also asked to evaluate the importance of assessing CO_2 or GHG emissions in developing and implementing SECAP measures. The responses varied, with only two municipalities rating it as "very important," while most rated it as "moderately important." Additionally, data availability emerged as a significant challenge in several municipalities. Two municipalities do not regularly collect data on energy consumption in buildings, and four municipalities collect data for each municipal building separately. In three municipalities, only common data for several buildings are available, while in two municipalities, some buildings have individually collected data while others have only common data. Only half of the surveyed municipalities collect data on energy costs. Respondents also cited human errors and a lack of procedures as the primary challenges in collecting energy consumption data.

Our analysis found that only five of the surveyed municipalities were able to provide specific information regarding the number of individuals directly involved and responsible for the implementation of SEAP. Additionally, only one municipality provided information on the budget allocated for implementing the plan. In other municipalities, the budget is planned within the overall framework of the municipality's development program, with only those measures included in the program receiving funding.

Regarding the establishment of working groups for monitoring and implementing SEAP, ten out of eleven municipalities have created such groups. However, the frequency of meetings among the working group members was generally low.

After conducting an analysis, we found that municipal SEAPs predominantly feature activities related to the renovation of municipal buildings and public lighting. This suggests that municipalities prioritize projects that are directly under their control over other forms of municipal infrastructure.

Effective monitoring is a critical aspect of successful energy management. However, two municipalities indicated that they do not monitor the implementation of SEAP measures. While five municipalities monitor the implementation of SEAP measures, only four municipalities monitor both implementation and effectiveness.

2.2. An Analysis of Climate Adaptation Integration in Six Municipal SECAPs

Six municipalities undertook the development of sustainable energy and climate action plans (SECAPs) and implemented demonstrative climate adaptation activities to move towards climate resilience. To facilitate effective development of the SECAPs, each municipality established a working group consisting of municipal employees with responsibilities related to one of the plan's focus areas. Additionally, public and private sector stakeholders were included in the working groups, and each municipality organized 2–3 stakeholder meetings to engage them in the process. Overall, the development of SECAPs involved 385 interested parties across the six municipalities, with Aguilas involving 61, Alfandega da Fe involving 44, Cartagena involving 69, Lorca involving 45, Mertola involving 70, and Smiltene involving 96 individuals.

The development of the SECAP in each municipality was accompanied by the implementation of a demonstration project to underscore the necessity of adaptation and provide a practical example of how it can be achieved. In addressing the impacts of climate change, Spanish municipalities prioritized the effects of heat and water scarcity, focusing on measures such as creating shade, planting greenery, establishing natural shade, and using treated wastewater for irrigation. Meanwhile, Portuguese municipalities also addressed heat risks through shade creation, as well as the risk of fires by installing water reservoirs. In Latvia, the municipality cleaned and deepened a lake, as well as reconstructed its locks, to mitigate the effects of eutrophication and reduce the risk of flooding in the city centre.

During the development of the sustainable energy and climate action plan, significant attention was given to stakeholder engagement and discussion to raise awareness, educate, and foster public support for adaptation activities. The discussions also included exploring potential measures to address the climate risks. The municipalities used the multi-criteria analysis method to evaluate all measures and selected the most suitable ones. Figure 2.1 provides a summary of the measures selected by the municipalities.

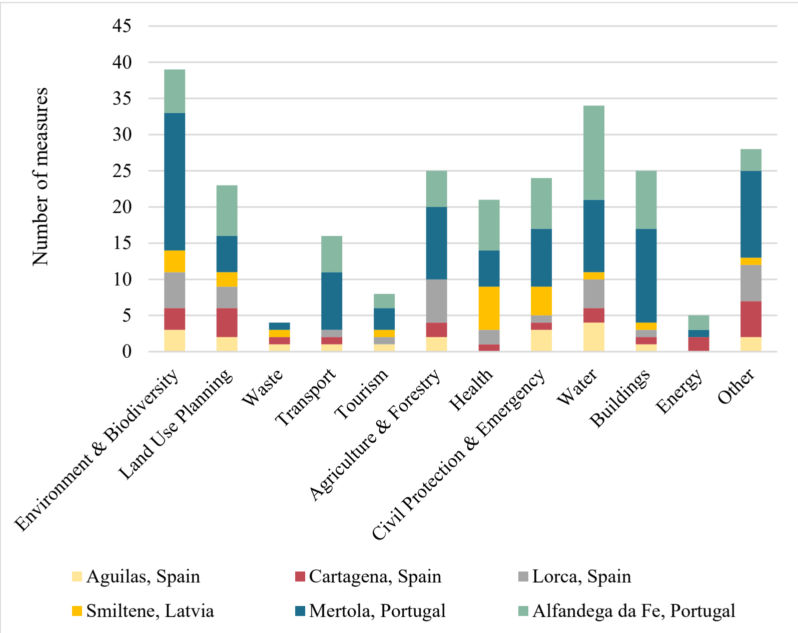

Fig. 2.1. SECAP measures divided by sectors.

The municipalities in Spain and Portugal used nine criteria to evaluate potential climate adaptation measures, whereas the municipality in Latvia employed a simplified analysis consisting of five criteria: effectiveness, urgency, synergy, financial aspects, and legitimacy. These five criteria were formulated in a manner that was easily comprehensible to municipal employees. The working group members were required to answer questions related to each measure, based on the criteria:

- Efficiency: Will the environmental and social benefits of the measure outweigh the financial and environmental costs?
- Urgency: How urgent is it to implement the measure? Measures that are not implemented may lead to environmental and/or financial losses in the near future.
- Practicality (synergy): Is it feasible to integrate the implementation of the measure into the daily work of the municipality, the existing budget, and planned activities? Measures that are difficult to integrate may require changes in existing municipal structures, such as the creation of a new department or new positions.
- Financial aspects: Is the implementation of the measure financially intensive, or would additional funding be required?
- Sustainability (legitimacy): Is the measure sustainable and aligned with the county's environmental, social, and development policies?

The municipality of Smiltene opted not to assign different weights to the criteria in order to simplify the application of the method. However, assigning different weights to each criterion is desirable to obtain a more objective result by evaluating the importance of factors. It is also recommended to make the multi-criteria analysis questionnaire easy to fill and to ask representatives of various local government institutions to fill it in to reduce the bias of opinions.

Figure 2.1 shows that the focus of each municipality differs. Most of the measures are aimed at improving the environment and biodiversity, water supply, and the building sector. All municipalities have included measures for the development of blue-green infrastructure, indicating their desire to develop a sustainable urban environment.

2.3. Implementation of the Energy Management System, Case Study

The municipality of Daugavpils formulated and implemented the sustainable energy action plan (SEAP) in 2015 and 2016, while simultaneously introducing an energy management system (EMS). The analysis of the EMS implementation process was divided into four phases, which are sequentially discussed below.

Stage 1: Motivation of the Municipality to Develop EMS (and SEAP)

Between 2010 and 2014, the city of Daugavpils undertook the renovation of several public buildings, primarily educational institutions. However, upon completion of these renovations, the anticipated energy savings were not achieved. This realization highlighted the need for a more comprehensive approach to address energy efficiency issues in the city.

Stage 2: Setting EMS (and SECAP) Boundaries and Targets

The EMS was initially developed to encompass a broad range of municipal assets, including 100 buildings, public street lighting consisting of 9,183 lamps spanning 351 km, and public transport, which included 90 vehicles serving 32 bus and 3 tram routes. In its first year (2016), the municipality established relatively achievable objectives, such as implementing and certifying the EMS system, identifying ten buildings with the highest specific energy consumption, and analysing consumption patterns and user behaviour to identify opportunities for energy savings. In addition, targets were set for the street lighting and public transport sectors, although limited historical data required the initial collection and analysis of monthly energy consumption data. Quantitative energy-saving and emission-reduction goals were established for subsequent years, starting in 2017.

Stage 3: Starting and organizing the EMS implementation process

The EMS planning and implementation process involves three main steps: developing manuals and procedures, assigning responsible individuals, and organizing training for employees involved in the process. Although the ISO 50001 standard does not mandate the development of a manual, municipalities often experience high turnover rates or may not have a proper system in place for retaining essential knowledge and information. In these cases, developing a manual can help ensure continuity in system maintenance and proper operation in the long run.

Stage 4: Monitoring and evaluation of the implementation process, including communication between departments and other stakeholders during implementation

Prior to the implementation of the EMS in Daugavpils, energy consumption data for municipal buildings were only collected at a building level, primarily for billing and accounting purposes. The flow of energy consumption data and costs prior to the EMS implementation are illustrated in Fig. 2.2.

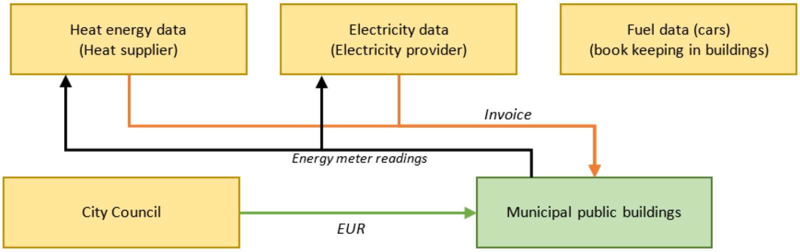

Fig. 2.2. Energy consumption data management system in Daugavpils municipal buildings before implementing EMS.

After implementing the EMS, the flow of information was improved and expanded to include central collection of data, which is regularly analysed (as shown in Fig. 2.3). As a result of analysing the collected data, feedback is provided to those responsible for building management in cases of deviation. Annual reports on the implementation of EMS and SEAP are also generated and presented to the working group and decision-makers.

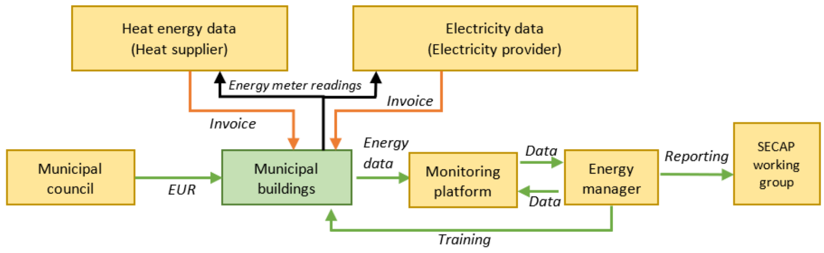

Fig. 2.3. Energy consumption data management system in Daugavpils municipal buildings after implementing EMS.

The methodology for determining the priority buildings in which the largest energy savings can be achieved is illustrated in Fig.e 2.4. This approach involves categorizing all buildings into four groups based on their total energy consumption and specific energy consumption, with heat energy data analysed for this purpose. The group boundaries are established according to the municipality's objectives and the current state of the buildings. The boundary lines (indicated by red dashed lines in Fig. 2.4) are placed as close to the lower-left corner as possible in order to select as many buildings as necessary. If certain buildings exhibit markedly different indicators than the rest, limiting the visualization of data from a sufficient number of buildings, the selection process can be carried out in multiple rounds. Once the selection is complete, the municipality provides feedback to those in charge of the chosen buildings and develops annual reports on the EMS and SEAP implementation, which are presented to decision-makers and the working group.

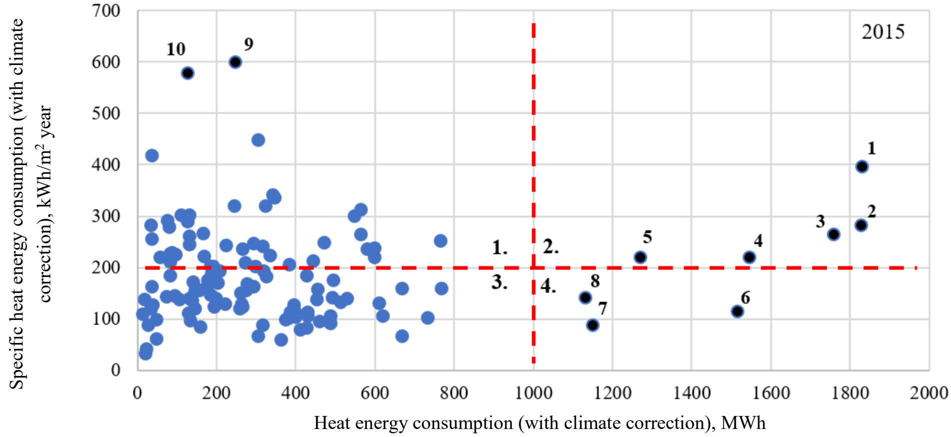

Fig. 2.4. Heat energy consumption at 123 municipal buildings of the city of Daugavpils in 2015.

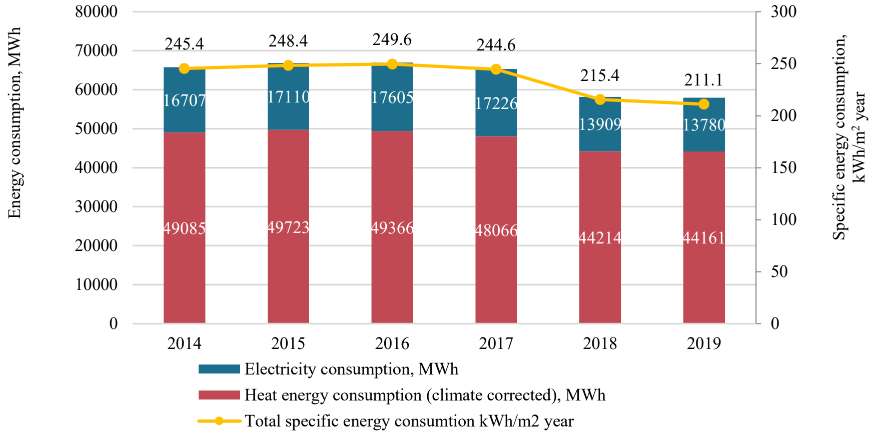

Fig. 2.5. Total energy consumption of 123 municipal buildings in Daugavpils (in 2014 and 2015 only partial historical data are available and energy consumption was higher).

Since the implementation of EMS in 2016, the heat energy consumption of all 123 buildings has decreased by 12 %, which translates to 5.2 GWh in 2019, according to the data with climate correction, as shown in Fig. 2.5. Furthermore, the electricity consumption in 2019 was 8 % lower than in 2016. It is important to note that complete energy consumption data is only available from 2016, which accounts for the increase in energy consumption between 2014 and 2016 due to gaps in the historical data for 2014 and 2015.

The municipality of Daugavpils city allocates around EUR 5.5 to 6 million annually for the provision of heat energy and electricity in municipal buildings. However, following the implementation of EMS and energy efficiency measures in 2019, the total energy costs decreased by 8 % compared to 2016, despite the increased price of electricity during this period. These significant savings demonstrate the effectiveness of the measures taken to improve energy efficiency.

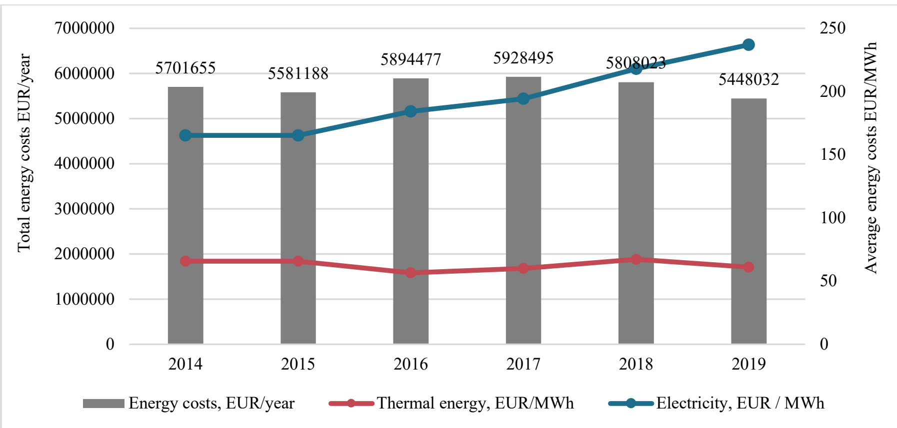

Fig. 2.6. Energy costs in 123 municipal buildings in the city of Daugavpils.

Based on the data provided by the energy manager, the implementation of EMS incurred a cost of approximately EUR 12 thousand for the municipality of Daugavpils, which was fully paid off within a year (refer to Fig. 2.6). This indicates the cost-effectiveness of the EMS implementation in achieving significant energy savings.

2.4. Enhancing Climate Neutrality Objectives of Local Governments through Behavioural Change Measures

The energy saving competition results are evaluated at three levels: buildings, municipalities, and countries. To enable a fair comparison of savings achieved by buildings of different sizes and types, the savings are expressed as a percentage. It is noteworthy that the analysis excluded buildings of three countries where data quality failed to meet the competition regulations. The study analysed data from 61 buildings in Croatia, France, Hungary, Latvia, and Spain, where reliable data were collected and the planned methodology for data analysis was followed. The thermal energy data analysis relied on 43 buildings, while accounting for 18 buildings that did not consume thermal energy.

Table 2.1

Changes in Heat Energy Consumption Compared to Baseline Heat Energy Consumption

n	Average	Median	Standard deviation	Max	Min
43	–6.7 %	–4.5 %	16.8 %	23.6 %	–39.8 %

The findings revealed an average reduction of heat consumption by 6.7 %, which is consistent with the results of previous studies. However, a high standard deviation of 16.8 % was also observed (refer to Table 2.1). It is important to note that the maximum value of the dataset showed a 23.6 % increase in heat consumption, while the minimum value indicated a decrease of 39.8 % in heat consumption. These significant variations in the data indicate that some buildings have achieved substantial energy savings, while others have experienced an increase in heat consumption.

The electricity consumption data of 61 buildings were analysed and the summarized results can be found in Table 2.2.

Table 2.2

Changes in Electricity Consumption Compared to Basic Electricity Energy Consumption

n	Average	Median	Standard deviation	Max	Min
61	–7.6 %	–7.5 %	12.6 %	23.9 %	–34.8 %

During the energy saving competition, the electricity consumption of buildings was reduced by an average of 7.6 %. Although the standard deviation was lower than that observed for heat consumption, it was still relatively high at 12.6 %. The results of the energy saving competition, presented in Table 2.3, showcase the changes in energy consumption (i.e., combined heat and electricity) in absolute terms for each of the five countries.

Table 2.3

Net Electricity and Heat Savings in the Year of the Saving Competition

Country	**$n_{electricity}$**	**Net electricity savings**	**n_{heat}**	**Net heat savings**	**Change in energy consumption**
Croatia	12	32.8 MWh	8	122.0 MWh	–5.5 %
France	12	220.3 MWh	11	122.0 MWh	–7.4 %
Hungary	10	131.5 MWh	10	260.2 MWh	–9.9 %
Latvia	15	55.9 MWh	14	163.6 MWh	–8.1 %
Spain	12	194.2 MWh	-	-	–6.8 %
Kopā	61	631.9 MWh	43	761.2 MWh	–8.4 %

After the energy saving competition, a survey was conducted to gather feedback from the energy team members of the participating buildings. A total of 134 valid questionnaires were collected from 52 buildings, which accounted for 57 % of all the participating buildings. Spearman's rank correlation coefficient was calculated to measure the correlation between the changes in electricity and heat consumption and the survey scores separately. Each correlation was tested to determine if it was significantly different from zero. The results of the analysis suggest that changes in electricity consumption had a stronger correlation with changes in user behaviour compared to changes in heat consumption. Therefore, the results of the survey can be considered reliable indicators of changes in user behaviour during the competition.

2.5. Impact of the Covid-19 Pandemic on Energy Consumption in Municipal Buildings

The energy consumption trends in municipal buildings vary greatly between municipalities and different types of buildings. As shown in Fig. 2.7, the results indicate that while electricity and heat energy consumption decreased in most buildings, there were a significant number of buildings in which energy consumption did not decrease or even increased during 2020 and 2021. On average, electricity consumption decreased by 12.1 % and heat energy consumption decreased by 3.6 % in 2020.

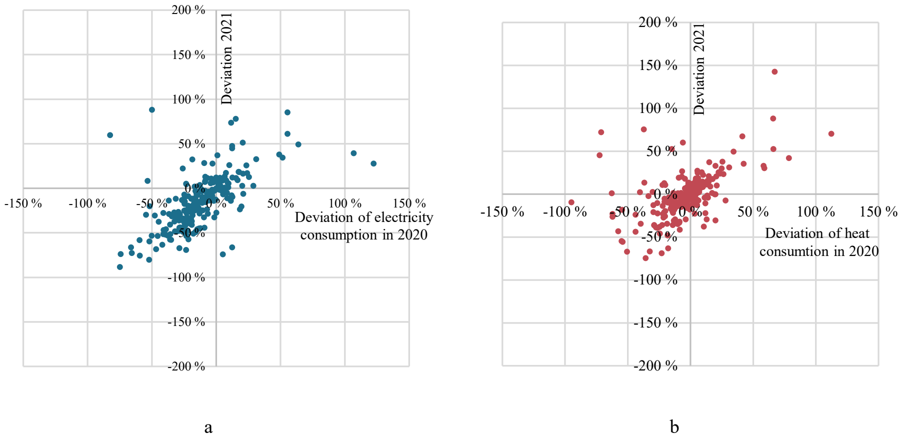

Fig. 2.7. a) Deviations in heat and b) electricity consumption data in municipal buildings in 2020 and 2021, compared to baseline (mean consumption of 2018 and 2019), %.

The impact of COVID-19 restrictions on electricity consumption was greater than on heat energy consumption, as shown by the lower average deviation of energy consumption for electricity. However, there were still a significant number of municipal buildings where energy consumption increased by more than 20 %, and it is important to conduct a detailed analysis to determine the reasons behind these changes.

The analysis of monthly electricity consumption data reveals that in schools and other educational institutions (46 buildings), the total heat energy consumption decreased by 5.5 % in 2021 and by 5.3 % in 2020 compared to the baseline. The highest reduction in consumption was observed in April and October 2020, with a decrease of 23 % and 28 %, respectively. In pre-school educational institutions (53 buildings), the heat energy consumption decreased by 9 % in 2020 and by 2 % in 2021 compared to the baseline. In administrative and office buildings (47 buildings), however, the total heat energy consumption increased by 8 % in 2021 and by 3 % in 2020 compared to the baseline. The only exceptions were March and October 2020, when heat energy consumption decreased by 2 % and 4 %, respectively. In other months, heat energy consumption increased on average by 1 % to 22 %. The total heat energy consumption in cultural institutions' buildings (25 buildings) also increased by 4 % in 2021 and by 3 % in 2020 compared to the baseline. It would have been anticipated that the energy consumption in cultural institutions would have decreased at least to the same extent as in schools, given the suspension of all gatherings in both types of establishments as a result of the Covid-19 restrictions.

Upon analysing the electricity consumption data, it is evident that the reductions in electricity usage are notably more substantial. Specifically, in schools and educational institutions, there was a decrease of 19 % in 2020 and 29 % in 2021. The most significant decreases occurred in April and May 2020 when these establishments were closed during the first wave of COVID-19, with reductions reaching 59 % and 62 %, respectively, compared to the baseline (as depicted in Fig. 2.8). Overall, the data from 2021 demonstrates a significant reduction in all months during which national COVID-19 restrictions were enforced.

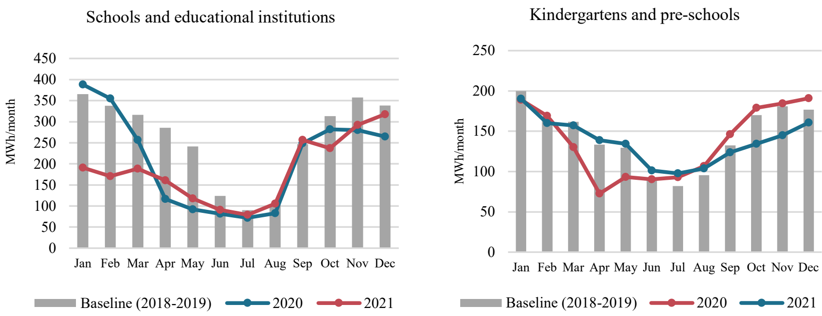

Fig. 2.8. Electricity consumption in schools and educational institutions and in kindergartens and pre-schools, MWh/month.

Meanwhile, a substantial decline in energy consumption was witnessed in pre-school educational institutions during the first wave of Covid-19, wherein electricity consumption decreased by 19 % in March, 46 % in April, and 28 % in May compared to the baseline (refer to Fig. 2.8). The second period where a significant decrease was observed was in October and November 2021, with electricity consumption decreasing by 21 % and 20 %. In total, from 2020 to 2021, the overall electricity consumption reduced by an average of 4 % compared to the baseline.

The consumption variations are relatively smaller in administration and office buildings, with total electricity consumption showing a decline of 8 % in 2020 and 11 % in 2021 compared to the base level. As for the buildings of cultural institutions, electricity consumption decreased by 9.4 % in both 2020 and 2021 compared to the base level, but the most significant reduction in consumption was observed in March 2020 (21 %) and April 2020 (32 %).

2.6. Implementation of the Energy Management System in Municipalities in Europe

The study examined 28 municipalities in the European Union that planned to implement a certified energy management system with support from *Compete4SECAP* project. Of these, 20 had implemented and obtained EMS certification according to the ISO 50001 standard, representing 71 % of all municipalities (with two more almost completing the certification process when this study was conducted). The energy consumption in these municipalities totalled 187 GWh and fell within the limits of the energy management systems. A year after implementing EMS, total energy consumption had already decreased by 15 GWh. The implementation process resulted in significant energy savings, demonstrating that EMS implementation stimulates savings and enables those in charge to identify areas of the municipal infrastructure with high potential for energy savings.

According to the data collected from 20 municipalities that had already implemented the energy management system (EMS) following the ISO 50001 standard, a total of 92 specific energy efficiency measures were planned. Among these, 55 % were technical measures, 30 % were related to organizational and institutional measures, and 15 % were focused on educational measures.

At the conclusion of the project, a survey was conducted among municipal energy managers and specialists who worked with the participating municipalities. Of the respondents, 83 % were energy managers from municipalities that had already obtained an energy management certificate. When asked if they believed their municipality would pursue re-certification of the energy management system, 21 % responded with an affirmative, while 47 % answered that they were most likely to do so. This indicates that two-thirds of the municipalities involved in the project view EMS as a long-term investment with significant benefits.

The primary reasons for the introduction of EMS in these municipalities were project support, better data collection on energy consumption, energy savings, reduction in energy costs, and reduction in greenhouse gas emissions. In addition, several respondents cited motivating factors such as raising awareness among decision-makers and colleagues, prioritizing investments in energy efficiency measures, and setting an example for sustainable management practices.

The surveys conducted after the implementation of EMS identified several challenges, including the acquisition of historical data and monthly data monitoring, which can make it difficult to motivate and create awareness among responsible municipal employees. Other challenges included the lack of financial and human resources and ensuring the involvement of top management for the implementation of measures. The need to ensure cooperation between different municipal departments was also mentioned as a major obstacle to overcome.

However, despite these challenges, 74 % of the consultants who provided support to municipalities during the project believed that achieving energy goals in these municipalities was possible or very possible. Furthermore, 74 % of municipalities had set moderately ambitious energy goals after the introduction of EMS.

CONCLUSIONS

1. Developing sustainable energy and climate action plans is a critical first step towards achieving energy and climate goals. However, simply developing a plan does not guarantee successful implementation of the measures and achieving the desired goals. Often, municipalities rely on external experts to analyse data and develop a plan, which limits the involvement of municipal employees and can hinder plan implementation. Creating cooperation between various municipal departments and structural units is one of the significant challenges in developing a sustainable energy and climate action plan. Therefore, it is essential to hold multiple working group meetings during the plan development phase to discuss the critical aspects of the current situation, data analysis results, potential measures, goals, and

responsibilities distribution. Additionally, frequent communication is crucial to promote municipal employees' understanding of climate neutrality and climate resilience issues.

2. The European Union's climate policy now emphasizes both climate change mitigation and adaptation. As a result, it is essential to incorporate adaptation aspects into municipal energy planning. However, measuring the benefits and effectiveness of adaptation measures can be challenging, as they often cannot be expressed in terms of savings or emission reductions. To address this issue, a multi-criteria measure selection method has been developed. This method enables the assessment of the benefits of measures in relation to their costs, thereby providing a useful tool for evaluating adaptation measures.
3. The unique nature of climate change adaptation measures poses additional challenges to effective communication within municipalities and with different societal groups. It is essential to involve a broad range of stakeholders in the process of developing the adaptation plan to increase understanding and garner support for the implementation of measures by both municipal employees and the public.
4. To test the impact of behaviour change measures on the energy consumption of buildings, energy saving competitions were organized in 61 municipal buildings across European municipalities. The systematic implementation of behaviour change measures resulted in an average reduction of 7.6 % in electricity consumption (61 building) and a 6.7 % reduction in heat energy consumption in 43 buildings. These results demonstrate the significant impact of building users' habits on the building's energy consumption indicators.
5. Building upon the findings of the Doctoral Thesis, a comprehensive approach (as illustrated in Fig. 2) has been developed to facilitate the systematic implementation of measures outlined in the sustainable energy and climate action plan across municipalities. As of September 2022, the approach is being implemented in 44 EU municipalities within the framework of the *OwnYourSECAP* project.
6. The analysis of energy management system implementation in Latvian and European municipalities, both qualitatively and quantitatively, indicates that EMS is an effective tool for municipalities to significantly improve their energy management practices and to undertake systematic measures towards achieving their climate neutrality goals. The introduction of EMS in Daugavpils city municipality resulted in a 12 % reduction in heat energy consumption in municipal buildings over a period of three years. Among the 28 EU municipalities studied, some were able to achieve energy savings of up to 10 % in the first year itself. The total energy consumption of the infrastructure covered by the EMS in these municipalities was 187 GWh, and a reduction of 15 GWh was achieved within a year without any major investments. In terms of management, the implementation of EMS provides several important benefits such as the development of a clear and detailed system with well-defined responsibilities, precise procedures for data collection and processing, and planning and implementation of energy-saving

measures. This enables the easy identification of municipal infrastructure with high potential for energy savings.

7. The impact of COVID-19 restrictions on energy consumption in municipal buildings was studied, and it was found that in some buildings, energy consumption did not decrease but even increased, indicating poor management practices. For instance, in cultural institutions, there was an average increase of 4 % in heat energy consumption in 2021 and 3 % in 2020, while in office and administration buildings, heat energy consumption increased by 8 % in 2021 and by 3 % in 2020. However, periodic declines in electricity consumption were observed, which were related to pandemic restrictions. It is important to evaluate the building's base energy consumption and its usefulness when the building's occupancy does not significantly affect its energy consumption.
8. Starting from August 2022, municipalities in Latvia are required to implement energy management systems to promote the systematic improvement of energy efficiency in their infrastructure. As found in this research, implementation of EMS is expected to result in significant energy savings and a return on investment within one year. As such, this practice can serve as a valuable example for other European countries looking to enhance their energy efficiency strategies.
9. The hypothesis presented in the thesis has been verified: the adoption of an energy management system indeed facilitates the establishment of cyclic and systematic measures related to climate and energy in the daily operations of the municipality. This finding highlights the effectiveness of energy management systems as a means of promoting sustainable practices and reducing energy consumption in local governance.

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