UNIVERSITY OF MISKOLC
FACULTY OF ECONOMICS

HANTOS ELEMÉR BUSINESS AND REGIONAL SCIENCES DOCTORAL SCHOOL

ADRIENN TAKÁCSNÉ PAPP

THE ROLES AND OPPORTUNITIES OF LOCAL MUNICIPALITIES IN THE ENERGY TRANSITION

THESES OF PH.D DISSERTATION

Miskolc, 2024

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Miskolc, 2024

CONTENT

1 SUMMARY OF THE RESEARCH OBJECTIVE

The European Union aims to reduce greenhouse gas emissions to net zero by 2050. Cities are responsible for more than 75 per cent of global greenhouse gas emissions (Melica et al., 2018). 80 per cent of the EU's population lives in cities, a proportion that is expected to rise further by 2050 (Eurostat, 2022).

More and more mayors recognise the responsibility of local municipalities in the fight for climate protection and commit their municipalities to greenhouse gas emission reduction targets. Although Hungary's National Energy and Climate Plan mentions the importance of localism, detailed information on this area still needs to be included (NEKT, 2020). Municipalities reduce this information gap joining the Covenant of Mayors for Climate and Energy. It is the largest association of European local authorities, founded in 2008. Thanks to its methodology, it helps its members develop and operate sustainable energy management at the municipal level, including energy transition, in the long term. Within two years of adhesion, members elaborate a Sustainable Energy and Climate Action Plan (SECAP), which assesses their baseline energy situation, their carbon dioxide (CO_2) or greenhouse gas (CO_{2eq}) emissions and, on this basis, formulates the measures that will enable them to achieve their minimum 40% emission reduction target by 2030. Transforming the initial energetic characteristics of municipalities by increasing energy efficiency and energy savings and using renewable energy sources will play a key role in achieving the mitigation targets (Bertoldi et al, 2018 a-c.).

In this doctoral thesis, energy transition is defined as the energy transformation and associated socio-economic changes by 2050, with 2030 as the first milestone. This research examines the roles and opportunities of local governments in the energy transition through the Sustainable Energy and Climate Action Plans (SECAP) of municipalities that are members of the Covenant of Mayors for Climate and Energy. The aim of this thesis is not to assess the credibility of the documents examined but rather to provide an analytical framework based on the principles of the SECAP methodology, which can be used to give a municipality-level energy picture and to assess the timeliness, scale and consistency of efforts in sustainable energy management and greenhouse gas emission reduction.

This is a novel approach to the topic. To my knowledge, no doctoral thesis has yet attempted to map the relationship between local municipalities and energy transition in Hungary based on SCEAP documents.

2 EMPIRICAL BASIS AND METHODOLOGY OF THE RESEARCH

Local municipalities and self-governance are institutions and a philosophy that embraces the stakeholders (citizens, industry, NGOs, churches) living and working in the municipality's jurisdiction. Therefore, analysing local authorities' role in the energy transition and the opportunities this change offers them can extend beyond a narrow definition of local municipality. This doctoral thesis explores the roles and opportunities of local municipalities in the energy transition through the Sustainable Energy and Climate Action Plans (SECAP) of municipalities that are members of the Covenant of Mayors for Climate and Energy. Subsection 2.1 summarises the literature sources that underpin the research, subsection 2.2 presents the conceptual model of the study and the framework for the analysis, subsection 2.3 describes the process of defining the study population and sample, and subsection 2.4 describes the chosen methodology.

2.1. LITERATURE REVIEW

Substantial literature research preceded the formulation of the research questions and hypotheses. Some of the sources deal with the conceptualisation of energy transition. According to the literature we can distinguish technological (Hirsh and Jones, 2014; Miller et al., 2013; Fouquet and Pearson, 2012; Smil, 2010; Eames et al., 2013 in. Bartiaux et al., 2019; Bridge et al., 2013; Urban Innovative Action, 2015 in Antal et al., 2018; Grubler, Wilson and Nemet, 2016; Liao et al., 2021) and political approaches (e.g. several EU laws, such as the EU's climate and energy policy framework for the period 2020-2030, the legislation helping to create the Energy Union, the EU's cohesion policy, the Renewable Energy Directive 2018/2001, the Energy Efficiency Directive 2018/2001, the European Green Deal) to energy transition. For this study, energy transition is defined as the energy transformation and associated socio-economic changes by 2050, with 2030 as the first milestone, the frontier of my analysis. The success of the global and EU's climate goals can only be achieved with effective cooperation between Member States and sub-national actors, such as local municipalities, and international climate and energy organisations. This is called effort sharing, which is a strategic frame for the institution of multi-level climate governance. The second phase of the literature search explored the specificities of multi-level climate governance. It established a link with the topic of the doctoral thesis, e.g. based on the works of Economidou et al. (2022), Melica et al. (2018), Salvia et al. (2021), Fuhr et.al. (2018). The most prominent of the climate and energy organisations that support municipalities is the Covenant of Mayors for Climate and Energy. This doctoral thesis focused on the national municipalities working with this organisation. The characteristics and functioning of the organisation are described in Berghi et al. (2016), Bertoldi et al. (2018d.), Cipriano et al. (2017), Croci et al. (2018), Dolge and Bumber (2021), Kona et al., (2018), Martire et al. (2018), Pablo-Romero et al. (2018), Pasimeni et al. (2019), Rivas et al. (2021a-b.), Salvia et al. (2021), Reckien et al. (2018, 2019).

Energy and energy management are needed to perform and operate local municipalities' compulsory and voluntary tasks, but to a varying extent, depending on the area. The exploration of the specificities of energy management of local municipalities was mainly supported by Holczreiter, Papp and Simon (2015), Ács et al. (2019), Mezei (2011), Bertoldi ed. (2018c.), the electronic list of competencies of local municipalities 2022, several EU calls for proposals, the National Energy and Climate Plan and Energy Strategy of Hungary, and the review and processing of about 40 pieces of legislation.

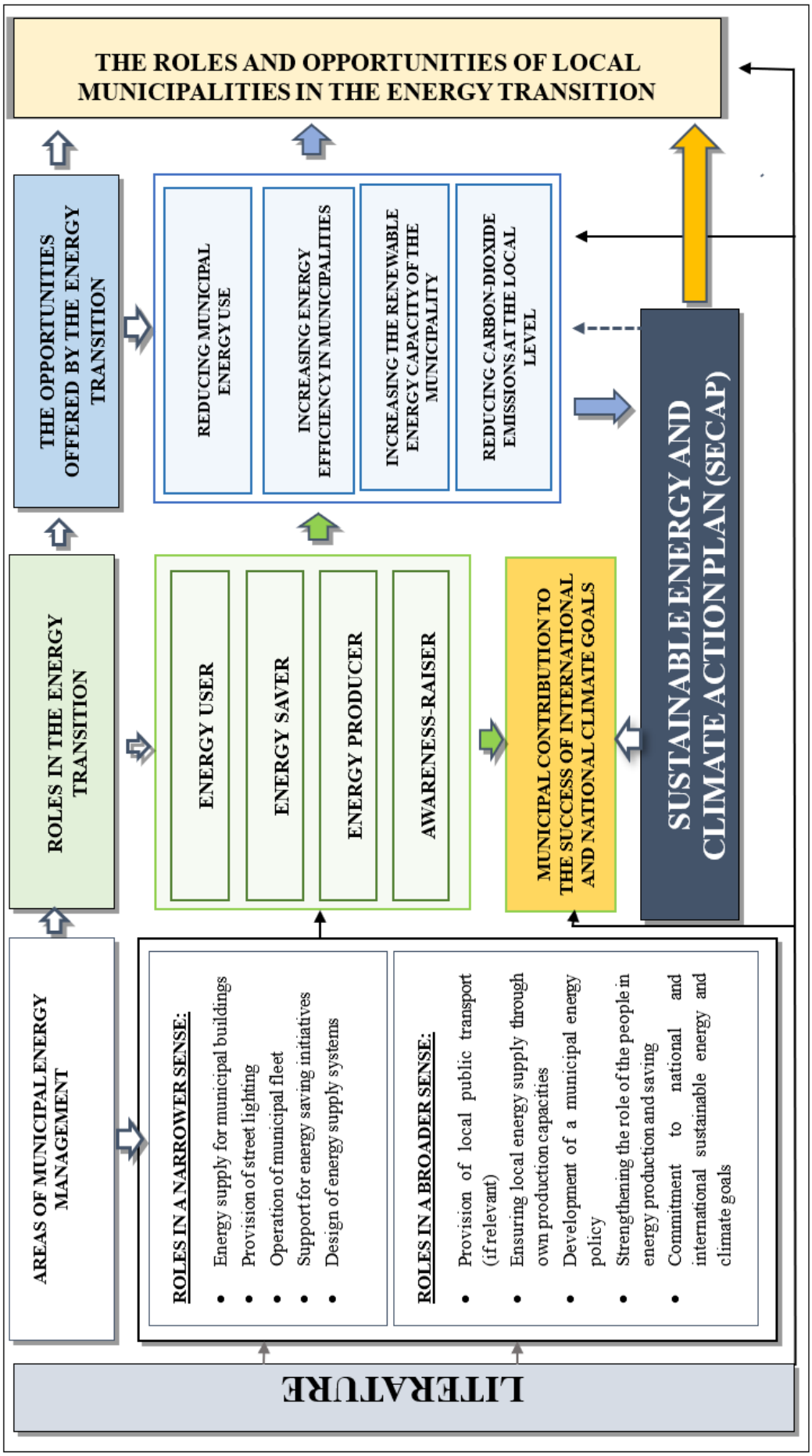


Figure 1. The roles and opportunities of local municipalities in the energy transition

Source: own elaboration

Based on the literature reviewed, I have developed a framework summarising municipalities' roles and opportunities in the energy transition (Figure 1).

The compulsory tasks of local municipalities are listed in the electronic list of competencies of local governments, available on the Government's website. The list contains a sectoral breakdown of tasks, the territorial level responsible for their preparation (capital, town with a county's rights, town, large village and village), the person responsible (mayor, notary, board, etc.) and the relevant legislation. The documents municipalities must draw up may also include energy management elements, such as the urban development concept, the economic development programme, and the environmental programme. The latter is directly linked to energy management in municipalities.

Energy management tasks can be interpreted more narrowly and broadly based on a review of the literature and the legislative background. In a narrower sense, this includes the energy supply of areas defined as mandatory tasks in Act CLXXXIX of 2011 on Local Governments in Hungary (Mötv) (e.g. municipal institutions, buildings), the provision of street lighting, the maintenance of the municipal vehicle fleet, support for energy saving initiatives and the installation of energy production equipment in municipal-owned properties. The conditions for performing the public tasks designated by the Municipalities Act and the tasks voluntarily undertaken by the municipalities are regulated by sectoral laws dependent on the territory and indirectly determine energy use.

In a broader sense, through their municipal-owned public service enterprises (e.g. district heating, electricity generation through solar parks, energy production projects), municipalities can play a role in providing energy to residential users and businesses and other organisations, in providing local public transport (where relevant), in regulating municipal transport, in raising the energy awareness of the population, and in possibly promoting energy saving subsidy schemes. Based on their commitment, they can also join various sustainability and energy efficiency efforts (e.g. Covenant of Mayors), which can include reducing the environmental burden associated with energy use (e.g. reducing carbon-dioxide or greenhouse gas emissions). This is summarised in the local energy policy and strategic framework of the municipality, which the energy management systems can significantly assist in place. The broader tasks are more loosely defined in legislation, with targets typically set by national or county-level strategies providing the basis for action.

In addition to the mandatory documents, municipalities can prepare planning documents that express their commitment to the development of their municipality, to community values, or their involvement in the fight against climate change. An example is the Sustainable Energy and Climate Action Plan (SECAP). In these documents, municipalities can set out goals and plans that influence the energy characteristics of the municipality and its stakeholders and move it towards a more sustainable, greener, energy-efficient operation.

Local authorities, through their narrow and broader functions, can play four possible roles: energy user, energy saver, energy producer, and awareness-raiser. They can take advantage of the opportunities offered by the energy transition.

Overall, the research is based on processing nearly 300 sources, including books, journal articles, internet sources, legislation, and SECAP documents.

2.2. CONCEPTUAL MODEL OF RESEARCH - FRAMEWORK FOR ANALYSIS

Figure 2. summarises the general framework of the research, the sources of data collection, the logical relationship between the research questions and the hypotheses, and the expected outcomes of the research.

According to the literature review, I sought to identify and analyse the roles and opportunities of local municipalities in the energy transition in Hungary and to answer the following research questions:

1. What characterises local authorities' commitment to achieving local and international climate goals?
2. What is the situation regarding municipalities' baseline energy use and energy mix in the SECAP documents?
3. Are there patterns in the commitments made by municipalities for 2030 regarding the timeframe of the planned actions and the scale and modalities of the commitments?

The results of this dissertation will contribute new and novel findings to research on the relationship between sustainability, climate change and energy management in municipalities in three areas:

1. the current extent and importance of local municipalities' commitment to national and international climate goals, particularly to the energy transition,
2. an exploration of the initial energy management situation of local municipalities (comparison at the municipal level),
3. a comparison of the timing of the measures planned by local municipalities, the specificities of the planned measures, and their consistency in responsibilities is needed.

In addition to the relevant literature, the data collection was based on the Covenant of Mayors for Climate and Energy's website, the Hungarian Central Statistical Office, the tender portal, Hungarian and EU legislation, and the available Sustainable Energy and Climate Action Plans (SECAP). Six hypotheses are linked to the three research questions that aim to explore municipalities' roles and opportunities in the energy transition.

Table 1. presents literature sources presenting international experiences with Sustainable Energy and Climate Action Plans prepared by local municipalities and the research questions and hypotheses formulated based on these sources.

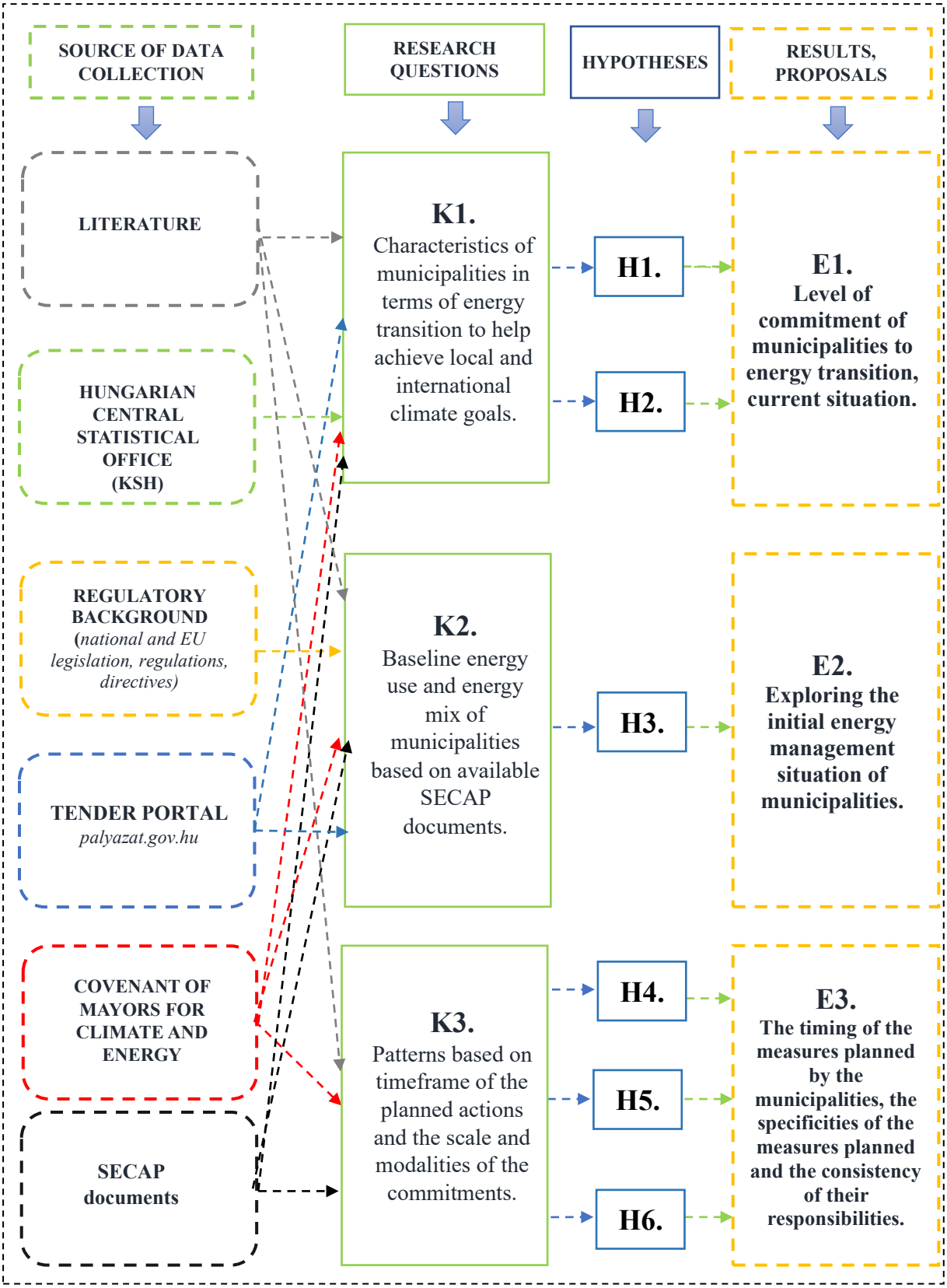


Figure2. Conceptual framework for research
Source: own editing

Table 1.

Summarising the research questions and the literature sources underpinning the hypotheses

Kutatási kérdés	Hipotézis	Főbb források
Q1. What characterises local authorities' commitment to achieving local and international climate goals?	**H1.** Besides increasing environmental awareness and energy efficiency, funding availability has boosted municipalities' willingness to join the Covenant of Mayors for Climate and Energy.	Reckien et al. (2018), Rivas et al, (2021a.), Kona et al. (2018), Reckien et al. (2019)
	H2. Larger municipalities have joined the Covenant of Mayors for Climate and Energy individually, while smaller municipalities have joined as a group. The date of adhesion follows the hierarchy of municipalities according to their legal status. The economic and social well-being of the municipalities influences the willingness to join.	Reckien et al. (2018), Rivas et al, (2021a.), Kona et al. (2018), Reckien et al. (2019)
Q2. What is the state regarding the initial energy use and mix of municipalities based on the SECAP documents?	**H3.** Municipalities that chose an earlier year to assess their baseline situation had less favourable energy characteristics (lower renewable share, higher per capita energy use) than those that chose a later baseline year.	Rivas et al. (2021a.), Reckien et al (2019), Croci et al. (2018), Pablo-Romero et al. (2018), Berghi et al. (2016), Pasimeni et al. (2019), Reckien et al. (2019), Dolge and Bumber (2021)
Q3. Based on the commitments made by municipalities for 2030, are there any patterns in terms of the timing, scale and consistency of efforts to reduce greenhouse gas emissions?	**H4.** Based on the date of adhesion and the selected baseline years, the municipalities and groups of municipalities show different behaviours in planning their mitigation objectives.	Martire et al. (2018), Cipriano et al. (2017), Reckien et al. (2019)
	H5. The characteristics of the emission reduction commitment are determined by the baseline annual greenhouse gas emission, the municipality's energy mix and status, and the time remaining until the target year.	Martire et al. (2018), Cipriano et al. (2017), Reckien et al. (2019),
	H6. Municipalities' narrower and broader role in energy management is crucial in the fight against climate change. When planning the area-specific reductions in their mitigation action plans, they have a realistic sense of the extent of their direct intervention potential and expect the municipal actors to take a more significant share of the planned measures.	Rivas et al. (2021. a-b.), Cipriano et al. (2017), Reckien et al. (2019), Croci et al. (2018), Pablo-Romero et al. (2018), Berghi et al. (2016), Pasimeni et al. (2019), Reckien et al. (2019), Dolge and Bumber (2021)

Source: own edition

2.3. DEFINITION OF THE STUDY POPULATION AND SAMPLE

The study population and sample were defined in a secondary survey from January 1, 2019, to January 1, 2023. This was assisted by a list of members (individual and group members) and a free word search on the Covenant of Mayors for Climate and Energy (CoM) website.

The association first addressed the cities; later, smaller municipalities were allowed to join in a group (associate) form. As of 01 January 2023, Hungary has 98 individual municipalities and 36 groups of municipalities, representing 1,087 municipalities, or 34.21% of Hungarian municipalities. With 36.56 per cent of the country's territory, a significant share of its population (50.19 per cent) and 51.71 per cent of the housing stock, the accession settlements will, in the future, benefit a significant part of the country.

The process of defining the study population is illustrated in Figure 3.

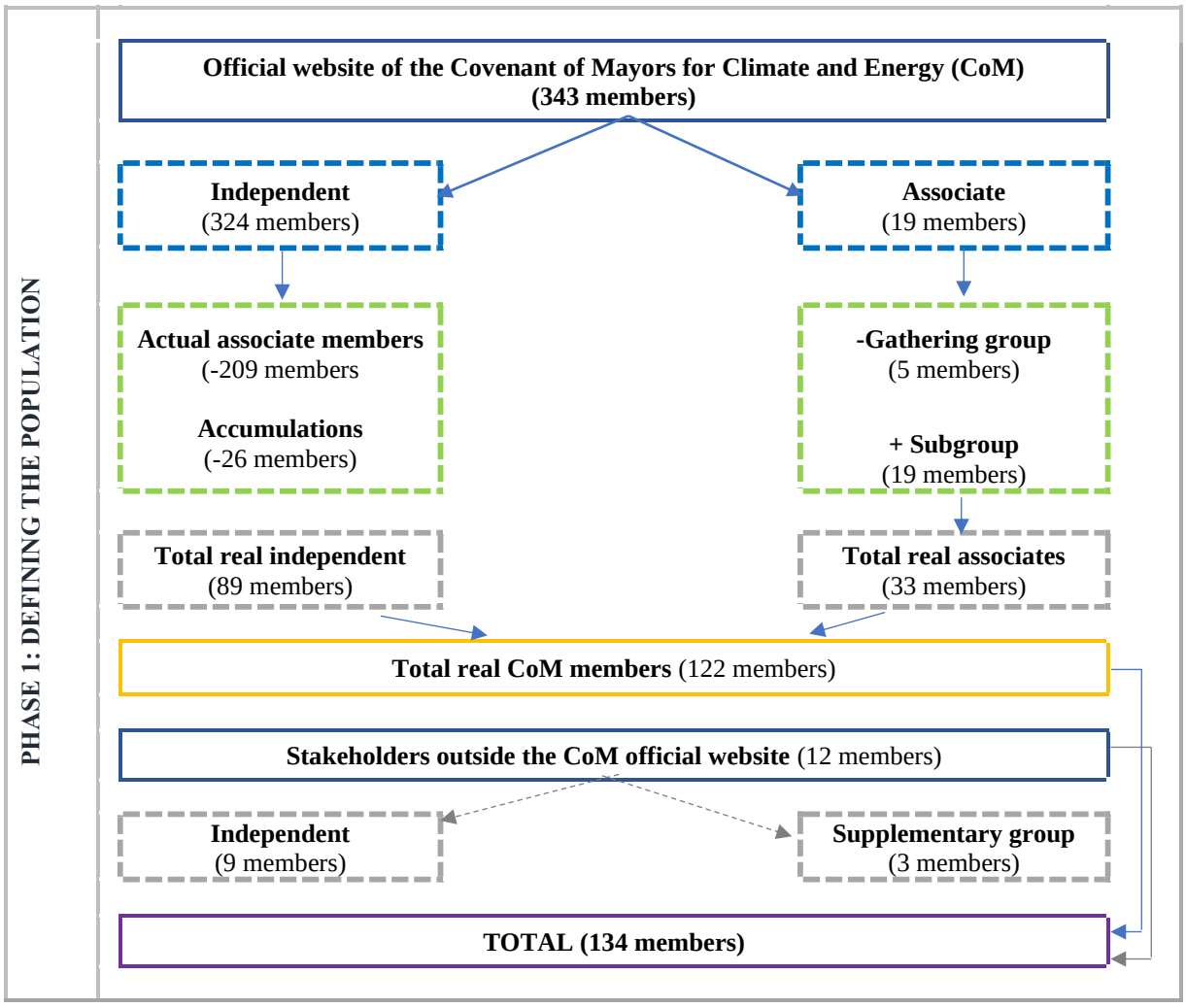


Figure 3. The process of defining the study population
Source: own edition

The 343 members on the CoM website included 19 associates and 324 individual members. Following a data cleaning process, the details of which are described in chapter 4.1.1 of the thesis, 122 real CoM members were identified, and 12 more were identified through an internet

search. This resulted in 134 members, of which 98 were individual and 36 were associate members.

The study focused on individual municipalities, capital districts, and local LEADER action groups. The research annualized those municipalities and groups with an accessible SECAP document.

The process of defining the study sample is illustrated in Figure 4.

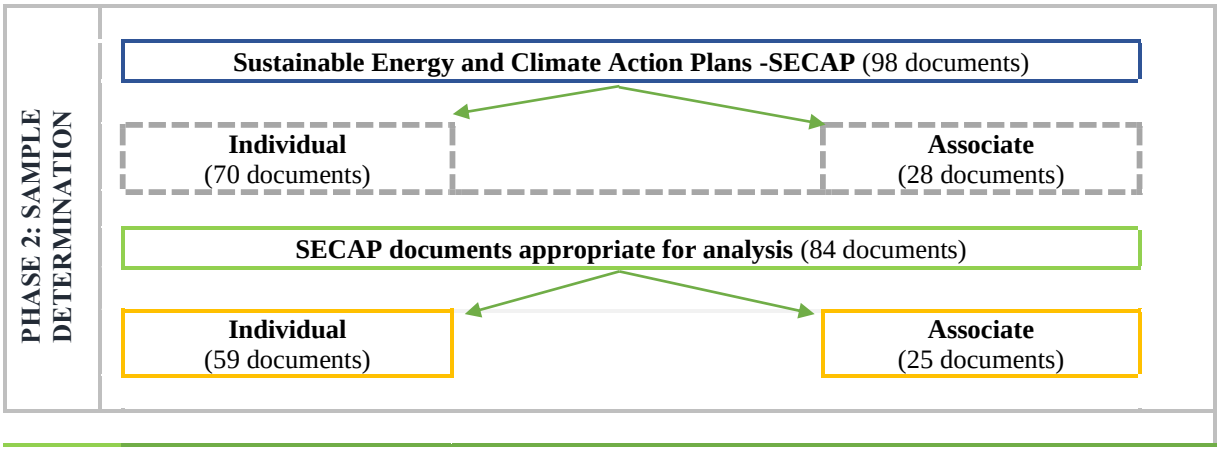


Figure 4. Process for determining the sample to be tested
Source: own edition

One primary data source for the research was the SECAP documents produced by the members of the Covenant of Mayors. The SECAP documents consist of a text report and an Excel spreadsheet. The text documents provide a concise, synthesised presentation of the municipality's initial energy and climate situation and the improvements and emission reduction targets to be achieved by 2030. Of the two documents, the Excel Annex provides detailed information on energy use, associated greenhouse gas emissions, and mitigation targets for the area.

A major research limitation was the lack of existing SECAP documents, especially Excel spreadsheets. As a result, only 98 of the 134 CoM members had action plans available, and 84 had action plans suitable for analysis. In the end, the study sample consisted of 84 SECAP documents. The detailed process of defining the study sample is described in chapter 4.1.2 of the thesis.

2.4. PRESENTATION OF THE CHOSEN METHODOLOGY

Based on the literature review, I formulated three research questions and six related hypotheses. Table 2 outlines the methodology used to investigate the research questions and hypotheses.

Table 2.
Summary table of research questions and methods used to test hypotheses

Research question	Hypothesis	Methods
K1.	H1.	Document analysis, descriptive statistical tools
	H2.	Document analysis, Pearson correlation coefficient, descriptive statistical tools
K2.	H3.	Document analysis, Pearson correlation coefficient, descriptive statistical tools
K3.	H4.	Document analysis, cross-tabulation analysis (Chi-square test, Cramer-V coefficient), descriptive statistical tools
	H5.	Document analysis Pearson correlation coefficient, cross-tabulation analysis (Chi-square test, Cramer-V coefficient), Non-parametric analysis (Mann-Whitney U test), graphical data summarisation methods, hierarchical clustering (Ward's method, squared Euclidean distance), descriptive statistical tools
	H6.	Secondary research, literature analysis, analysis of variance (ANOVA), Bonferroni post-hoc test, descriptive statistical tools

Source: own editing

The result of this research is a complex database of well-structured nominal, ordinal, categorised metric and numerical variables, and an analysis of the roles and opportunities of municipalities in the energy transition.

3 NEW AND NOVEL FINDINGS OF THE THESIS

After the presentation of the research framework based on the literature, the next and most crucial step of the research was to test the hypotheses, formulate the doctoral thesis based on the results and finally answer the research questions. This provided a complex picture of the role and opportunities of local municipalities in the energy transition, i.e. how and to what extent the Hungarian municipalities can contribute to the fulfillment of national and international climate goals, including the energy transition, by 2030 by changing their energy situation, based on the SECAP documents. The next three sub-chapters present the new and novel findings of the research in the order of the research questions. Subsection 3.1 first answers what characterises municipalities in terms of their commitment to energy transition to help achieve local and international climate goals (Q1-H1, H2). Subsection 3.2 describes the situation regarding municipalities' baseline energy use and energy mix based on the SECAP documents (Q2.-H3.). Finally, subsection 3.3 presents the results on the timeframe for implementing the municipalities' 2030 commitments, their extent and modalities, and their consistency with the competencies (Q3.-H4, H5, H6).

3.1 COMMITMENT OF LOCAL MUNICIPALITIES TO ENERGY TRANSITION THAT SUPPORTS SUSTAINABILITY AND CLIMATE OBJECTIVES - Q1

The EU and Covenant of Mayors member municipalities consider the Sustainable Energy and Climate Action Plans (SECAPs) one of the most effective tools for achieving sustainability and climate objectives. The short and long-term measures set out in the documents create the potential for achieving the energy transition at the municipal level. By answering research question Q1, we got a general picture of the extent and form of the commitment of Hungarian municipalities to the EU targets (timing and prevalence of adhesion to the CoM) by 1 January 2023 and the circumstances that have helped this commitment to spread.

Q1. What characterises local authorities' commitment to achieving local and international climate goals?

Based on the literature review by Reckien et al. (2018), Rivas et al. (2021a.), Kona et al. (2018), Reckien et al. (2019), I formulated the following statement in Hypothesis H1:

H1. Besides increasing environmental awareness and energy efficiency, funding availability has boosted municipalities' willingness to join the Covenant of Mayors for Climate and Energy.

To test hypothesis H1., I first presented the evolution of the association's membership each year (see Figure 5). By 1 January 2023, Hungary had 98 independent municipalities and 36 groups of associate municipalities, which represents 1,087 municipalities, 34.21% of the total number of municipalities.

Figure 5 shows the evolution of the number of municipalities joining the Covenant of Mayors on an annual and cumulative basis between 2009 and 2022.

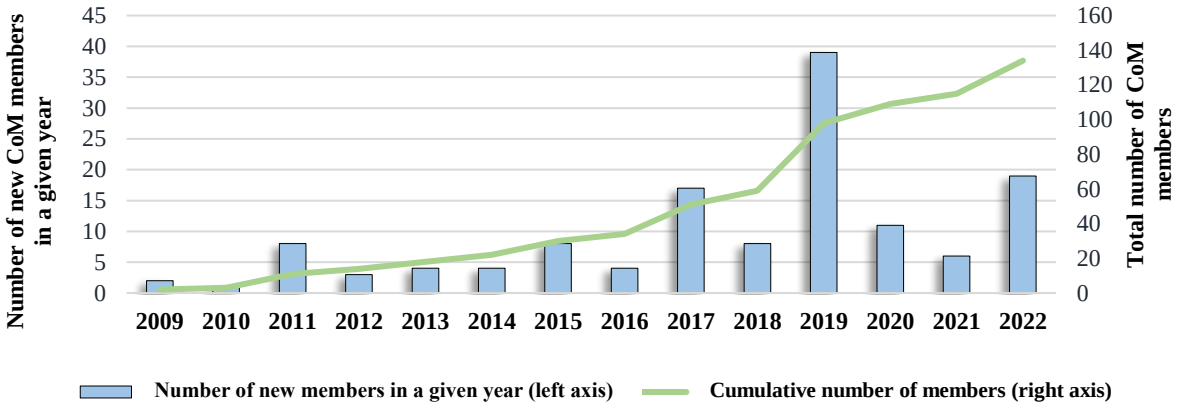


Figure 5. Evolution of the number of municipalities joining the Covenant of Mayors between 2009 and 2022

Source: own calculation and editing based on CoM and additional data

The graph shows that the number of subscribers has increased since 2014. The peak year was 2019 when the number of new entrants reached 39. In 2022, the Association grew to 12 individual and 7 associate members.

After analysing the number of joined municipalities, the research sought to determine whether the emergence and growth of tendering opportunities had contributed to the intensification of connectivity. Reports on the evaluation of tendering cycles (KPMG, ÁSZ) and my data collection on palyazat.gov.hu illustrated the role of tendering opportunities, which included data on some 3,737 municipal tenders.

The three tendering cycles between 2004 and 2020 have allowed municipalities to become more energy-conscious in their planning and management. Several energy investments and production facilities have been built during this period thanks to the funding provided. We are now in the fourth funding cycle (2021-2027), which will provide additional funding for energy improvements and financial support for preparing SECAP documents. Based on the analysis of the completed and available documents, 67 of the 134 CoM members have prepared their action plans for projects. At the same time, 67 of them could not identify the project involvement due to a lack of information or SEAP/SECAP documents.

The fourth programming cycle is expected to see a higher increase in the number of connections compared to the first three programming cycles. This is reinforced by the fact that the existence of SECAP documents and the achievement of the objectives set out in them may be a condition for access to the funds that will be announced later. Based on the co-movement between the evolution of the number of accessions by year and the emergence of targeted funding, I have accepted hypothesis H1 and formulated the following thesis.

T1. Municipalities have taken advantage of opportunities to improve their energy management in the last three closed programming cycles, and their activity has increased with the opportunities. The schemes announced relieved the municipalities' budgets. In addition to the commitment to energy transition and climate protection, financial considerations have also played a role in stimulating the uptake of connections.

In the second part of the analysis, I sought to find out whether there is a pattern between the form of adhesion, the date of adhesion and the legal status and socio-economic characteristics of the municipality in Hungary. In Hypothesis H2., I formulated three propositions based on the studies of Reckien et al. (2018), Rivas et al. (2021a.), Kona et al. (2018), Reckien et al. (2019).

H2. Larger municipalities have joined the Covenant of Mayors for Climate and Energy individually, while smaller municipalities have joined as a group. The date of adhesion follows the hierarchy of municipalities according to their legal status. The economic and social well-being of the municipalities influences the willingness to join.

Related to the first part of hypothesis H2 ***("Larger municipalities have joined the Covenant of Mayors for Climate and Energy individually, while smaller municipalities have joined as a group")***, I examined the forms of adhesion by municipalities' legal status.

Table 3 shows the forms of joining by traditional legal status for the 1087 municipalities in the Covenant.

Table 3.
Form of adhesion by legal status of settlements (N=1087)

Type of adhesion	Capital district	Village	Town with a county's rights	Large village	Town	Total
Individual (%)	100	2,45	100	2,44	34,82	**9,02**
Associate (%)	0	97,55	0	97,56	65,18	**90,98**
Total (%)	**100**	**100**	**100**	**100**	**100**	**100**

*Baja is taken into account as a town with county's right.

Source: own editing and calculation based on CoM, KSH and relevant county data

Table 3 shows that the capital districts and towns with county's rights joined the organisation independently. At the same time, smaller settlements, such as villages and large villages, preferred to join the organisation as associates. The towns (n=112) showed a greater diversity. A higher proportion, 65.18 per cent, were associated members and 34.82 per cent joined independently. In addition, it was confirmed that municipalities with a larger population joined the organisation individually, while municipalities with a smaller population joined as a group. Overall, 90.98% of the Hungarian municipalities that joined the organisation preferred to join as associates.

To verify the second part of H2 ***("The date of adhesion follows the hierarchy of municipalities according to their legal status.")***, I examined the evolution of the average year of adhesion by the legal status of municipalities, treating the associated accessions as a separate category (Table 4).

Table 4.
Average year of adhesion by the legal status of municipalities and associated members

The legal status of municipalities and associated members	Average year of adhesion
Town with a county's rights	2016,55
Town	2017,15
Village	2018,05
Capital district	2018,08
Associate	2018,92
Large village	2019,00
Average of all connected members	**2017,78**

Source: own editing, based on CoM and own collection

The analysis shows that the towns with county's rights were the earliest to join the organisation (average year of joining: 2016.55), followed by towns, then villages (2018.05) and capital districts (2018.08). The average year of towns, large villages and villages that joined in associate form was 2018.92. Within the surveyed population, Nyírbogát was the only large village[1] to join in 2019. If the villages and large villages are treated as one, the average adhesion year changes to 2018.53. This confirms that the date of adhesion followed the hierarchy of legal status, i.e. larger municipalities joined the initiative earlier than smaller ones.

The third part of H2 states, ***"The economic and social well-being of the municipalities influences the willingness to join."*** The economic and social well-being of the municipalities was considered based on two indicators: the complex indicator defined in Government Decree 290/2014 (26.11.2014) and the average GDP per capita. The former was only available at the district level, while the latter was only at the county level, thus providing a more generous picture, contrary to the initial intention. Thus, the results should be assessed taking this research limitation into account.

At the county level, the most willing to join were the municipalities of Veszprém, Szabolcs-Szatmár-Bereg, Komárom-Esztergom, Borsod-Abaúj-Zemplén and Bács-Kiskun counties. While it is true that 100 and 99.4 per cent of the municipalities in the two counties with the lowest complexity indicators, Szabolcs-Szatmár-Bereg and Borsod-Abaúj-Zemplén, respectively, joined the Covenant of Mayors, the coverage of the other counties varies widely. The evolution of average GDP per capita shows a more dispersed picture. Szabolcs-Szatmár-Bereg is also one of the counties with one of the lowest average values. Based on the Pearson bivariate correlation coefficient, at a significance level of α=5%, no statistically significant relationship can be found between the prevalence of connection (the ratio of municipalities connected from the county to the total number of municipalities in the county) and the average GDP per capita (p=0.640) and the value of the complex indicator (p=0.971). The results show that the socio-economic situation of the county does not influence the prevalence of connection.

Based on the results of the study, I partially accepted hypothesis H2 and formulated the following thesis:

T2. One way local authorities are committed to energy and climate goals is by joining the Covenant of Mayors for Climate and Energy. Larger municipalities (capital districts, town with a county's rights, towns with a larger population) have made a formal commitment to the energy and climate targets earlier. Smaller municipalities (smaller towns, villages, large villages) joined the CoM later, typically by exploiting the synergies of the association. The average socio-economic well-being indicators for the counties do not show a statistically significant relationship with the prevalence of joining.

These T1 and T2 are relevant mainly to the joined municipalities. From this point of view, I have examined to what extent the results can be considered representative regarding legal status if the total population is considered all municipalities in Hungary. On this basis, the municipalities that joined the Covenant of Mayors for Climate and Energy are roughly representative of Hungarian municipalities regarding legal status. The towns with a county's rights and the capital districts are minimally over-represented in the sample. The difference in

[1] Erdőkertes is the largest municipality in Hungary, with 8771 inhabitants. According to Section 20 (2) of the Mötv., *"The title of large municipality may be used by those municipal self-governments which had the title of large municipality at the time of the entry into force of the Act and which have at least 3,000 inhabitants."* Thus, there is no substantive difference between municipalities and large municipalities for this analysis.

absolute terms is 10 districts for the metropolitan districts and only one for a town with a county's rights.

3.2 FINDINGS ON THE INITIAL ENERGY SITUATION OF MUNICIPALITIES - Q2

The SECAP methodology, developed by the Covenant of Mayors for Climate and Energy, will help municipalities develop sustainable mitigation measures in the future, starting with identifying the municipality or group of municipalities' baseline energy situation. In research question Q2 and the related hypothesis H3, I investigated how municipalities' initial energy use and energy mix can be characterised based on available SECAP documents. The results refer to members (n=84) with an assessable SECAP document.

Q2. What is the state regarding the initial energy use and mix of municipalities based on the SECAP documents?

The expected level of emission reductions will be set in line with EU targets. The first step in identifying the necessary measures is to assess its members' energy mix by area and energy source. I formulated the H3 hypothesis based on the work of Rivas et al. (2022), Reckien et al. (2019), Croci et al. (2018), Pablo-Romero et al. (2018), Berghi et al. (2016), Pasimeni et al. (2019), Reckien et al. (2019), Dolge and Bumber (2021), for the initial energy situation of municipalities.

H3. Municipalities that chose an earlier year to assess their baseline situation had less favourable energy characteristics (lower renewable share, higher per capita energy use) than those that chose a later baseline year.

A key element of emission reduction strategies is the time to implement them. Municipalities have chosen 16 different baseline years between 2005 and 2020 to assess their initial characteristics. Two years stand out in terms of the distribution of years: 2011 and 2014, which highlight two impacts, a so-called census impact and a project impact. The 2011 census gave a comprehensive picture of the municipalities, providing a reliable starting point for many members to assess their energy use in the baseline year and compile their baseline emissions inventories. The 2011 baseline year was selected by 25 of the 84 members, representing 29.76% of the sample surveyed. Thus, the choice of the baseline year was influenced by the availability of census data so that the census effect could be valid. 2014 is another important milestone in the accession process, as the 2014-2020 application cycle started this year. This period can be considered as a period of targeted energy investments. The 2014 baseline year was chosen by 13 members, representing a share of around 15.48%. Therefore, the choice of the baseline year was influenced by the availability of funding and the so-called project effect. The other baseline years were spread around an average year of 2012.5 (σ=4.8).

To analyse the initial energy state, I first analysed the energy mix of the municipalities. In the doctoral thesis, a ternary plot diagram (Figure 6) illustrates the energy mix of each type of municipality, broken down by energy source. The values of the axes are plotted along the grid lines. The right leg of the triangle (along the horizontal grid line) shows the share of district heat and electricity, i.e. energy coming from the grid, the left leg (along the grid line from the left side of the triangle towards the right vertex) shows the share of renewable energy, and the

bottom of the triangle (along the grid line from the right side of the triangle towards the bottom left vertex) shows the share of fossil energy[2].

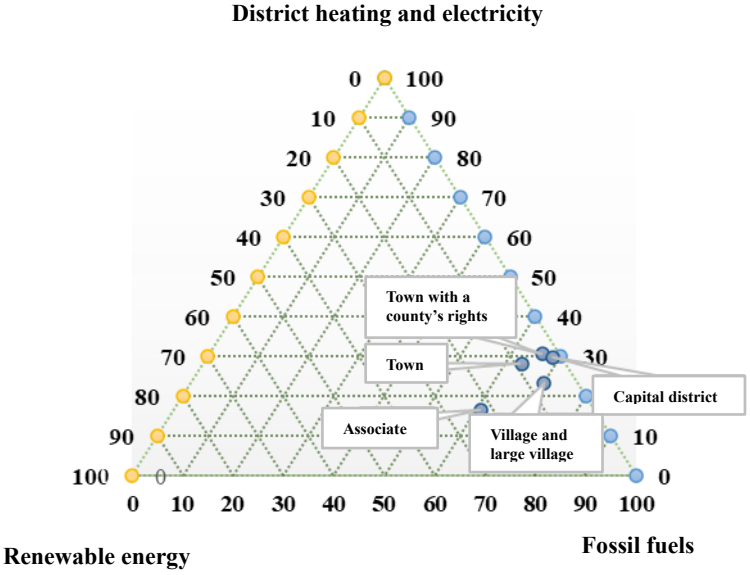


Figure 6. Breakdown of energy sources used by legal status in the year of the BEI
Source: own calculation and editing based on SECAP data

The data reflect the national average in the distribution of all five legal statuses, with an average share of fossil fuels of 64.98%. The highest shares of district heating and electricity in the presence of district heating are in the towns with a county's rights (30.51%), the capital districts (29.78%), and the towns (28.2%), 23.39% in the case of villages and large villages, and 16.57% in the case of associated municipalities.

The share of renewables in the energy mix varies across the five groups, with a significantly lower overall weight than the other two energy uses. The share of renewables is highest in the associated members, reaching 22.47%; in cities, it is only 8.64%; in municipalities, 6.63%; in county towns, 3.44%; and in metropolitan districts, only 1.53%. These ratios can largely be explained by the fact that the total energy consumption of the members is 100 per cent, which is the sum of the energy consumption of different areas[3]. For those members where public transport is also present, the share of renewable energy sources will be lower if we discuss diesel buses or trams.

Four possible energy mix combinations could be identified depending on the energy used in the sample: those containing only electricity and fossil fuels, those containing electricity and fossil fuels plus district heating, those containing electricity, fossil fuels and renewable energy, and those containing electricity and fossil fuels plus district heating and renewable energy. A detailed analysis of these initial energy mix types, broken down by legal status category, is presented in Chapter 5.2 of the doctoral thesis.

To verify the statement in H3, I examined the per capita energy use of municipalities as a function of the chosen base years. Per capita energy use helped to filter out differences in size between municipalities.

[2] Unfortunately, due to incomplete data reporting, it was impossible to fully describe exactly what subdivision fossil energy covers for each member.

[3] The SECAP methodology considers municipal, residential, and tertiary sector buildings and transport as key Covenant sectors. Their data collection is mandatory. Occasionally, members also measure the energy use of industries not covered by the EU ETS, but this is not mandatory and therefore not common.

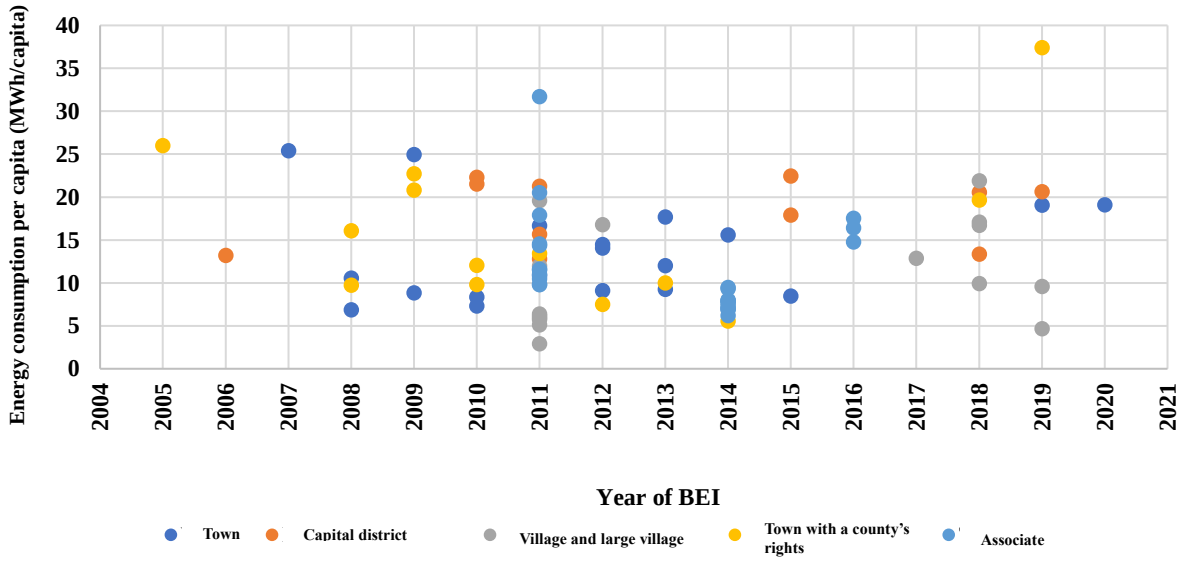


Figure 7. Energy use per capita by baseline (BEI) year
Source: own edition

Figure 7 shows that the municipalities choosing the same base year's specific energy use show a varied pattern and that the earlier BEI does not show higher specific energy use. The Pearson correlation coefficient calculation also did not confirm the relationship between the base year (BEI year) and specific energy use at the 5% significance level (p=0.577).

In addition to energy use, I also examined renewable energy use per capita. In this case, there is no clear pattern that the previous base year represents a worse energy situation in terms of renewable energy use. In fact, the energy mix of one municipality joining in 2005, one in 2006 and one in 2007 already included renewable energy.

In summary, fossil fuels dominate the municipalities' initial energy mix, with an average share of 64.98 per cent. The percentage distribution of electricity, district heating, and renewable energy varies by status, with renewables predominating in the case of associated municipalities. The early baseline year does not explain the lower share of renewables and specific energy use.

Based on the results of the study, I reject hypothesis H3 and formulate the following thesis:

T3. Despite the time interval of almost 15 years, the selected baseline year does not affect the municipalities' baseline energy use characteristics. The municipalities that choose an earlier baseline year do not have a lower renewable share or higher specific energy use than their later counterparts.

3.3 FINDINGS ON THE COMMITMENTS OF LOCAL AUTHORITIES - Q3

Municipalities or groups of municipalities make a mitigation commitment to meet national and Community climate targets based on a baseline emissions inventory. The Covenant of Mayors expects signatories that join after 2015 to achieve at least 40 per cent emission reductions. The mitigation measures in the SECAPs aim to increase energy efficiency, but renewable energy production also plays an important role in ending dependence on fossil fuels. Municipalities have a dual role to play in this process: on the one hand, as the primary coordinator, they must formulate a long-term mitigation strategy for their municipality together with its stakeholders, and on the other hand, as an active player, they must take decisive steps to reduce their energy use and thus their emissions and to improve their environment.

In research question Q3 (related hypotheses H4, H5, and H6), I asked whether there were patterns in the timing, scale, and consistency of efforts made by municipalities based on their 2030 commitments.

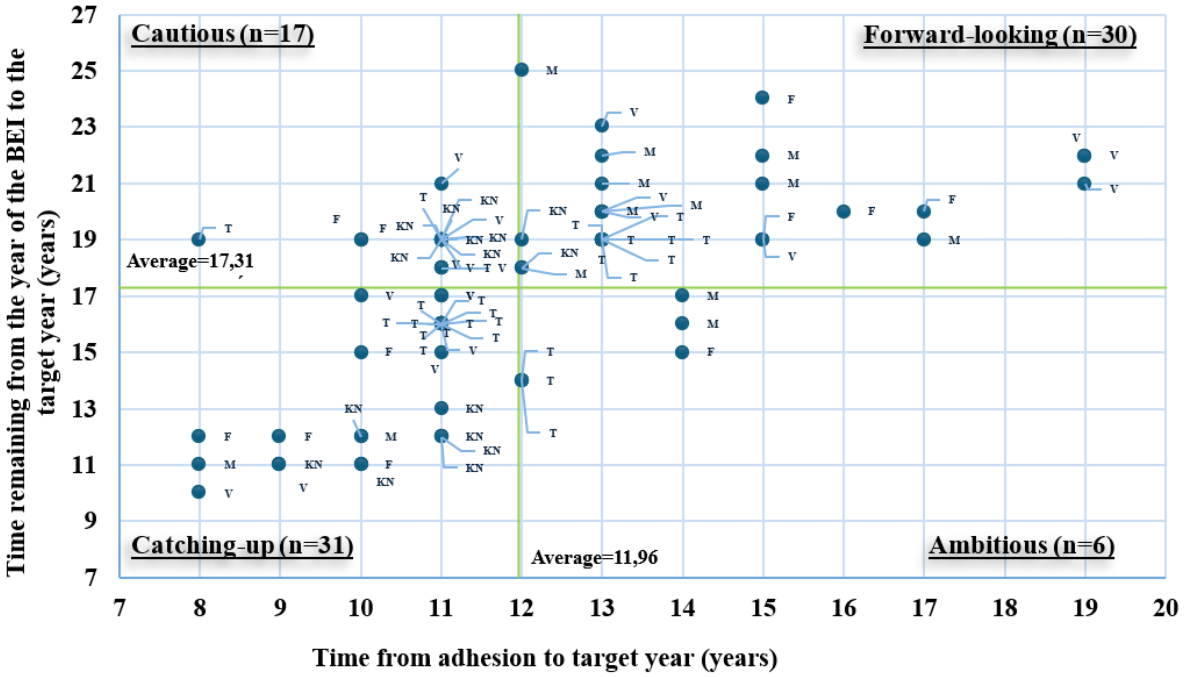
Q3. Based on the commitments made by municipalities for 2030, are there any patterns in terms of the timing, scale and consistency of efforts to reduce greenhouse gas emissions?

As we have seen earlier, the initial energy endowments of a municipality or group of municipalities are significant in determining the path toward the emissions reduction target. However, members have a wide margin of discretion when choosing the base year for the initial energy assessment. The SECAP methodology only specifies that it should be a year close to 1990, but if no data are available, members should choose a base year that ensures continuous data collection and subsequent time series comparisons (Bertoldi ed, 2018b.). In examining the identification of emission reduction behaviours, I formulated the following proposition based on the literature work of Martire et al. (2018), Cipriano et al. (2017), and Reckien et al. (2019).

H4. Based on the date of adhesion and the selected baseline years, the municipalities and groups of municipalities show different behaviours in planning their mitigation objectives.

The timeframe for achieving emission reductions is determined by two factors: the difference in years between the target year, in this case, 2030, and the year of accession, i.e. how many years earlier the municipality or group of municipalities joined the CoM compared to 2030, and how many years they have to implement their planned measures (the difference in years between 2030 and the year of the BEI). On average, the surveyed members (n=84) joined the CoM in 2018 (2018.04), while their base year was set at 2013 (2012.69) on average, meaning that members joined on average 11.96 years earlier than the target year (2030), while they have an average of 17.31 years to implement their actions. Four groups were identified based on the averages: cautious, forward-looking, ambitious and catching-up.

The quadrant diagram in Figure 8 illustrates the relative position of each group. The catching-up group joined later than the average and planned less time to implement their measures. However, do not go back to much earlier years for the BEI to ensure that they will achieve their goals, but commit to achieving them within a relatively short timeframe. There is a high reduction potential in their case, and improvements may already be underway (the average BEI year is 2016, with a standard deviation of 2.4). The cautious ones joined later than the average but took longer to achieve their goals, so they chose a much earlier baseline year to assess their initial state (BEI year 2011 on average; standard deviation 0.659). In their case, the earlier baseline year reflects investments already underway or started, contributing to achieving the commitments set. Forward-looking typically joined the alliance earlier than the average and took more time than the average to implement their plans (BEI year 2010 on average; 1.736 standard deviations). In the sample studied, they took the first step in the fight against climate change, with energy measures as an essential pillar. Group members are assumed to have relied more on their plans than on projects already underway or completed. Ambitious municipalities joined the organisation earlier than average but took less time than average to implement their plans (BEI year 2015 on average; 1.3 standard deviations), so they chose a later base year to assess their baseline.



*Legal status of the municipalities: M: town with county's rights, V: town, KN: village, large village, F: capital district, T: associate

Figure 8. Behaviour categories based on timeframe for achieving emission reductions

Source: own calculation and editing

Within the cautious group, villages and large villages dominate (41.2%); within the forward-looking group, towns with county's right (30%); and within the catching-ups and ambitious groups, associate members (35.5% and 50%, respectively)[4].

To better understand the characteristics of the municipalities, I used a cross-tabulation analysis to compare the relationship between the four categories and the groups by legal status. Although the cross-tabulation analysis indicates a relationship between legal status and behavioural categories (χ^2=21.614, df=12, p=0.042), the Pearson Chi-square test for the magnitude of the expected counts was unfortunately not met, so the result cannot be reliably accepted (moreover, the Cramer-V indicator shows a significant weak relationship between the two variables - Cramer-V=0.293, p=0.042).

The data reflect that the capital districts and towns have typically formulated a more balanced strategy (later accession—moderate reduction, earlier accession—larger reduction). The villages and large villages show a mixed picture despite their later accession. The towns with county's rights have generally taken more time to implement their plans. Most smaller municipalities that have joined in an associative form are still in the catching-up phase, thus playing an increasingly important role in the energy transition process.

Based on the results, I accept hypothesis H4 and formulate the following thesis.

T4. The municipalities show different mitigation strategies based on the date of adhesion and the selected baseline year. We distinguish catching-up, cautious, forward-looking, and ambitious groups based on the average time from adhesion to the target year (2030) and the average number of years to achieve it.

[4] The sample of 84 is made up of a total of 11 capital districts, 16 villages and large villages, 13 towns with county's rights, 19 towns and 25 associated members.

The Sustainable Energy and Climate Action Plans (SECAPs) formulate municipal responses to climate change using a methodologically fixed framework. One of its pillars is mitigation, which means reducing emissions linked to energy use. Its measure is the percentage reduction in carbon dioxide (or greenhouse gas emissions measured in carbon dioxide equivalent) between the target and baseline years. Climate change has become a complex global problem that cannot be measured and analysed in terms of a single indicator, even at the local level. In aggregate terms, for example, a 40% reduction in emissions at the municipal level is only sometimes achieved through the most sustainable option since emissions from energy use can also result from a reduction in the average level of consumption while maintaining an unfavourable energy mix.

I formulated the H5 hypothesis based on the work of Martire et al. (2018), Cipriano et al. (2017), Reckien et al. (2019).

H5. The characteristics of the emission reduction commitment are determined by the baseline annual greenhouse gas emission, the municipality's energy mix and status, and the time remaining until the target year.

The analysis for H5 aims to explore whether there are patterns in the commitments made by municipalities for 2030. A cluster analysis was performed using two variables: the specific annual average planned emission reduction (tCO2eq/capita/year) and the average emission factor (tCO2eq/MWh). I used a Mann-Whitney U test (p=0.796, Mann-Whitney U=382) to confirm that, despite the different units of measurement used by the members of the sample (tCO2 and tCO2eq), emissions are comparable, and the results are expressed in carbon dioxide equivalent (tCO2eq).

Differences in the surveyed municipalities' size, base years and energy mix made comparisons significantly more difficult, especially as 15 years elapsed between the earliest and latest BEI years. The level of greenhouse gas emissions depends not only on the amount of energy used but also on its energy mix. Options for determining emission factors related to direct and indirect energy use are discussed in detail in the doctoral thesis.

On this basis, a direct comparison between members was not possible. In order to overcome this, I had to train indicators suitable for comparison, which became the variables included in the clustering mentioned above:

- The specific annual average planned emission reduction per capita (tCO2eq/person/year): the average annual planned emission reduction per capita (tCO2eq/person/year), determined by the number of years remaining until the target year. This resolves differences in the size of municipalities and the baseline years.
- The average emission factor (tCO2eq/MWh): the average emission factor for total energy use (tCO2eq/MWh), which measures the average greenhouse gas emissions per megawatt-hour of energy use and greenhouse gas emissions that establish the link between energy use and greenhouse gas emissions, and from which the goodness of the members' baseline energy mix can be inferred.[5]

The study fulfilled the conditions for the applicability of cluster analysis (the statistical verification of the conditions is presented in detail in the paper). No significant relationship was found between the variables included in the clustering (Pearson correlation r=0.186, p=0.09); thus, they are suitable for clustering. Due to the different data scales, the municipalities/municipality groups were clustered using Ward's method and squared Euclidean distance by transforming the data with variable z to a scale of 0-1 to create a data set with 0

[5] Based on the SECAP methodology, GHG emissions are defined as the energy use per energy carrier (MWh) multiplied by the emission factor (tCO2eq/MWh) associated with that energy carrier (Bertoldi ed., 2018b.).

mean and 1 standard deviation. Running this procedure resulted in four well-differentiated homogeneous clusters (Figure 9).

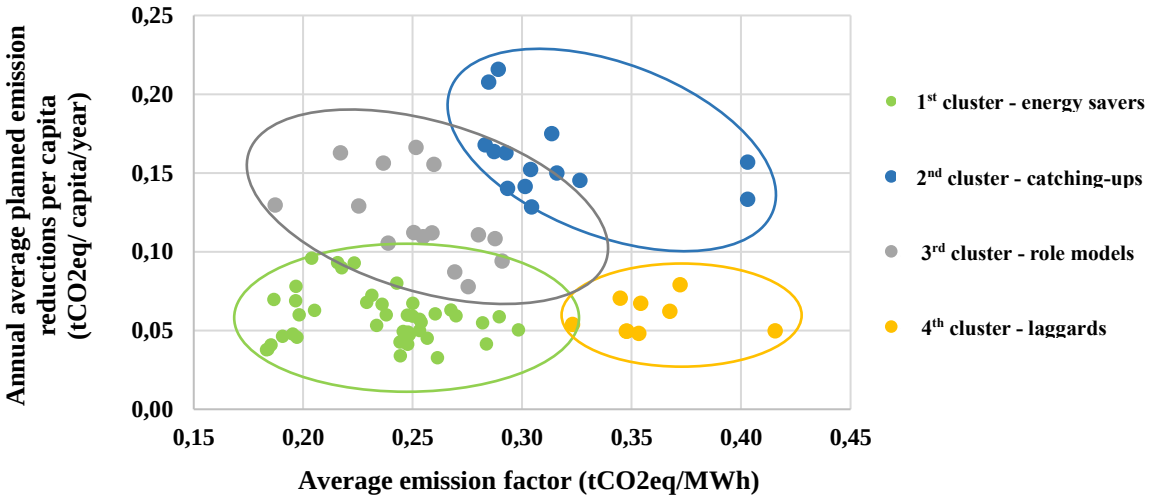


Figure 9. Homogeneous groups in the sample
Source: own edition

The first cluster (green – energy saver) comprises municipalities and groups of municipalities that operate with a less polluting energy mix and have committed to relatively lower specific annual reductions, have presumably already exploited the opportunities offered, and could, therefore, typically play an energy-saving role in the future. A worse energy mix and higher reduction intentions characterise the second cluster (blue – catching-up). They are at the beginning of the energy transition, so not only are these municipalities/municipal groups characterised by a poor energy mix but presumably also by high energy use. The third cluster (grey – role model) is associated with a lower emission mix and a higher commitment. Members belonging to this cluster commit to a higher effort compared to the other clusters, as their baseline energy mix already assumes a lower emission, yet they commit to a higher specific annual average planned emission reduction. The members of the fourth cluster (yellow – laggard) have a less favourable mix and a lower commitment. The members of this cluster are expected to make the slightest effort in the future but have the most significant potential for improvement.

The next step after the clustering was the identification of the differences between the clusters, i.e. the specific characteristics, which I did along three aspects:

1. the differences between the clusters according to their legal status,
2. the characterisation of the clusters according to their initial energy state and greenhouse gas emissions,
3. the cluster specificities resulting from the survey of other areas.

I analysed nominal variables using cross-tabulation analysis and mixed relationships using graphical representation (bar and boxplot diagrams). To explore the differences, I also test the applicability criteria of the analysis methodologies. These analyses are detailed in the doctoral thesis. Despite their more favourable energy mix, the role models are planning higher emission reductions than the other clusters. Energy savers can further increase their contribution to the energy transition by increasing their renewable capacities and through energy efficiency measures. Catching-up and laggard have a higher average share of renewables in their energy mix (22.34% and 26.68%, respectively) than the other clusters and can be better positioned by replacing fossil fuels with lower emission alternatives and increasing energy efficiency measures. For the laggards, it is worth exploring reduction opportunities in more detail. In many

cases, replacing resources and increasing renewable energy use will require costly technological change. Energy saving is considered the cheapest option.

Based on the results of the study, I accept hypothesis H5 and formulate the following thesis:

T5. The municipalities and groups of municipalities can be classified into four clusters based on the specific annual average planned emission reductions (tCO2eq/capita/year) and the average emission factor (tCO2eq/MWh): energy saver, catching-up, role model and laggard. Investments in energy efficiency, increased use of renewables, a shift to lower-emission energy sources and energy-saving measures can increase emission reductions with varying intensity.

Municipalities' perspectives on energy management tasks go beyond their classic role as energy consumers. Meaningful progress can be expected from their roles in energy efficiency, energy saving, production, and awareness raising (see Figure 1). The Covenant of Mayors for Climate and Energy has set a minimum mitigation target of 40 per cent for absolute emission reductions for its members but does not specify the level and nature of the effort expected from which areas. The SECAP methodology requires municipalities to assess not only energy use (MWh) and carbon dioxide (tCO2) or greenhouse gas (tCO2eq) emissions related to their own institutions and vehicle fleet within their jurisdiction but also data related to the residential, tertiary sector, industrial areas, and possibly agriculture, waste management and wastewater treatment (Bertoldi ed. 2018c.). In the so-called key Covenant sectors identified by the Covenant, such as municipal, residential, and tertiary sector buildings and transport, the influence of municipalities varies (Bertoldi ed. 2018b.). The development of sectoral plans using the SECAP template is a municipal competence, but the capacity of mayors, notaries, and elected representatives to implement interventions and provide financial background for them is often already limited.

About the roles of municipalities and the measures planned, I formulate the following hypothesis, drawing on the work of Rivas et al. (2022). Cipriano et al. (2017), Reckien et al. (2019); Croci et al. (2018), Pablo-Romero et al. (2018); Berghi et al. (2016), Pasimeni et al. (2019), Reckien et al. (2019), Dolge and Bumber (2021).

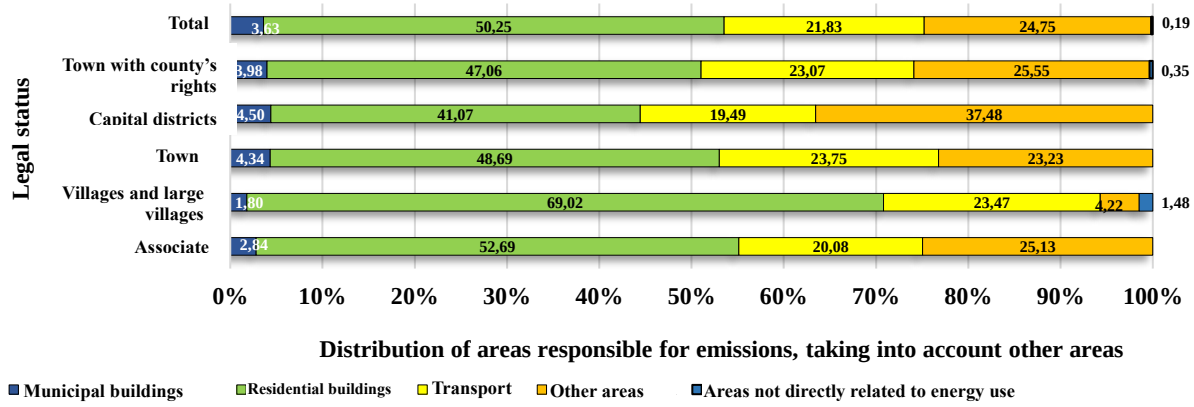
H6. Municipalities' narrower and broader role in energy management is crucial in the fight against climate change. When planning the area-specific reductions in their mitigation action plans, they have a realistic sense of the extent of their direct intervention potential and expect the municipal actors to take a more significant share of the planned measures.

To prove the hypothesis, I have carried out calculations in several areas. In this summary, I present only two of them: the distribution of GHG emissions by key area according to the baseline emission inventories and the conclusions drawn from comparing the results of the planned emission reductions for each area. Further analysis is presented in Section 5.3.3 of the doctoral thesis.

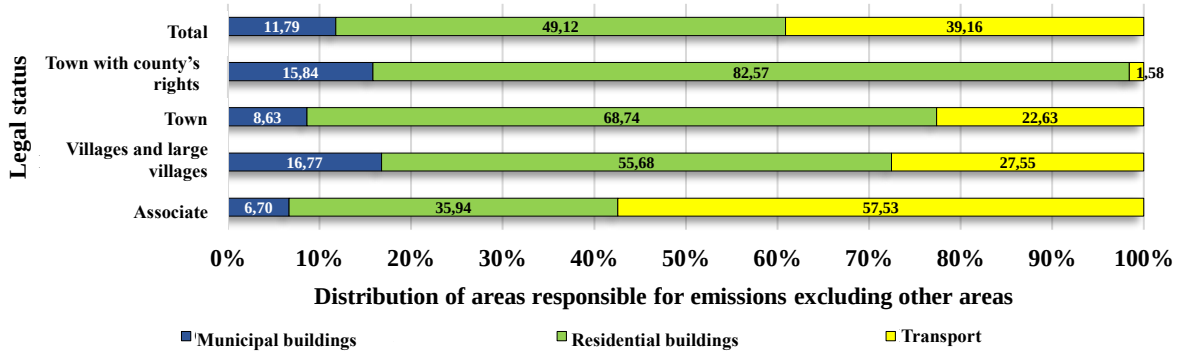
The Excel annexes of the 84 SECAP documents available were not available in most cases. These annexes contain essential information that would provide detailed information on the plans, the persons and institutions responsible for implementation, the costs associated with the measure and which measures were already underway when the SECAP was drawn up. This information is essential for a comprehensive evaluation. However, many textual documents only refer to emission reductions, and in many cases, not in full. This does not mean that the document itself does not follow the principles laid down in the methodology but that these areas

need to be fully covered in the text documents[6]. To validate the data, I have multiplied the emission reduction target (tCO2eq) obtained by multiplying the baseline emissions inventory by the mitigation multiplier defined (in most cases 40%) by the sum of the area data that can be extracted from the documents. Based on the results, the exclusion of 12 documents was necessary to define a -10% deviation threshold. Only 72 of the 84 documents were suitable for a sub-analysis. The 10% threshold was set arbitrarily.

Regarding energy use, residential buildings, municipal buildings, and transport are key areas, as are buildings in the tertiary sector, but none of the members assessed the latter. For complete coverage, the other category includes data for the tertiary sector, industry and agriculture. The areas not directly related to energy use include waste and wastewater treatment emissions. For this reason, the analyses have been carried out in two different breakdowns. The first part of the analysis includes data from those municipalities that have measured their other areas, and the second part includes data from those that have not measured their other areas.



a.) Survey of other areas (n=54)



b.) Did not survey other areas (n=18)

Figure 10. Breakdown of GHG emissions by area and legal status according to the baseline emission inventory (BEI)

Source: own edition

Looking at the distribution of GHG emissions by area according to the base year inventory (BEI) (Figure 10), it can be said that:

– For the members that have assessed their other areas, emissions related to residential buildings are, on average (50.25%), followed by other areas (24.75%) and then transport (21.83%). The share of municipal buildings is negligible compared to other

[6] When uploading the SECAPs, municipalities need to fill in the Excel template online (Energy Club - personal consultation).

areas (3.63%). Emissions from areas not directly related to energy use are lower, averaging 0.19%.

– For those members who have not surveyed their other areas, the above proportions are obviously skewed in favour of the other areas. However, the order of emissions has not changed, with residential buildings (49.12%) being the largest emitting area, followed by the transport sector (39.16%) and finally municipal buildings (11.79%).
– The proportions differ slightly by legal status, but the order of the areas does not differ fundamentally (only in the village/large village category is the proportion of other areas decreasing behind the transport area).

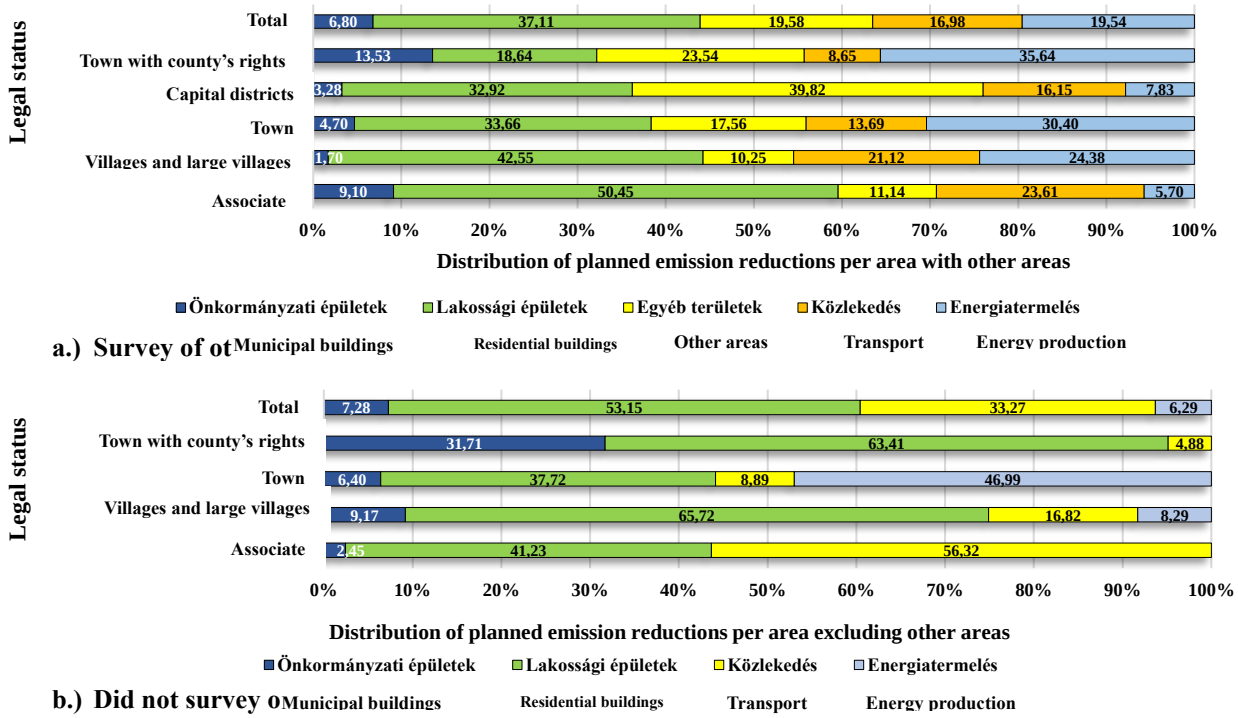


Figure 11. Distribution of planned emission reductions by legal status for each area
Source: own edition

The distribution of planned emission reductions by area (Figure 11) shows that:

– The members that have assessed their other areas typically expect the highest reduction rate for residential buildings (37.11%), followed by other areas (19.58%) and then transport (16.98%). A greater reduction intention for municipal buildings (13.53%) is only in the case of towns with county's status.
– Members that did not measure their other areas typically expect the highest reduction rate from residential buildings (53.15%), followed by transport (33.27%), then municipal buildings and energy production, with a smaller share. Only in the case of towns with county's rights is a more significant reduction in favour of municipal buildings (31.71%).
– There are more significant differences in the breakdown of planned emission reductions by legal status.

Comparing the two results, municipalities are planning greater reductions in areas more responsible for greenhouse gas emissions. Local authorities are, therefore, realistic about the extent of their intervention options when planning the emission reductions they expect from each area.

Each municipality has different intervention possibilities depending on its legal status. The doctoral thesis presents the analysis of intervention options by legal status in detail but not in this summary due to space limitations.

Based on the results of the study, I accepted hypothesis H6 and formulated the following thesis:

T6. When planning the area-based reductions set out in their mitigation action plans, municipalities realistically perceive the extent of their direct intervention potential and expect most of the planned measures to be implemented by municipal actors so they can best help to achieve the targets by setting an example, organising awareness-raising events and seeking funding sources. Therefore, their indirect role in energy management is critical in the fight against climate change.

Table 6 summarises the research questions, hypotheses, methods, and theses.

Table 5.
Summary table of methods used to test the research questions, hypotheses and evaluation of the theses

Research question	Hypothesis	Methods	Evaluation of the hypothesis	Thesis
Q1.	H1.	Document analysis, descriptive statistical tools	Accepted	T1.
	H2.	Document analysis, Pearson correlation coefficient, descriptive statistical tools	Partially accepted	T2.
Q2.	H3.	Document analysis, Pearson correlation coefficient, descriptive statistical tools	Rejected	T4.
Q3.	H4.	Document analysis, cross-tabulation analysis (Chi-square test, Cramer-V coefficient), descriptive statistical tools	Accepted	T3.
	H5.	Document analysis Pearson correlation coefficient, cross-tabulation analysis (Chi-square test, Cramer-V coefficient), non-parametric analysis (Mann-Whitney U test), graphical data summarisation methods, hierarchical clustering (Ward's method, squared Euclidean distance), descriptive statistical tools	Accepted	T5.
	H6.	Secondary research, literature analysis, analysis of variance (ANOVA), Bonferroni post-hoc test, descriptive statistical tools	Accepted	T6.

Source: own editing

4 PRACTICAL RELEVANCE OF RESULTS, FURTHER RESEARCH DIRECTIONS

The European Union is one of the world's largest energy consumers and greenhouse gas emitters, and the Paris Climate Agreement's success depends primarily on it (Liobikienė-Butkus, 2017). In the future, cities and smaller municipalities will play an increasingly important role in implementing a carbon-neutral economy. The success of the fight against climate change in the future will arguably also depend on the efforts of local governments (European Commission, 2019). Several studies and publications are exploring the sustainability and resilience of local governments in Hungary (Ács et al., 2019, p. 278; Nagy et al., 2018 a.-b.; Szép et al. 2021), but the focus of Hungarian academic attention on Sustainable Energy and Climate Action Plans is not typical. Eisenack and Roggero (2022), based on their review of the literature, express uncertainty as to whether the implementation of mitigation plans impacts emission reductions and whether other factors may be behind the mitigation. In their 2018 publication, Fuhr et al. cites the work of Gouldson et al. (2016) and Bansard et al. (2016), arguing that progress in GHG mitigation is not entirely attributable to the involvement of local governments and international organisations but rather to the independent programmes and circumstances that are already underway. Buildings had the highest emissions in the areas studied in the thesis, which aligns with the literature. Cipriano et al. (2017) criticised the SECAP methodology. They suggested that considering the floor area or net helpful floor area of buildings would provide more accurate information and make it easier to identify properties with poor energy performance. In contrast, Cinocca et al. (2018) argue for the goodness of the SECAP methodology and conclude that monitoring reports are continuously improving the methodology, allowing municipalities to have an increasingly accurate picture of the emissions associated with their area and the effectiveness of measures to reduce them.

The International Renewable Energy Agency (IRENA, 2019b, p. 28) estimates that *"by 2050, the share of renewables in energy production could reach 60%, mainly from solar and wind energy"*. A critical pillar of the energy transition is the deployment of renewables. However, according to research by Dolge and Blumberga (2021), investments in energy efficiency can contribute twice as much to the success of the European Green Deal than renewables. Hungary aims to achieve a 20% renewable share in its energy mix by 2030, predominantly through solar PV systems. The share of wind energy is envisaged at the current level (Sáfián, 2018).

Based on the experience of the 2004-2020 tendering cycles, EU funds have proven to be an essential driver of the energy transition in Hungary. Defining the conditions and criteria for tenders remains challenging for the government and experts. The Sustainable Energy and Climate Action Plans are essential in the 2021-2027 tendering cycle. On the one hand, additional municipalities and groups of municipalities can apply for funding to support their preparation under the TOP Plus tenders. On the other hand, their existence is an advantage when winning tenders. The increasing number of documents produced is also likely to lead to changes in the application system since the justification of the group to be supported is an essential criterion in all cases. It follows that the existence of documents will no longer be an advantage but that the emphasis will be on their content. While international research has been very active on the subject, this is the first study in Hungary that attempts to identify the characteristics of Hungarian municipalities and groups of municipalities from SECAP documents. The practical utility of the research lies in the fact that it provides its analytical framework based on international literature, which allows for the evaluation and comparison of the commitments of individual members. Although the research did not show significant differences between the baseline year (BEI year) and energy use and GHG emissions, the time available for

implementation of the planned measures (2030 as the target year and the year of accession in years) and the time horizon of the planned measures (the difference between 2030 and the BEI year) did reveal some patterns of emission reduction behaviour specific to the municipalities, taking into account the temporality of the plans. Based on the planned emission reductions and the energy mix of the municipality, it was possible to cluster the CoM members and identify four typical reduction strategies.

This thesis is the first step in a long-term research project. From the perspective of local governments in Hungary, it has provided a basis to explore further the factors that facilitate and hinder energy transition at the municipal level. The research carried out was based on document analysis. Actual motivations, incentives and barriers were identified through field research, questionnaire surveys and focus group interviews. An assessment of these could greatly assist not only the decision-making of mayors or government but, if formulated comprehensibly, could also provide lessons for the general public. Another crucial area that future research should address is the implementation of planned measures and the evaluation of their impact. The so-called monitoring reports will be produced every two years.

One of the most critical issues for current policy is encouraging individuals and local communities to participate more actively in the energy transition. Let us consider collective action as a transaction. It is necessary to clarify at the local level who we consider to be contracting parties, what we expect from the transaction, who is responsible for it and what its costs are. Based on the paradox of collective action (Olson, 1997; Gedeon and Katona, 2020), smaller groups can organise themselves to achieve a collective good, but larger groups cannot. In their case, failure is guaranteed without external incentives. From this perspective, it is necessary to interpret what is considered a small and large group in the case of settlement and what effective incentives can be used to promote the organisation of large groups. Based on the gaps identified in the energy management of municipalities, the research has identified three primary recommendations for improvement, which current policy can significantly help to address:

1. There is currently no comprehensive database on municipal energy management. To overcome this gap, further support for the production and effective monitoring of SECAP documents is proposed. The increasing uptake of smart meters would be of significant help to municipalities. However, the necessary financial resources for deployment need to be found.
2. The management, expansion and evaluation of the data assets generated by the development of SECAPs is difficult for municipal staff and, in most cases, requires external professional assistance. At present, hiring an energy specialist is costly for most municipalities and is therefore not feasible. It is proposed that training courses be organised to provide designated employees with the necessary professional and IT skills to manage energy data or to include the salary of an energy technician in the task funding.
3. On the policy side, it is proposed to further strengthen local authorities' awareness-raising role and provide them with financial support for such campaigns.

5 LIST OF PUBLICATIONS ON THE SUBJECT OF THE DOCTORAL THESIS

1. Takácsné Papp, A., Szucs Markovics, K., Horváth, Á., 2023. Change in Energy Intensity and Energy Mix of the EU's Food, Beverages, and Tobacco Industry. in Róbert, ŠTEFKO; Richard, FEDORKO; Eva, BENKOVÁ (szerk.) *Economics, Management & Business 2023: Contemporary Issues, Insights and New Challenges: VIII. International Conference, Spa Nový Smokovec – Congress Centre, High Tatras, the Slovak Republic* 28 – 29 September 2023. Presov, Szlovákia: University of Prešov (2023) 1,110 p. pp. 62-71., 10 p.
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