



UNIVERSITY OF PANNONIA

Doctoral School of Chemical Engineering and Material Sciences

**Decision-Support Approaches for Urban Climate Action  
Planning and Environmental Assessment**

Ph.D. THESES

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## **Introduction**

Cities have become central to the way societies respond to climate change. They concentrate population, economic activity, and infrastructure, and they are at once major sources of greenhouse gas emissions and the places where the consequences of a changing climate (heat, flooding, drought) are felt most directly. Over the past two decades, local governments across Europe and beyond have committed to act, and a large number of municipal climate strategies have been published as a result. Yet the question of how a city should choose its climate actions, and how those choices should be evaluated, remains far from straightforward.

The difficulty lies in the diversity of urban contexts and in the breadth of the interventions available. Two cities of similar size may face very different climatic and socio-economic conditions, and the catalogue of possible actions ranges from building renovation and renewable energy to public-awareness campaigns and nature-based solutions. In practice, decisions are often guided by experience, local precedent, or the priorities of individual experts rather than by a structured analysis of what has already been done elsewhere. This makes it hard to compare strategies between cities and to justify why one action is preferred over another.

At the same time, two developments have created an opportunity. The Covenant of Mayors and the associated Sustainable Energy and Climate Action Plans (SECAPs) have produced a substantial body of comparable, publicly available climate strategies, while advances in data science have made it possible to learn systematically from large collections of such documents. So far, however, these resources have mostly been used to describe what cities are doing, rather than to support the practical choice of which actions a given city should adopt.

The aim of this Ph.D. thesis was to develop decision-support approaches for urban climate action planning that draw on this published experience rather than on intuition. The work combines three perspectives that are usually treated separately: a systematic, analytical reading of existing climate action plans; a data-driven model that links the characteristics of a city to the actions it is likely to need; and an environmental assessment of the materials those actions require. Taken together, these perspectives are intended to make the planning of climate action more structured, more comparable, and more firmly grounded in evidence.

My goal is to move from analysis to application. Starting from a large set of European climate action plans, I first developed a structured categorization of the actions cities undertake, which provides a common vocabulary for the rest of the work. Building on this, I examined the role of public awareness as an enabling factor for environmental outcomes, then trained a decision-tree-based decision-support model that uses a city's characteristics to suggest appropriate categories of action. Finally, I evaluated the environmental performance of material-intensive interventions through a project-level life-cycle assessment, so that the consequences of a chosen action can also be quantified.

## **Methods**

During my research, I developed a set of decision-support approaches for urban climate action planning. The aim was to combine a systematic reading of published climate action plans, a data-driven model linking the characteristics of a city to the actions it is likely to need, and a project-level environmental impact assessment of the materials those actions require, so that the planning and evaluation of climate actions can rest on empirical evidence rather than on the judgement of individual experts.

For the verification of my hypotheses the following main methods were used:

- a) systematic text mining and thematic analysis of published Sustainable Energy and Climate Action Plans (SECAPs) to identify and categorize recurring urban climate actions,
- b) an exploratory analysis of a sample of 99 SECAP reports to derive and validate the initial categorization scheme,
- c) statistical analysis of the relationship between public-awareness measures, education levels, and environmental indicators such as air quality and emissions, across contrasting countries,
- d) construction of a structured database of climate actions and city characteristics from 443 European cities,
- e) feature selection and the development of a decision-tree classification model linking city characteristics to categories of climate action,
- f) tuning of the model through maximum-depth selection and post-pruning, and analysis of the contribution of each feature using SHAP values,

- g) validation of the model through train–test evaluation, cross-validation, and performance metrics beyond accuracy,
- h) selection of representative, material-intensive climate-action projects as case studies and quantification of the type and amount of construction materials used in each,
- i) a project-level environmental impact assessment of these materials, based on life-cycle assessment principles, to estimate indicators such as global warming potential (GWP), ozone depletion potential (ODP), and human toxicity (HT),
- j) comparison of the modelled results with experimental and literature values to verify the emission factors and to interpret the discrepancies between them.

## **Theses**

The new scientific results achieved during my PHD research are formulated in the following four theses:

1. Thesis:

I developed a structured categorization of urban climate actions, beginning with a preparatory analysis of 99 SECAP reports and subsequently enlarging the dataset to 454 reports published by 443 European cities across 32 countries on the Covenant of Mayors platform. Using text mining, actions were grouped into ten consistent categories on a functional equivalence basis, whereby distinct measures serving the same objective (for example, car sharing schemes and public bus upgrades were assigned to a single category such as transport optimization). The associated co-benefits were likewise extracted and categorized. Unlike existing classifications, which are largely top-down sector taxonomies, the proposed categorization is derived bottom-up from published municipal practice and structured to serve as input for comparative analysis, data-driven modelling, and environmental assessment.

2. Thesis:

Motivated by the high frequency of public awareness actions observed in the analysed plans, I examined, as an exploratory analysis, the role of public awareness and education in urban climate action. The comparison was conducted at the national level, in three contrasting countries (Germany, Brazil, and Kenya), because comparable education indicators are available primarily at the country scale rather than the city scale. I observed

that higher awareness and education levels are associated with more favourable trends in air quality and greenhouse gas emissions. Because this finding rests on a limited number of national cases, it is presented as an associational and motivating observation rather than a causal claim. On this exploratory basis, the thesis shows that social and educational dimensions are a relevant supporting factor alongside technical action.

### 3. Thesis:

I developed a data-driven decision support model for urban climate action planning based on a structured database of 454 climate action reports from 443 European cities in 32 countries, characterised by 24 features organised into three groups: geodemographic, spatial-distribution, and action-related variables. Using this database, I constructed an interpretable Gini-based classification tree of depth 12, refined through feature importance (SHAP) analysis and post-pruning, which increased the testing accuracy to 32.9% while improving readability. The analysis identified budget and population density as the most influential drivers of the selected category. The resulting model translates empirical patterns in published plans into a transparent, context-based tool that indicates the climate action category most consistent with the observed practice of cities sharing similar characteristics. This thesis demonstrates that combining large-scale empirical analysis with interpretable model development transforms past municipal experience into a practical decision-support tool for more consistent and evidence-based planning.

### 4. Thesis:

I developed a material based evaluation framework that assesses climate action projects at the project level through three elements: The quantification of construction materials used in each project, the comparison of their environmental impacts using Global Warming Potential, Ozone Depletion Potential, and Human Toxicity, and the use of normalized functional units to enable consistent comparison across heterogeneous interventions. I demonstrated that environmental performance is governed primarily by the type and intensity of materials used rather than by project category alone, so that projects in the same category can differ substantially in impact. This thesis demonstrates that material intensity, expressed through normalized functional units, is a decisive criterion for accurate environmental evaluation in climate action planning.

## List of Publications Strongly Related to the Research Theses

### Journal papers

1. **Rjiba, I.B.**, Sebestyén, V., Tóth-Nagy, G.: Role of raising awareness in ensuring the cities resilience, Hungarian Journal of Industry and Chemistry, Vol. 51, Number 2, pp. 43-49, 2024. **IF: 0.5, Q4.**
2. **Rjiba, I.B.**, Tóth-Nagy, G., Rostási, Á., Gyurácz-Németh, P., Sebestyén, V.: How should climate actions be planned? Model lessons from published action plans, Vol. 370, pp. 122648, 2024. **IF: 8.00, D1.**
3. **Rjiba, I.B.**, Tóth-Nagy, G., Rostási, Á., Gyurácz-Németh, P., Sebestyén, V.: A structured dataset of urban climate actions in European cities, Data in Brief, Vol. 64, pp. 112311, 2026. **IF: 1.4, Q1.**

Database accessibility:

Repository name: Database-of-article-How-should-climate-actions-be-planned-Model-lessons-from-published-action-plans.

Data identification number: 2437596

4. **Rjiba, I.B.**, Tóth-Nagy, G., Kristófné Makó, É., Sebestyén, V.: Comparative environmental assessment of construction materials in climate action projects, Results in Engineering, Vol. 29, pp. 109796, 2026. **IF: 7.9, Q1.**

### Conference papers

1. **Rjiba, I.B.**, Tóth-Nagy, G., Sebestyén, V.: Cities strategies to protect their energy and climate security, VII. Turizmus és Biztonág Nemzetközi Tudományos Konferencia, Tanulmánykötet, pp. 357-364, 2023.
2. **Rjiba, I.B.**, Kristófné Makó, É., Tóth-Nagy, G., Sebestyén, V.: Life Cycle Assessment of Construction Materials in Climate Action Projects, 1st African Conference on Sustainable Development of Energy, Water and Environment Systems, Oujda-Saidia, Morocco, May, 27-31, 2025.

### International Conference presentations

1. **Rjiba, I.B.**, Kristófné Makó, É., Tóth-Nagy, G., Sebestyén, V.: Life Cycle Assessment of Construction Materials in Climate Action Projects, 1st African

- Conference on Sustainable Development of Energy, Water and Environment Systems, Oujda-Saidia, Morocco, May, 27-31, 2025.
2. **Rjiba, I.B.**, Sebestyén, V., Tóth-Nagy, G.: Strategic Localization of Climate Actions: A Methodological Approach for Urban Climate Resilience, 2nd International Conference of the Hellenic Society for Circular Economy (HSCE), Crete, Greece, September 17-19, 2025.
  3. **Rjiba, I.B.**, Sebestyén, V., Tóth-Nagy, G.: Integrating spatial indicators for climate action planning, 16th ICEEE Conference (Global Environmental Development & Sustainability: Research, Engineering & Management), Budapest, Hungary, November, 20-21, 2025.

### **International Hungarian conference presentations**

1. **Rjiba, I.B.**, Tóth-Nagy, G., Sebestyén, V.: Cities strategies to protect their energy and climate security, VII. International Scientific Conference on Tourism and Security, Zalakaros, Hungary, December 9, 2022.
2. **Rjiba, I.B.**, Sebestyén, V., Tóth-Nagy, G.: Ma these en 180 secondes- A disszertáció 180 másodpercben, Hungarian Selection 2023 Edition, Budapest, Hungary, március 21, 2023.
3. **Rjiba, I.B.**, Tóth-Nagy, G., Sebestyén, V.: Role of raising awareness in ensuring the cities resilience, 51th Chemical Engineering Days, Veszprém, 2023. April 18-20.
4. **Rjiba, I.B.**, Sebestyén, V., Tóth-Nagy, G.: Impacts of public awareness on climate adaptation, 26th Spring Wind Conference, Miskolc, május 5-7, 2023.
5. **Rjiba, I.B.**, Sebestyén, V., Tóth-Nagy, G.: Exploring construction materials and processes to reduce greenhouse gas emissions, Materials science day XXIII of PhD students, Veszprém, Hungary, November, 19-20, 2023.
6. **Rjiba, I.B.**, Tóth-Nagy, G., Sebestyén, V.: Model-supported climate action plans: an innovative framework for climate security, VIII. International Scientific Conference on Tourism and Security, Zalakaros, Hungary, December 1, 2023.
7. **Rjiba, I.B.**, Sebestyén, V., Tóth-Nagy, G.: Data-driven climate action plans: Fostering sustainable resilience through innovative models, 52th Chemical Engineering Days, Veszprém, April, 16-17, 2024.

8. Tóth-Nagy, G., **Rjiba, I.B.**, Sebestyén, V.: Climate adaptation in urban environments: Practical examples and lesson learned, IX. International Symposium 2025, Budapest May, 8-9, 2025.
9. **Rjiba, I.B.**, Tóth-Nagy, G., Sebestyén, V.: A Spatially Driven Framework for Data-Based Climate Action Planning in Cities. Materials science day XXV of PhD students, Veszprém, november 17, 2025.
10. **Rjiba, I.B.**, Sebestyén, V., Tóth-Nagy, G.: Sustainable Tourism and Urban Safety Through Spatial Analysis, X. International Scientific Conference on Tourism and Security, Zalakaros, December, 5, 2025.