Innovation Action

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# D5.4 - City impact evaluation procedure

**WP5, Task 5.1**

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| | | | | |
|---|---|---|---|---|
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# Abbreviations and acronyms

| Acronym | Description |
|---|---|
| DAQ | Data acquisition |
| DoA | Description of Action |
| EeB | Energy-efficient Buildings |
| GDPR | General Data Protection Regulation |
| GHG | Greenhouse gas |
| KPI | Key Performance Indicator |
| LH | Lighthouse cities (Groningen and Oulu) |
| PED | Positive Energy District |
| RTO | Research and Technology Organisation |
| SCC | Smart Cities and Communities |
| SCIS | Smart Cities Information System |
| WP | Work Package |

# Executive Summary

WP5 aims to monitor and evaluate the effectiveness of the project actions and interventions, compared to the initial situation, initial objectives and expected results. The MAKING-CITY evaluation framework considers two different but complementary levels for carrying out this evaluation: city and project level.

The main objective of this deliverable is to define the evaluation procedure to measure the impact of the MAKING-CITY project at city level. The first step carried out within this framework was the definition of a set of city level indicators that will allow measuring the impact of the project in each of the cities that participate in it. The indicator definitions and the methodology to calculate them have been reported in the D5.1 (City level indicators). Part of the defined indicators have been obtained through the analysis of the existing city plans reported in the D1.2 (City diagnosis: analysis of existing plans).

The city level indicators will be used in the evaluation to show to what extent overall policy goals have been reached in the project's cities, whereas project indicators will be considered in the evaluation of the technical and non-technical actions in technical, economic and social aspects. The project level evaluation procedure for PED actions will be reported in the D5.3.

# Keywords

Evaluation procedure, city level indicators, impact assessment

# 1 Introduction

## 1.1 Purpose and target group

WP5 aims to monitor and evaluate the effectiveness of the project actions and interventions, compared to the initial situation, initial objectives and expected results. The MAKING-CITY evaluation framework considers two different but complementary levels for carrying out this evaluation: city and project level.

The main objective of this deliverable is to define the evaluation procedure to measure the impact of the MAKING-CITY project at city level. The first step carried out within this framework was the definition of a set of city level indicators that will allow measuring the impact of the project in each of the cities that participate in it. It has been reported in the D5.1 (City level indicators) and part of the defined indicators has been obtained through the analysing the existing city plans reported in the D1.2 (City diagnosis: analysis of existing plans).

This set of city level indicators is key in the definition of this evaluation procedure but it has been needed to establish not only the best way to measure these indicators, but also how the results can be compared in order to identify correctly the impact of the implemented actions.

The defined procedure will also support cities in the establishment of strategic goals since the methodology proposed will allow them to simulate different scenarios modifying the value of the indicators that have been included in the framework

## 1.2 Contribution partners

The following Table 1 depicts the main contributions from participant partners in the development of this deliverable.

**Table 1: Contribution of partners**

| Partner nº and short name | Contribution |
|---|---|
| 01 - CAR | General structure. Main contributor on the description of the methodology followed. Synergies with city diagnosis and city level indicators. Coherence between evaluation and planning at city level. |
| 03 - GRO | Feedback from Groningen city. |
| 06 – SEV | Feedback from Groningen city. |
| 07 - WAM | Feedback from Groningen city. |
| 12 - HUAS | Feedback from Groningen city. |
| 13 - OUK | Feedback from Oulu city. |
| 20 - VTT | Leading contributor. Feedback from Oulu city. |

## 1.3 Relation to other activities in the project

The following Table 2 depicts the main relationship of this deliverable to other activities (or deliverables) developed within the MAKING-CITY Project and that should be considered along with this document for further understanding of its contents.

**Table 2: Relation to other activities in the project**

| Deliverable nº | Relation |
|---|---|
| D1.2 | City Diagnosis: analysis of existing plans. The city level indicators defined in the deliverable 5.1 were calculated by all project cities and they were presented in the D1.2. |
| D1.5 – D1.12 (D1.25 – D1.32, Initial Versions) | The evaluation procedure developed in this deliverable will provide mechanisms to establish strategic objectives at city level and evaluate their achievement. |
| D1.13 – D1.20 | The evaluation procedure developed in this deliverable will provide mechanisms to establish strategic objectives at city level and evaluate their achievement. |
| D4.3 (D4.16 Initial Version) | The evaluation procedure at city level presented in this deliverable will be useful for the selection of candidate areas to become a PED in the follower cities |
| D5.1 (D5.13 initial version) | Definition of the city level indicators within D5.1 |

# 2 Evaluation framework at city level

WP5 "Evaluation framework and social innovation" aims to monitor and evaluate the effectiveness of the project actions and interventions, compared to the initial situation, initial objectives and expected results. The scope of the monitoring protocol is twofold, firstly in order to measure the performance of the actions deployed to reach a validation of PED concept and secondly to evaluate the impact at city level.

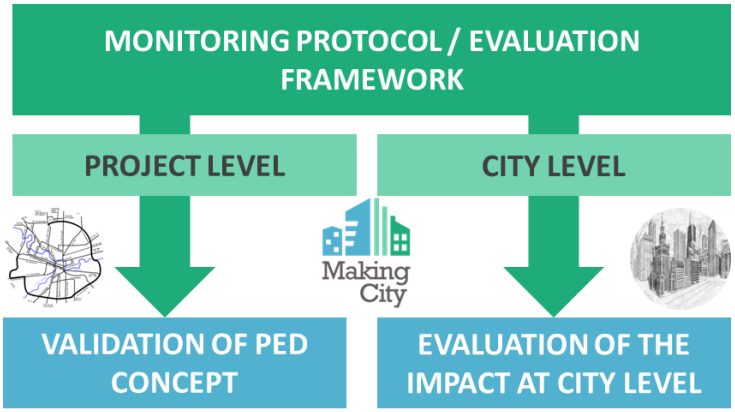


**Figure 1: MAKING-CITY Evaluation Framework (source: D9.8)**

This deliverable is focused on proposed procedure for the evaluation at city level whose basis is the definition of a set of key performance indicators. Despite the difficulties to standardize a methodology and to select the most appropriate indicators, a good definition of the Evaluation Framework can be very effective to obtain significant information for cities for improving their sustainability.

Demonstration projects enable the validation of the benefits and potential of the implementation of integrated solutions to improve key parameters that affect overall quality of life in the city. Ranging from the pure environmental ones, passing through those related with citizens' comfort and leading to those that allow a progress in the socioeconomic conditions as the promotion and attraction of talents, or new businesses yielding to and intensive job creation. These projects, in general financed with extra funds (with respect to conventional) should offer society an open pathway to the city transformation, where citizens and stakeholders' engagement is ensured and well structured.

However, inside this context, the weakness related with upscaling and replicability of the solutions successfully deployed is commonly perceived. A real continuity of the urban transformation depends on the city commitment. This commitment can be constrained by several factors that can delay this city transformation and even in some cases, it can be jeopardised.

In order to define and establish the Smart City plans for the lighthouse and follower cities based on the replication potential of the interventions implemented in MAKING-CITY, it is necessary to start analysing the selected actions in an urban context in the earliest stage, i.e. identifying the opportunities and the barriers to the implementation of these actions. This will make it possible to study the feasibility of their implementation, but also to give priority to actions with a favourable context and to raise the barriers for other actions. The actions with a difficult context can then be compared to similar actions set up in partner cities and solutions can be sought to overcome the identified barriers. At this point, a strong coordination with the lighthouse cities will be required to integrate useful information as open data e.g. within the ICT-city Platforms.

The demand side vs. supply side scenarios assessment should be based on a multi-criteria methodology evaluating the sustainability of the scenarios proposed under the three sustainable development dimensions: the economic, social, and environmental impacts of the different scenarios generated.

The reasoning for the impact-based evaluation in MAKING-CITY project is depicted by the Logic-model (Figure 2), that describes the intended logic between the direct outputs and outcomes of the activities and interventions of the project (PED) level (short term effects) and the incurred impact on the city level (medium- or long-term effects).

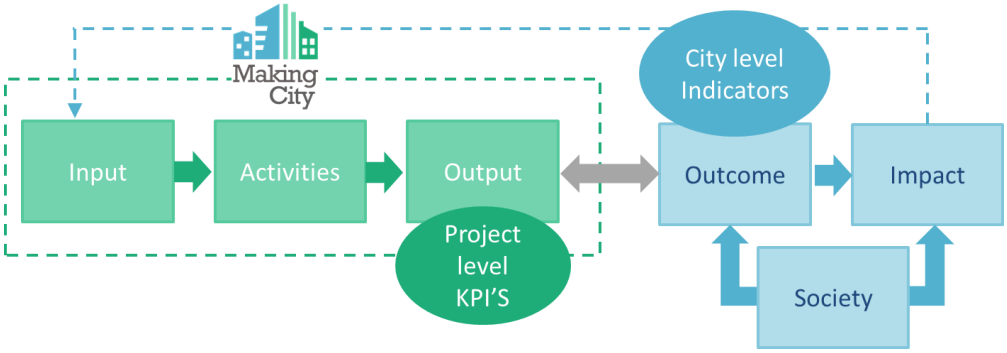


**Figure 2: The Logic-model describes the steps from input to impact**

Despite this intended logical methodology, the reality in some of the smart city projects - including MAKING-CITY - is that the project level (PED area) represents just a demo-scale selection of mainly energy related actions and technologies, and upscaling the outputs/outcomes from this level into city level impacts, is not necessarily going to represent the real progress or even desired goals. It is of course possible to generate simulations of what would it be like, but in real world, cities are much more complex entities, and just aggregating the demonstration results up to the city level, would be somewhat useless.

This is why in MAKING-CITY, the city level and project level evaluation (starting with indicators vs. KPIs) have intentionally been separated from each other. Only the main energy and environment related indicators are similar (comparable) in both levels. The city level is more concentrated on overall city level development targets (e.g. SECAP, long-term city strategies), whereas the project level aims to introduce new technologies for producing renewable energies and saving energy as much as possible and economically feasible. Both levels are important, but it is not that relevant to try to scale the PED level outcomes up to city level in this case. However, what could be up-scaled, are the new technologies, business models and social innovations that can rise successfully up from the demonstrations. This is what cities could actually spread around in the planning of their smarter futures.

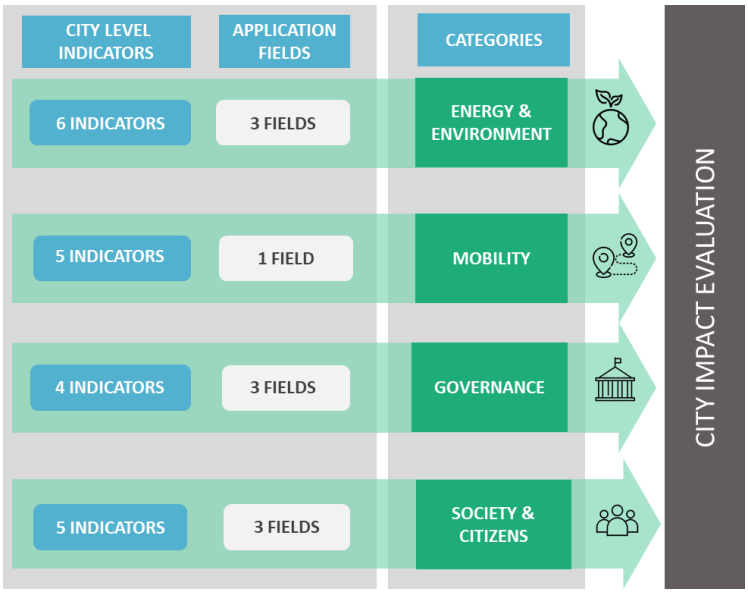


**Figure 3: Levels of MAKING-CITY evaluation framework at city level**

MAKING-CITY project has defined a set of city level indicators focuses on monitoring the evolution of a city towards an even smarter city. The city level indicators were defined in the 5.1 "City Level Indicators" and they are also presented in the section 3 of this deliverable.

A structure has been created where individual indicators have been grouped into different application fields, and these, in turn, in categories, establishing three levels at which to make comparisons

Individual indicators are first step to stockpiling existing quantitative and qualitative information. These indicators are normalized, weighted and aggregated to calculate the indices of upper levels. The application fields are thematic indicators where individual indicators are grouped together around a specific area. Categories are composite indicators formed when thematic indicators are compiled into a synthetic index and presented as a single composite measure.

Once the city level indicators were selected and grouped, an evaluation procedure has been defined taken into account two main objectives:

- Objective 1: City characterization. The methodology supports cities to identify their main needs and priorities, considering targets identified in the existing city plans.

  The methodology is adapted to each city and cities are in charge of organize hierarchically the indicators, at their different levels, according to the priorities of the city and the objectives established in their plans

- Objective 2: Impact evaluation at city level. The objective is to evaluate the impact that the project actions are having on the city, so the weighting of the indicators will be common for all cities. Experts have been in charge of carrying out the establishment the most proper weights with a more global point of view not focused on the particularities of an only city.

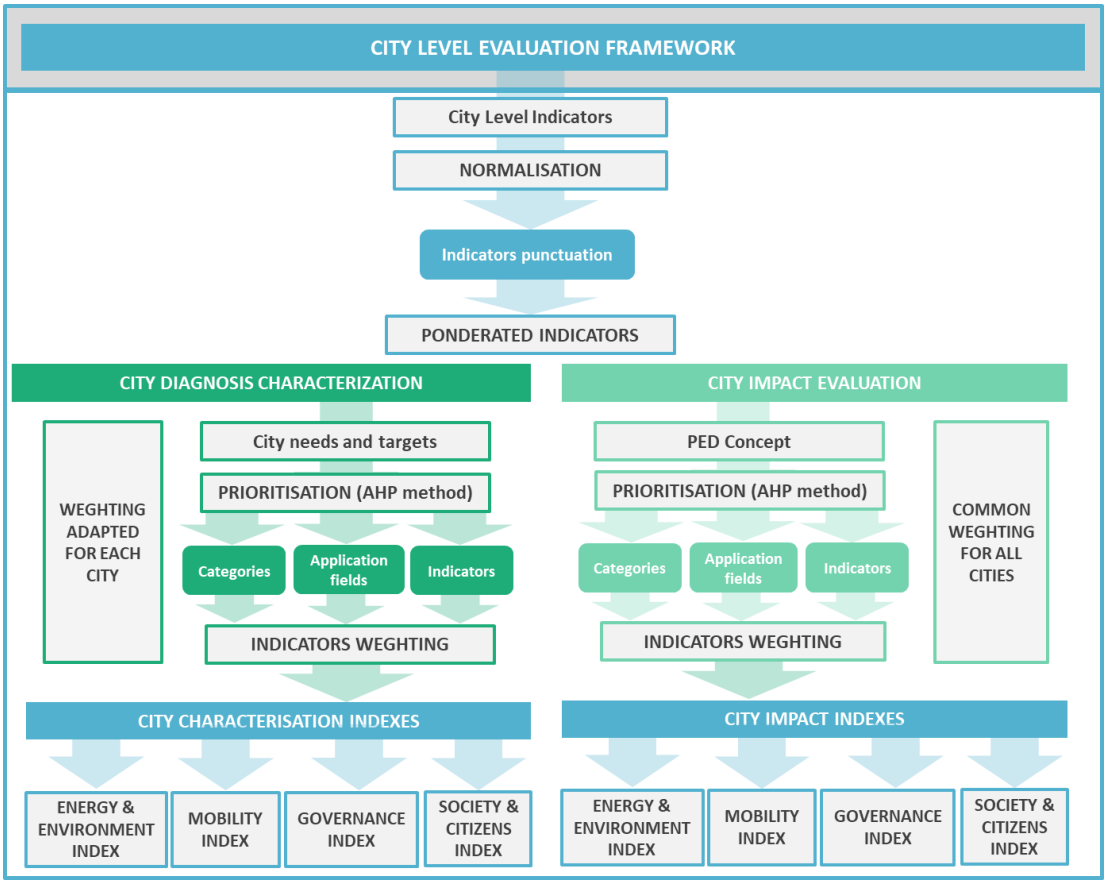


**Figure 4: City level evaluation framework scheme**

As can be seen in the scheme presented in Figure 4, the defined procedure has a common part independently of the objective sought. If the objective is to carry out a characterization of the city or if it is to analyse the impact of the implementation of solutions associated with a PED, the first steps for both cases are common and consist of calculating and normalizing a set of indicators defined and grouped into 10 application fields and 4 categories.

After these first steps, if the objective is to characterize the city, we will work with the Analytic Hierarchy Process method taking into account the priorities and needs of the city. Since the priorities and needs of cities are different in each case and each one has different urban plans and characteristics; prioritization will be adapted to those characteristics of the city and therefore will be different for each city.

If, on the contrary, the procedure is used to know the impact of the project in each of the cities, we will have a common weight system for all of them where a group of experts will be in charge of weighing each of the indicators, also using the Analytic Hierarchy Process method.

In both cases the procedure to generate the necessary indices for the evaluation will be carried out following these four steps:

- Step I: Indicators Calculation, where objective results are obtained.
- Step II: Indicators Normalisation, where results are scored according to a scale (from 0 to 10).
- Step III: Prioritisation of categories, application fields and indicators (through the AHP method).
- Step VI: Aggregation to calculate city indices, where final indices are obtained both per category and per application field.

# 3 Procedure for city evaluation

## 3.1 Step I: City Level Indicators Calculation

The foundation for the evaluation procedure presented in this document is the city level indicators that were defined in the D5.1 "City Level Indicators". Consequently, indicators are the lowest level variables of the evaluation framework linked with particular characteristics of cities or projects. Indicators are valuable to establish a diagnosis of starting points, to track progress towards defined goals, to benchmark and to analyse the effect of some actions and assist on the decision-making process.

In task 5.1, indicators have been selected for tracking the overall progress of sustainability targets (related to energy & environment, mobility) and other smart functions (related to governance, society & citizens, ICT) in the project cities. Indicators are an essential part of the evaluation framework, which provides guidelines for monitoring the evolution of a city towards a smarter city. In MAKING-CITY, the city level indicators will be used to show to what extent overall policy goals have been reached in mid- or long-term energy planning considering all project cities in the pursuit of emission neutral cities with intelligent energy systems.

The four sectors or indicator categories selected for the project are energy & environment, mobility, governance and society & citizens (Figure 5). They are further divided into more detailed application fields (see Figure 6). The tables in the following subsections list and briefly describe the individual indicators selected to be the metrics in the city level evaluation. More detailed descriptions and calculation methodology with data needs can be found in D5.1 "City Level Indicators". These indicators have been calculated by all project cities (baseline calculation), and further utilized for city characterization and diagnosis in D1.2. All values can be found in the Annex 1 of this document.

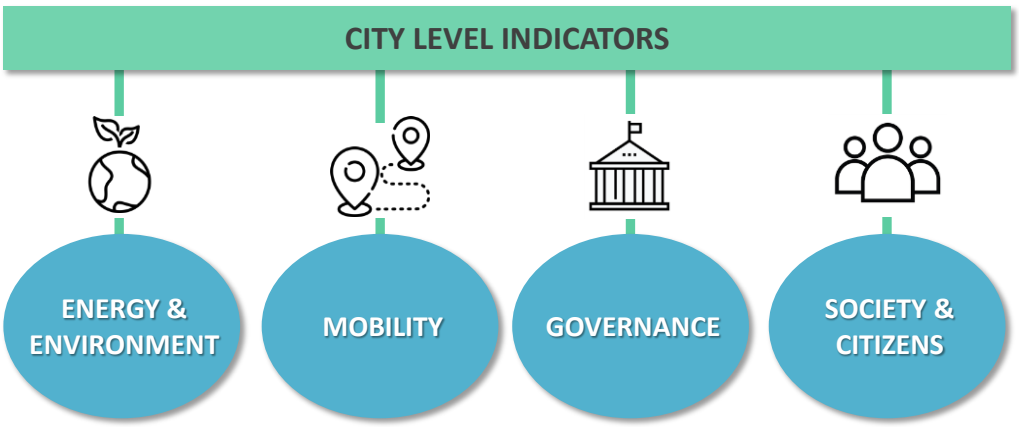


**Figure 5: Classification of the City Level Indicators**

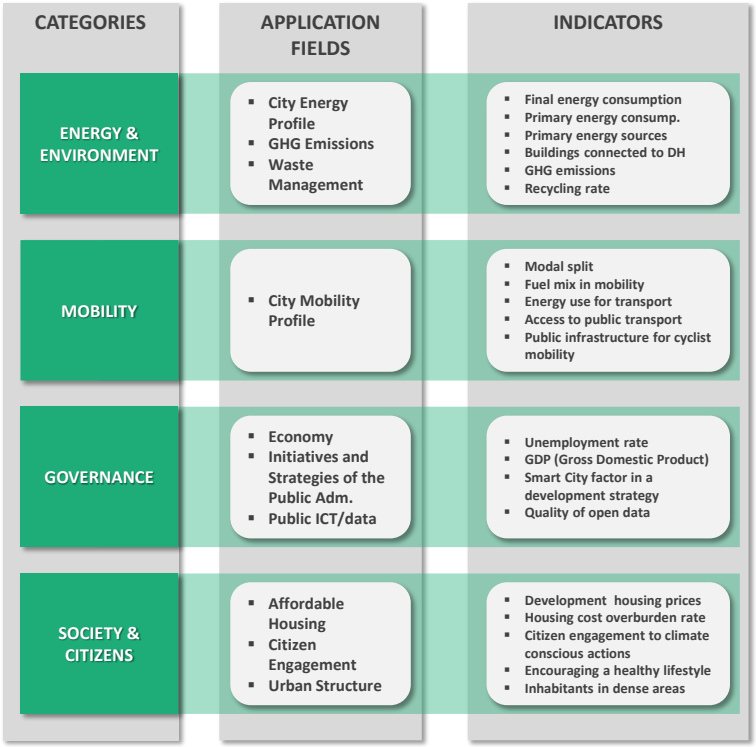


**Figure 6: Top down structure for MAKING-CITY indicators**

### 3.1.1 Energy & environment

**Table 3: City Energy Profile indicators**

| City Energy Profile | | |
|---|---|---|
| Indicator | Unit | Description |
| Final energy consumption per capita | MWh/cap | Annual final energy consumption for all uses and forms of energy. End users include residential, tertiary sector, public lighting, industry and transport.<br>The final energy consumption is divided by the number of inhabitants in the city (total city population). This applies to the other per-capita indicators. |
| Primary energy consumption per capita | MWh/cap | This indicator corresponds with the primary energy consumed in the city that is the energy forms found in nature (e.g. coal, oil and gas) which have to be converted (with subsequent losses) to useable forms of energy. |
| Primary energy sources (shares) | % and MWh/cap | Shares of different fuel types used for energy generation inside city boundaries [Solid fossil fuels, Natural gas, Oil and petroleum, Renewables and biofuels, Electricity from the grid]. |
| Building connected to the DH-network or renewable energy grid | % of buildings/city | Percentage of buildings connected to high-efficiency district heating network or local renewable energy grid in the city. |

**Table 4: GHG Emissions indicators**

| GHG Emissions | | |
|---|---|---|
| Indicator | Unit | Description |
| GHG emissions per capita | Tonnes of $CO_2$/cap | The $CO_2$ emissions generated over a calendar year by all activities including indirect emissions outside city boundaries. |

**Table 5: Waste Management indicators**

| Waste Management | | |
|---|---|---|
| Indicator | Unit | Description |
| Recycling rate | % of tonnes | Percentage of city's solid waste that is recycled. |

### 3.1.2 Mobility

**Table 6: City Mobility Profile indicators**

| City Mobility Profile | | |
|---|---|---|
| Indicator | Unit | Description |
| Modal split | % | Shares of different modes of transportation. The indicator searches the total number but also to distinguish in inner-city traffic and commuter-traffic (from outside) [Walk, bike, public transport, car; private motor vehicle]. |
| Fuel mix in mobility | % | Percentage of the market share of transport fuel for each type of fuel used [Gas oil and diesel oil, Gasoline, Blended biodiesels, Liquefied Petroleum Gases, Electricity, Other fuels]. |
| Energy use for transportation per capita | MWh/cap | Final energy consumption of the transport sector. |
| Access to public transport | % of people | Share of population with access to a public transport stop within 500 meters. |
| Public infrastructure promoting low-carbon mobility | km/100,000 people | Length of lanes in the city for low-carbon mobility per 100,000 inhabitants: cycling lanes (including the length of combined cycling and walking lanes, and streets with speed limit <=30 km/h). |

### 3.1.3 Governance

**Table 7: Economy indicators**

| Economy | | |
|---|---|---|
| Indicator | Unit | Description |
| Unemployment rate | % of active population | Percentage of the labour force unemployed. |
| GDP (Gross Domestic Product) | €/cap | City's Gross Domestic Product per capita. |

**Table 8: Initiatives and Strategies of the Public Administration indicators**

| Initiatives and Strategies of the Public Administration | | |
|---|---|---|
| Indicator | Unit | Description |
| Smart city factor in a city development strategy | Likert scale | Inclusion and level of detail of smart cities strategies in the urban strategic plans of the city. Likert scale:<br>Not at all – 1 – 2 – 3 – 4 – 5 – Very detailed |

**Table 9: Public ICT / Data indicators**

| Public ICT / Data | | |
|---|---|---|
| Indicator | Unit | Description |
| Quality of open data | Likert scale | The extent to which the quality of the open data produced by the city was increased. Likert scale:<br>Not at all – 1 – 2 – 3 – 4 – 5 – Excellent |

### 3.1.4 Society & citizens

**Table 10: Affordable Housing indicators**

| Affordable Housing | | |
|---|---|---|
| Indicator | Unit | Description |
| Development of housing prices | % of change or % of €/$m^2$ | Development of average price for buying an apartment per $m^2$ in the city. |
| Housing cost overburden rate | % | The percentage of the population living in households where the total housing costs ('net' of housing allowances) represent more than 40 % of disposable income ('net' of housing allowances). |

**Table 11: Citizen Engagement and Empowerment indicators**

| Citizen Engagement and Empowerment | | |
|---|---|---|
| Indicator | Unit | Description |
| Citizen engagement/empowerment to climate conscious actions | Likert scale | Appreciation of the benefits of city actions; Energy empowerment at home, satisfaction, happiness of people. Likert scale: No engagement – 1 – 2 – 3 – 4 – 5 – High engagement |
| Encouraging a healthy lifestyle | Likert scale | The extent to which policy efforts have been undertaken to encourage a healthy lifestyle. Likert scale: Not at all – 1 – 2 – 3 – 4 – 5 – Excellent |

**Table 12: Urban Structure indicators**

| Urban Structure | | |
|---|---|---|
| Indicator | Unit | Description |
| Inhabitants in dense areas | % of people | Percentage of the population living in dense areas of the city (over 20 inhabitants/ hectare). |

## 3.2 Step II: Indicators Normalisation

Normalisation gives a score to each indicator, regarding some criteria, to be able to compare and diagnose or understand at a glance the state of the city according to certain aspects.

Taking into account the commonly used methods of normalisation[1] the method chosen combines the Standardisation method (or z-scores), the re-scaling, and the distance to a reference country.

1. Standardisation (or z-scores): for each indicator the average value and the standard deviation across counties are calculated. The normalised indicator value for a city is then calculated as the ratio of the difference between the raw indicator value and the average divided by the standard deviation. This is the most common normalisation technique because it converts all indicators to a common scale. With this approach, the range (minimum, maximum) differs among the normalised indicators.
2. Re-scaling: each indicator for a given city at a given time is calculated as the ratio of the difference between the raw indicator value and the minimum value divided by the range. This method uses the range rather than the standard deviation. All normalised indicators have identical range (0,1).
3. Distance to a reference country: this method divides the indicator value for a given country at a given point in time with the value of a reference country at an initial time.

The method transforms the indicator values to have an identical range (0-10), where 10 is always the best value, and 0 is the worst; and information regarding relative distances between indicators is retained.

[1] From the European Commission website: COIN (Competence Centre on Composite Indicators and Scoreboards), Step 5: Normalisation, online: https://composite-indicators.jrc.ec.europa.eu/?q=10-step-guide/step-5-normalisation

In first place, a target value was assigned to each indicator. This target or "ideal" value receives a score of 10, which will be the score of all cities that reach or exceed it. This target was obtained for most of the indicators from European plans or forecasts. For indicators that do not have a defined European target, this is assigned to the best value among the eight project cities or to the average of the values of the cities, as consider (the values of the indicators corresponding to the eight cities used for these calculations can be found in the D1.2 and a summary has been included in the Annex 1). And finally, qualitative indicators, which are those measured on Likert scale, have already a best value (target) which would be 5 according to the scale.

Once having the target value, which may be the minimum or maximum, depending on the indicator, the opposite value is calculated, that is, the worst value, to which the zero score will be assigned. This value is calculated using the standard deviation and the average value of the project city figures in the following way:

- If the worst value searched for will be the maximum value:

  Max = Average + 2.5* Standard deviation

- If the worst value searched will be the minimum value:

  Min = Average – 2.5* Standard deviation

With the correspondent worst value for each indicator, the maximum or the minimum, or both in case the that the target value is an average value, and they are inadvisable values above and below; the indicators values of the cities are scored following the Min-Max method, consisting of calculating the difference between the value of the indicator and maximum or minimum value depending of if target value is maximum or minimum and dividing it by the difference between the maximum and minimum value.

If target value is the maximum between target and worst values:

$$\text{Score of the indicator} = \left(\frac{|\,\mathbf{X-min\ value}\,|}{|\mathbf{Target\ value-Worst\ value}|}\right) \boldsymbol{x}\ \mathbf{10},$$

If target value is the minimum between target and worst values

$$\text{Score of the indicator} = \left(\frac{|\,\mathbf{X-max\ value}\,|}{|\mathbf{Target\ value-Worst\ value}|}\right) \boldsymbol{x}\ \mathbf{10},$$

where X is the value of the indicator, target value and worst value would be the maximum and the minimum values or vice versa, depending on the indicator; and multiplied by 10 to have the score scaled from 0 to 10.

The following tables Table 13 to

Table 18 show the values established as targets and those as worst for each indicator, calculated as explained above. The source or way in which the target value has been obtained has also been included in order to better understand and identify where it comes from for each indicator.

**Table 13: Energy & Environment indicators normalisation methodology**

| ENERGY & ENVIRONMENT INDICATORS | | | | | |
|---|---|---|---|---|---|
| Application field | Indicator | Unit | Target value | Worst value | Source of the Target value |
| City Energy Profile | Final energy consumption per capita | MWh/cap | 16.93 | 34.84 | Covenant of Mayors [1] |
| | Primary energy consumption per capita | MWh/cap | 33.73 | 48.04 | EEA (European Environment Agency) [2] |
| | Primary energy sources (renewables and biofuels) | % | 20% | 0% | Eurostat [3] |
| | | MWh/cap | 2.29 | 0.00 | Covenant of Mayors [1] |
| | Building connected to the DH-network or renewable energy grid | % of buildings/ city | Values in Table 14 according to the Heating degree days | | Euroheat [4] |
| GHG Emissions | GHG emissions per capita | Tonnes of $CO_2$/cap | 4.11 | 9.76 | Covenant of Mayors [1] |
| Waste Management | Recycling rate | % of tonnes | 50% | 21% | EEA (European Environment Agency) [5] |

As the cities are all European and have no substantial differences between them, they have not been clustered, since the targets do not vary according to the circumstances of the cities. However, a clustering for the indicator *Building connected to the DH-network or renewable energy grid* has been carried out, since for this specific indicator the temperature of the city influences the greater or lesser need to implement a DH system.

The classification that has been carried out to cluster the cities has been done according to the heating degree-days, dividing it into 3 types of climate. In addition, Table 14 below also shows the correspondence made of each type of climate established with the target percentage of buildings connected to the District Heating network or renewable energy grid.

**Table 14: Heating degree-days classification and target values regarding DH-network**

| Classification of cities according to the Heating degree days | | Building connected to the DH-network or renewable energy grid | |
|---|---|---|---|
| Climate | Heating degree days | Target value | Worst value |
| Cold climate | > 3,000 | 50% | 0% |
| Temperate climate | 2,000 – 3,000 | 15% | 0% |
| Warm climate | < 2,000 | 2% | 0% |

The following Table 15 shows the assignment of each type of climate defined with each project city according to their heating degree-days, so that according to the resulting climate type, the cities will have different targets in this indicator.

**Table 15: Cities clustering according to their heating degree-days**

| Classification of cities according to the Heating degree-days during the year 2018 |
|---|

| City | Heating degree days in the year 2018[2] | Climate |
|---|---|---|
| Groningen | 2,235.0 | Temperate climate |
| Oulu | 4,655.0 | Cold climate |

**Table 16: Mobility indicators normalisation methodology**

| MOBILITY INDICATORS | | | | | |
|---|---|---|---|---|---|
| Application field | Indicator | Unit | Target value | Worst value | Source of the Target value |
| City Mobility Profile | Modal split (use of non-car transport: walk, bike and public transport) | % | 74% | 21% | Kadiköy value (best value) (30% target in Covenant of Mayors [1] is exceeded by almost all cities) |
| | Fuel mix in mobility (electric mobility) | % | 10.00% | 0.00% | Eurostat [6] |
| | Energy use for transportation | MWh/cap | 5.16 | 11.08 | Covenant of Mayors [1] |
| | Access to public transport | % of people | 100% | 64% | Value of: Groningen, León, Kadiköy and Vidin (best value) |
| | Public infrastructure promoting low-carbon mobility | Km/ 100.000 people | 217.00 | 0.00 | Average value of MAKING-CITY cities |

**Table 17: Governance indicators normalisation methodology**

| GOVERNANCE INDICATORS | | | | | |
|---|---|---|---|---|---|
| Application field | Indicator | Unit | Target value | Worst value | Source of the Target value |
| Economy | Unemployment rate | % of active population | 5.00% | 18.64% | Sustainable Development Goal 8 [6] |
| | GDP (Gross Domestic Product) | €/cap | 20.638 | 0 | Average value of MAKING-CITY cities |
| Initiatives and Strategies of the Public Administration | Smart city factor in a city development strategy | Likert scale | 5 | 1 | Qualitative indicator |
| Public ICT/ Data | Quality of open data | Likert scale | 5 | 1 | Qualitative indicator |

[2] Data collected from Degree Days website: https://www.degreedays.net/

**Table 18: Society & Citizens indicators normalisation methodology**

| SOCIETY & CITIZENS INDICATORS | | | | | |
|---|---|---|---|---|---|
| Application field | Indicator | Unit | Target value | Worst value | Source of the Target value |
| Affordable Housing | Development of housing prices | % of change | 2.50% | -20.07% / 26.47% | The balance [8] (based on the Ideal GDP growth, which resembles the growth that housing should consequently have). |
| | Housing cost overburden rate | % | 6.60% | 20.17% | Oulu value (best value) |
| Citizen Engagement and Empowerment | Citizen engagement to climate conscious actions | Likert scale | 5 | 1 | Qualitative indicator |
| | Encouraging a healthy lifestyle | Likert scale | 5 | 1 | Qualitative indicator |
| Urban Structure | Inhabitants in dense areas | % of people | 78.08% | 10.62% | Average value of MAKING-CITY cities |

## 3.3 Step III: Prioritisation of categories, application fields and indicators

Once the indicators have been calculated and their values normalized, the third step of the proposed methodology consists in assigning different weights to every normalised indicator and group of indicators.

There are several methods for weighting indicators [9] that can be categorized into groups:

- Equal weighting: it is a method itself, in which all variables are given the same weight. This method could result in an unbalanced structure in the composite index when there are variables grouped into dimensions and those are further aggregated into the composite (because the dimensions grouping the larger number of variables will have higher weight).
- Statistic-based method: in this category PCA (Principal components analysis), Benefit of the doubt approach (BOD), Regression Analysis (RA) and Unobserved component models (UCM) would be included
- Public/expert opinion-based weighting: Budget allocation (BAL), Public opinion (PO), Analytic hierarchy process (AHP) and Conjoint analysis (CA) are in this third category.

The method adopted for this step is the Analytic hierarchy process (AHP), which is a multi-criteria decision-making approach introduced by Saaty [10]. The AHP [11,12] is a decision support tool which can be used to solve complex decision problems. It uses a multi-level hierarchical structure of objectives, criteria, sub-criteria, and alternatives. The pertinent data are derived by using a set of pairwise comparisons. These comparisons are used to obtain the weights of importance of the decision criteria, and the relative performance measures of the alternatives in terms of each individual decision criterion.

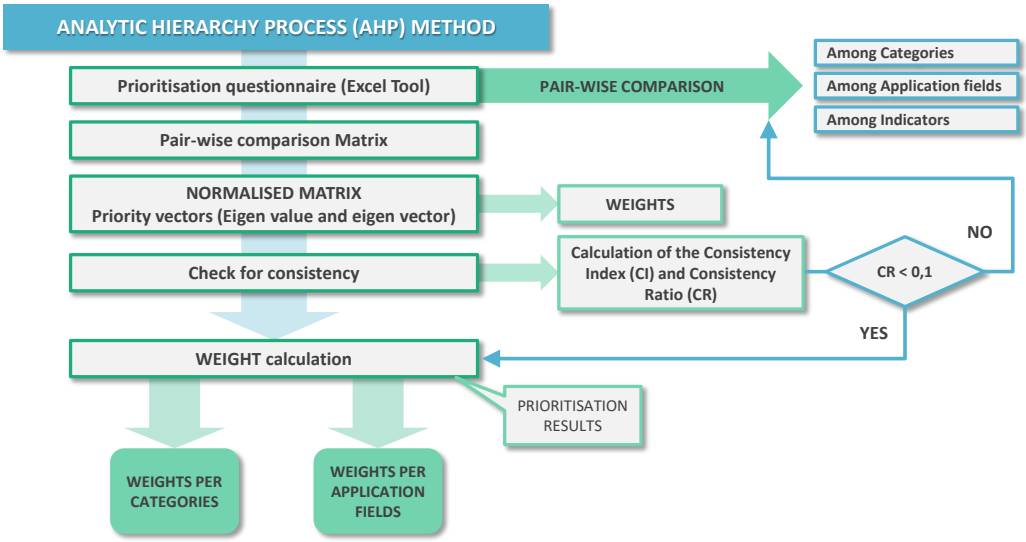


**Figure 7: Analytic Hierarchy Process (AHP) approach**

The method follows three steps:

- First step is to structure the indicators into a hierarchical framework with successive levels of goal, criteria and alternatives; which are the categories and application fields to structure the indicators as shown in Figure 6
- Second step is the comparison analysis, once the hierarchy has been structured, the ratio priorities must be established for each node of the hierarchy. This is done through pair-wise comparisons with respect to the importance of the item to the parent node.

The pair-wise comparison of the second step within the AHP is structured in the following parts, according to the structure of the MAKING-CITY indicators:

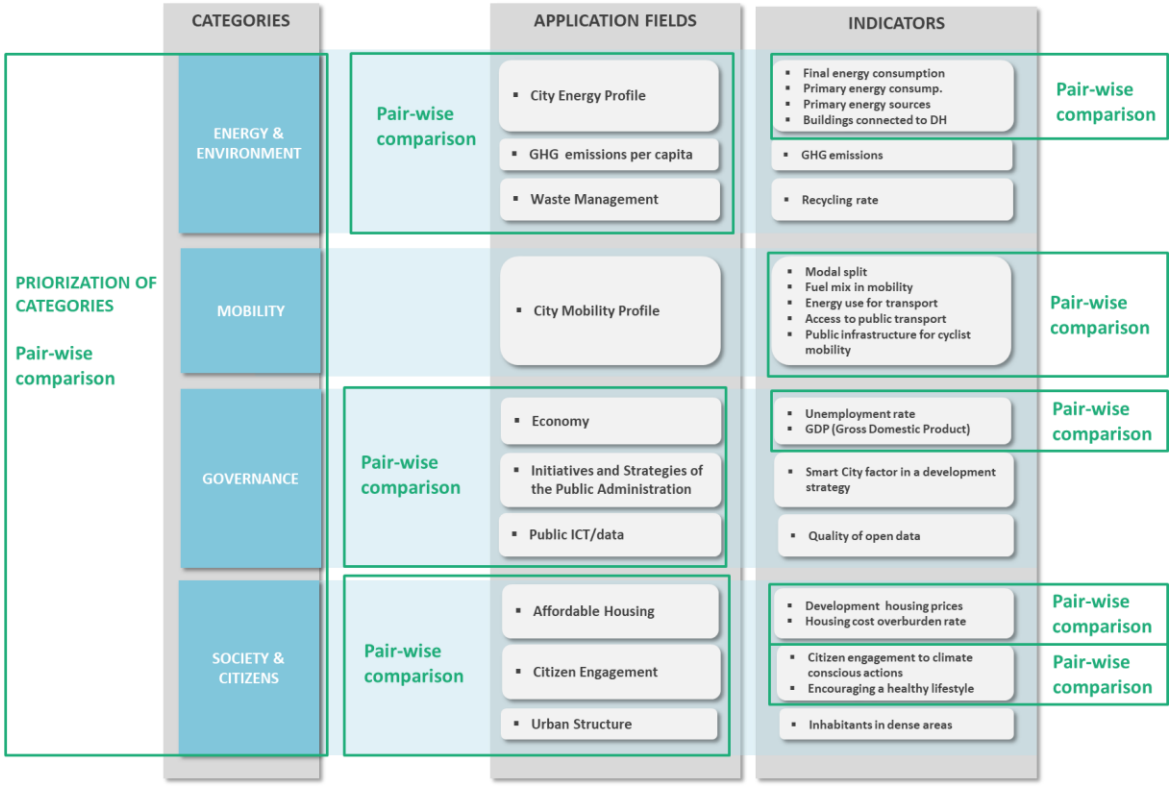


**Figure 8: Pair-wise comparison defined within the structure of the MAKING-CITY indicators**

- Third step is aggregate the local weights into a composite priority. This final step is done by multiplying local weights by the product of all higher-level priorities. Within the hierarchy, this process transforms the local weights into global weights that measure the importance of each node in the total hierarchy.

  For the last step of the AHP methodology, the calculation of composite priority is done by using a nine-point scale. The deployment of AHP involves successive comparisons between each alternative, criterion by criterion, according to the fundamental scale of Saaty (1980), as presented in Table 19.

**Table 19: Scale of relative importance of the AHP method**

| The comparison scale | | |
|---|---|---|
| Scale | Definition | Comments |
| 1 | Equal importance | Element A is just as important as element B |
| 3 | Moderate importance | Experience and judgement slightly favour element A over B |
| 5 | Essential importance | Experience and judgement strongly favour element A over B |
| 7 | Very strong importance | Element A is much more important than element B |
| 9 | Extreme importance | The greater importance of element A over B is beyond doubt |
| 2, 4, 6, 8 | Intermediate values | |

From the comparison matrix, next step is to compute the priority vector, which is the normalised Eigen vector of the matrix. The normalised principal Eigen vector can be obtained by averaging across the rows, and it is also called priority vector, which shows the relative weights among the categories that are being compared.

Aside from the relative weight, consistency needs to be checked. The comparison matrix is considered to be adequately consistent if the corresponding consistency ratio (CR) is less than 10% (Saaty, 1980 [10]). The CR coefficient is calculated from the consistency index (CI), which is estimated by adding the rows in the comparison matrix and multiply the resulting vector of priorities obtained earlier. This yields an approximation of the maximum Eigen value, denoted $\lambda_{MAX}$. Then, the CI value is calculated by using the formula: $CI = (\lambda_{MAX} - n) / (n - 1)$, where *n* is the matrix size. Next, the consistency ratio (CR) is obtained by dividing the CI value by the Random Index (RI): $CR = CI / RI$

An example of this prioritization process has been included in Annex 2 – Example of prioritisation exercise: Energy and Environment prioritization.

The AHP method is applied as is presented in Annex 2 to calculate the weights of the application fields and indicators of the all the MAKING-CITY categories, obtaining the corresponding weights for all the categories.

## 3.4 Step IV: Aggregation to calculate the city indices

For this last step of the MAKING-CITY methodology, there are several aggregation techniques. The purpose of this step is to aggregate the indicators and their weights to obtain a composite index. These composite Indices will be calculated per categories and per application fields.

According to the European Commission 10 Step Guide [13] and to the OECD [14], the most common aggregation techniques are as follows [15]:

- Additive methods: this method is consisting of sum up the normalised values of sub-indicators to form a sustainability index. The simplest additive aggregation method entails the calculation of the ranking of each city according to each individual indicator and summation of the resulting rankings (it is based on ordinal information). The second method is based on the number of indicators that are above and below a given benchmark; this uses nominal scores for each indicator to calculate the difference between the number of indicators above and below and arbitrarily defined threshold around the mean. By far, the most widespread linear aggregation is the summation of weighted and normalised individual indicators.
- Geometric aggregation: it is a less compensatory approach. This method utilizes multiplicative instead of additive functions. The compensability between is allowed with certain limitations. These limitations exist because the ability of indicators with very low scores is limited to be fully compensated for by indicators with high scores.
- Non compensatory multi-criteria approach (MCA): in both additive and geometric aggregations the substitution rates among indicators are equal to the weights of the indicators up to a multiplicative coefficient. For the weights to be interpreted as “importance coefficients”, non-compensatory aggregation procedures must be used to construct the composite indicators. This procedure is based on decision-maker preferences and is centred on the fact that a general objective of most indices is to create rankings. Therefore, the core of this method is to construct a ranking algorithm that is more consistent than the linear aggregation rule. This last method is not compatible with the selected method AHP for weighting, since at least with the multi-criteria methods require weights as importance coefficients.

The OECD [14] states that linear aggregation method is useful when all individual indicators have the same measurement unit, provided that some mathematical properties are respected. Geometric aggregation is better suited if the modeler wants some degree of non-compensability between individual indicators or dimensions. Furthermore, linear aggregations reward base-indicators proportionally to the weights, while geometric aggregations reward those cities with higher scores.

In addition, in both linear and geometric aggregation, weights express trade-offs between indicators. A deficit in one dimension can thus be offset (compensated) by a surplus in another. The selected method to construct the indices is the linear aggregation. This is because after normalisation step, all the indicators are scored on the same scale, and it is also convenient for this diagnostic analysis that some of them can be compensated by other better rated ones that fall within the same category or application field (since they have been grouped together precisely because of the interrelation they have).

The aggregation is carried out in two ways, obtaining two types of diagnoses: one more general with four indices of the categories; and another one more in detail or specific that includes the ten indices for the application fields. This is in accordance with the previous obtaining of the weights by category and application field, so that once the scoring in Step II and the weighting in Step III are calculated, the aggregation in this Step IV is done directly by multiplying each other and adding it into each category or application field.

For each city, apart from the numerical obtaining of these indices, a graphic representation is also made in the form of a radar diagram.

# 4 Deployment of the methodology for evaluation at city level in MAKING CITY

Since one of the main objectives of MAKING-CITY project is to achieve evidences about the actual potential of the PED concept, it is important to evaluate the actions deployed in the lighthouse cities at project level but also it is needed to know the impact of these actions in the city as a whole. Knowledge about the final results and real impacts achieved will be very useful from the replicability point of view but also the conclusions of the project after the evaluation procedure will be able to be considered for the development of new and integrated strategies that will be defined to address the urban energy system transformation towards low carbon cities, with the positive energy district approach as the core of the urban energy transition,

As mentioned in previous sections, the MAKING-CITY evaluation methodology can be applied with two different objectives. As can be seen in the Figure 9, the methodology can be used for the characterization of the city and the establishment of its demand, and on the other hand, the methodology allows evaluating the impact of the actions implemented in the project by comparing the initial state with the final one, after the implementation of the project interventions.

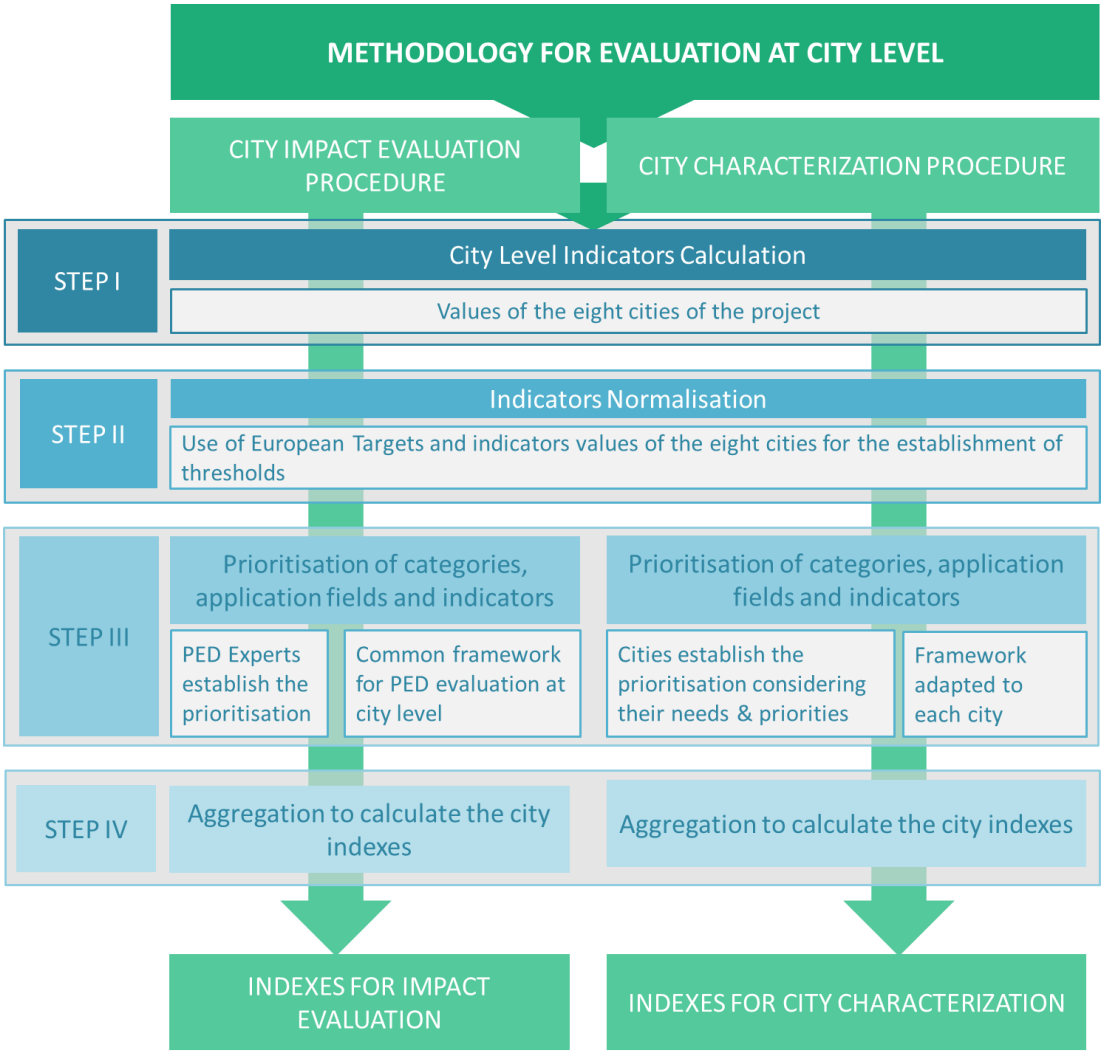


**Figure 9: Scheme of methodology for city level evaluation**

The first two steps of the methodology are common regardless of the objective that wants to be achieved. The main difference is found in the third step of the methodology where the establishment of the necessary weights for the prioritization of categories, fields of application and indicators is done.

When the objective is to characterize the city, it is needed to consider the existing city plans and the particular conditions of each city, so the cities themselves have been in charge of establishing their priorities and the necessary weights for the calculation of the final indices. This task has been carried out by the eight cities of the project and the results have been presented in the D1.2.

If, on the contrary, the objective is to analyze the impact that MAKING-CITY actions have had on the city in a global way, the establishment of the weights has to be common for all cities which want to evaluate the impact of the Positive Energy District in the city. For this reason, the weighs have been established by a group of experts who have taken into account the most relevant aspects of the implementation of the PEDS and how these aspects can impact in the city.

This methodology has been applied to the two lighthouse cities and the results presented in this deliverable will be considered as baseline to be compared with the status of these indicators at the end of the project, after the implementation of the three Positive Energy Districts.

## 4.1 Step I: Indicators Calculation by the eight project cities

The indicators are calculated using available data, according to their definition and the formula provided. One of the biggest problems at this step is related to the lack of certain data. Due to the studied and careful selection of the indicators within the T5.1, this problem has been minimized in the cities, being non-existent in most of them. For cases where it is not possible to obtain an indicator, data is taken at regional or country level when available, what can be compared with the nearest neighbour method among the methods suggested by the European Commission in the 10 Step guide[3], Step 3: Imputation of missing data.

For cases in which an indicator could not be calculated and the national (or preferably regional if possible) did not work or did not exist, the estimate would be done by comparing the city with another with similar characteristics in the terms of the purpose of the indicator.

The eight cities of the project have calculated the city level indicators and the results can be found in D1.2. The units in which each indicator is measured and the disaggregation that had to be done in those requiring more than one figure were fixed; with what they are well prepared to be compared and normalised in a common way and between the different cities under the same criteria.

D5.4 is focused on the city impact evaluation procedure, so although the eight cities of the project have calculated the city level indicators for their characterization (D1.2), in this deliverable only the results related to the lighthouse cities are presented since the city impact evaluation is focused on the impact assessment of the actions implemented in these cities.

The city level indicators of the two lighthouse cities are presented in the following tables (Table 20 to

Table 23):

[3] From the European Commission website: COIN (Competence Centre on Composite Indicators and Scoreboards). Online: https://composite-indicators.jrc.ec.europa.eu/?q=10-step-guide/, Step 3: Imputation of missing data, online: https://composite-indicators.jrc.ec.europa.eu/?q=10-step-guide/step-3-imputation-missing-data

**Table 20: Energy and environment indicators calculation**

| ENERGY & ENVIRONMENT | | | | | |
|---|---|---|---|---|---|
| Application field | Indicator | | UNIT | GRONINGEN VALUES | OULU VALUES |
| City Energy Profile | Final energy consumption per capita | | MWh/cap | 24.60 | 23.00 |
| | Primary energy consumption per capita | | MWh/cap | 30.60 | 26.00 |
| | Primary energy sources | Solid fossil fuels | % | 0.00% | 27.00% |
| | | Natural gas | | 51.80% | 0.00% |
| | | Oil and petroleum | | 24.00% | 30.00% |
| | | Renewables and biofuels | | 4.30% | 35.00% |
| | | Electricity from the grid | | 19.90% | 9.00% |
| | | Solid fossil fuels | MWh/cap | 0.00 | 6.67 |
| | | Natural gas | | 15.85 | 0.00 |
| | | Oil and petroleum | | 7.34 | 7.19 |
| | | Renewables and biofuels | | 1.32 | 8.56 |
| | | Electricity from the grid | | 6.09 | 2.11 |
| | Building connected to the DH-network or renewable energy grid | | % of buildings/city | 1% | 61% |
| GHG Emissions | GHG emissions per capita | | Tonnes of $CO_2$ /cap | 5.40 | 5.50 |
| Waste Management | Recycling rate | | % of tonnes | 78% | 99% |

**Table 21: Mobility indicators calculation**

| MOBILITY | | | | | |
|---|---|---|---|---|---|
| Application field | Indicator | | UNIT | GRONINGEN VALUES | OULU VALUES |
| City Mobility Profile | Modal split | Walk | % | 15% | 22% |
| | | Bike | | 55% | 21% |
| | | Public transport | | 3% | 4% |
| | | Non-car transport | | 73% | 47% |
| | | Car (private motor vehicle) | | 27% | 54% |
| | Fuel mix in mobility | Gas oil and diesel oil | % | 43.20% | 52.00% |
| | | Gasoline | | 54.50% | 32.00% |
| | | Liquefied Petroleum Gases | | 2.10% | 0.00% |
| | | Electricity | | 0.20% | 2.00% |
| | | Other fuels | | 0.00% | 14.00% |

| MOBILITY | | | | |
|---|---|---|---|---|
| Application field | Indicator | UNIT | GRONINGEN VALUES | OULU VALUES |
| | Energy use for transportation | MWh/cap | 6.20 | 7.00 |
| | Access to public transport | % of people | 98% | 70% |
| | Public infrastructure promoting low-carbon mobility | Km/100,000 people | 275.00 | 1,000.00 |

**Table 22: Governance Indicators calculation**

| GOVERNANCE | | | | |
|---|---|---|---|---|
| Application field | Indicator | UNIT | GRONINGEN VALUES | OULU VALUES |
| Economy | Unemployment rate | % of active population | 7.20% | 9.60% |
| | GDP (Gross Domestic Product) | €/cap | 44,800 | 31,300 |
| Initiatives and Strategies of the Public Administration | Smart city factor in a city development strategy | Likert scale | 4 | 4 |
| Public ICT/ Data | Quality of open data | Likert scale | 3 | 4 |

**Table 23: Society and citizens indicators calculation**

| SOCIETY & CITIZENS | | | | |
|---|---|---|---|---|
| Application field | Indicator | UNIT | GRONINGEN VALUES | OULU VALUES |
| Affordable Housing | Development of housing prices | % of change or % of €/m$^2$ | -4.00% | 1.90% |
| | Housing cost overburden rate | % | 9.40%[4] | 6.60% |
| Citizen Engagement and Empowerment | Citizen engagement to climate conscious actions | Likert scale | 4 | 4 |
| | Encouraging a healthy lifestyle | Likert scale | 4 | 4 |
| Urban Structure | Inhabitants in dense areas | % of people | 95.30% | 56.80% |

[4] Data at country level since Groningen data are not available

## 4.2 Step II: Indicators Normalisation for impact evaluation & city characterization

Taking into account the target and worst values established for each indicator and the indicators calculated by the cities (Table 20 to Table 23) these were normalized and the results can be seen in the following tables. For the establishment of the target values the results of all the cities collected in the D1.2 were taken into account in order to obtain a better reference value.

**Table 24: Normalized values for Energy & Environment indicators**

| ENERGY & ENVIRONMENT | | | |
|---|---|---|---|
| Application field | Indicator | GRONINGEN NORMALIZED VALUES | OULU NORMALIZED VALUES |
| City Energy Profile | Final energy consumption per capita | 5.72 | 6.61 |
| | Primary energy consumption per capita | 10.00 | 10.00 |
| | Primary energy sources (shares) | 3.96 | 10.00 |
| | Building connected to the DH-network | 0.67 | 10.00 |
| GHG Emissions | GHG emissions per capita | 7.72 | 7.54 |
| Waste Management | Recycling rate | 10.00 | 10.00 |

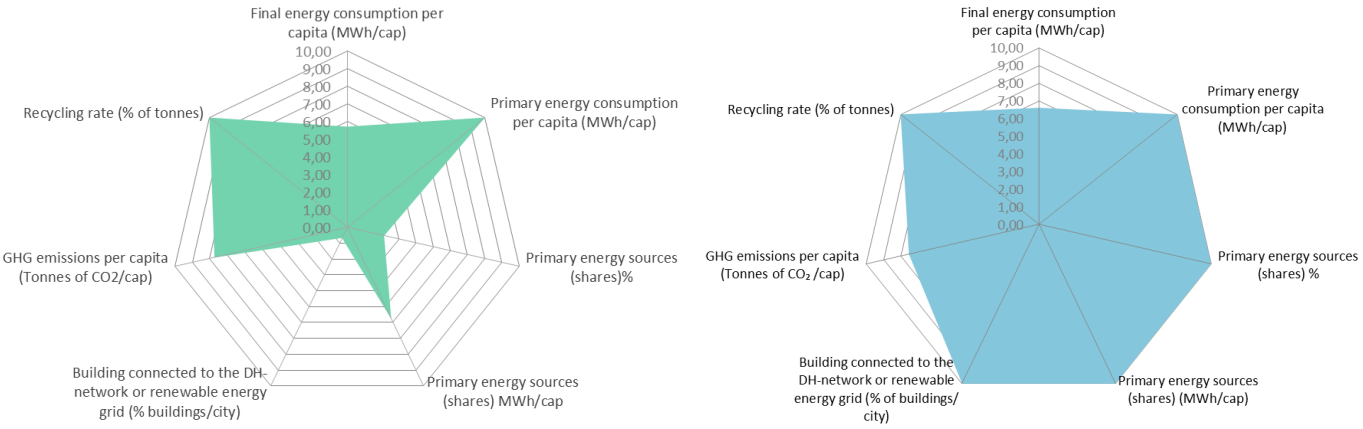


**Figure 10: Normalized values for Energy and Environment indicators (Groningen in green and Oulu in blue)**

**Table 25: Normalized values for Mobility indicators**

| MOBILITY | | | |
|---|---|---|---|
| Application field | Indicator | GRONINGEN NORMALIZED VALUES | OULU NORMALIZED VALUES |
| City Mobility Profile | Modal split | 9.81 | 4.94 |
| | Fuel mix in mobility | 0.20 | 2.00 |

| | | | |
|---|---|---|---|
| | Energy use for transportation | 8.24 | 6.89 |
| | Access to public transport | 9.44 | 1.59 |
| | Public infrastructure promoting low-carbon mobility | 10.00 | 10.00 |

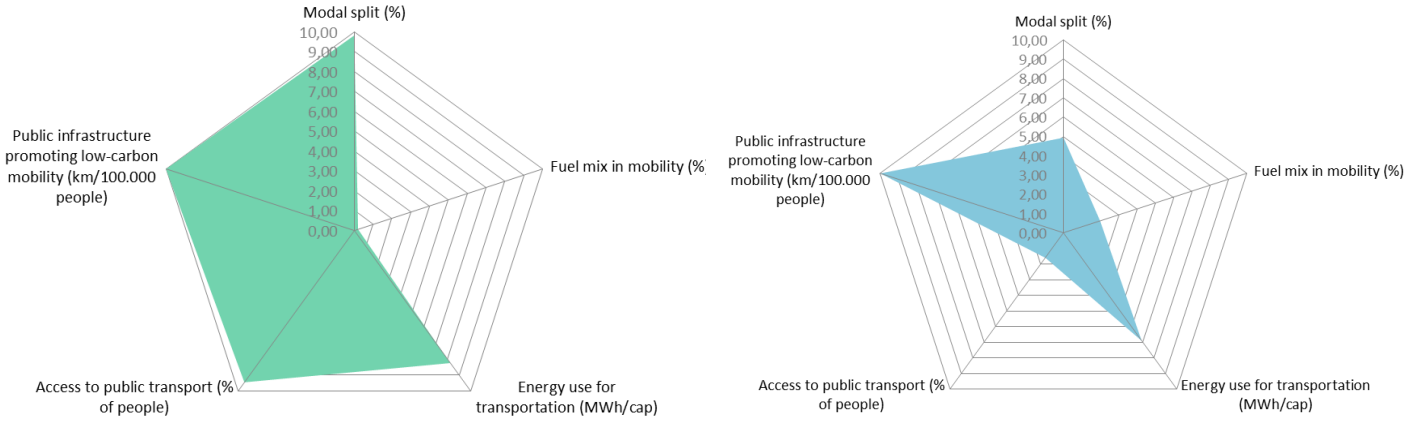


**Figure 11: Normalized values for Mobility indicators (Groningen in green and Oulu in blue)**

**Table 26: Normalized values for Governance indicators**

| GOVERNANCE | | | |
|---|---|---|---|
| Application field | Indicator | GRONINGEN NORMALIZED VALUES | OULU NORMALIZED VALUES |
| Economy | Unemployment rate | 8.39 | 6.63 |
| | GDP (Gross Domestic Product) | 10.00 | 10.00 |
| Initiatives and Strategies of the Public Administration | Smart city factor in a city development strategy | 7.50 | 7.50 |
| Public ICT/ Data | Quality of open data | 5.00 | 7.50 |


**Figure 12: Normalized values for Governance indicators (Groningen in green and Oulu in blue)**

**Table 27: Normalized values for Society and Citizens indicators**

| SOCIETY & CITIZENS | | | |
|---|---|---|---|
| Application field | Indicator | GRONINGEN NORMALIZED VALUES | OULU NORMALIZED VALUES |
| Affordable Housing | Development of housing prices | 6.12 | 9.64 |
| | Housing cost overburden rate | 7.94 | 10.00 |
| Citizen Engagement and Empowerment | Citizen engagement to climate conscious actions | 7.50 | 7.50 |
| | Encouraging a healthy lifestyle | 7.50 | 7.50 |
| Urban Structure | Inhabitants in dense areas | 10.00 | 6.85 |

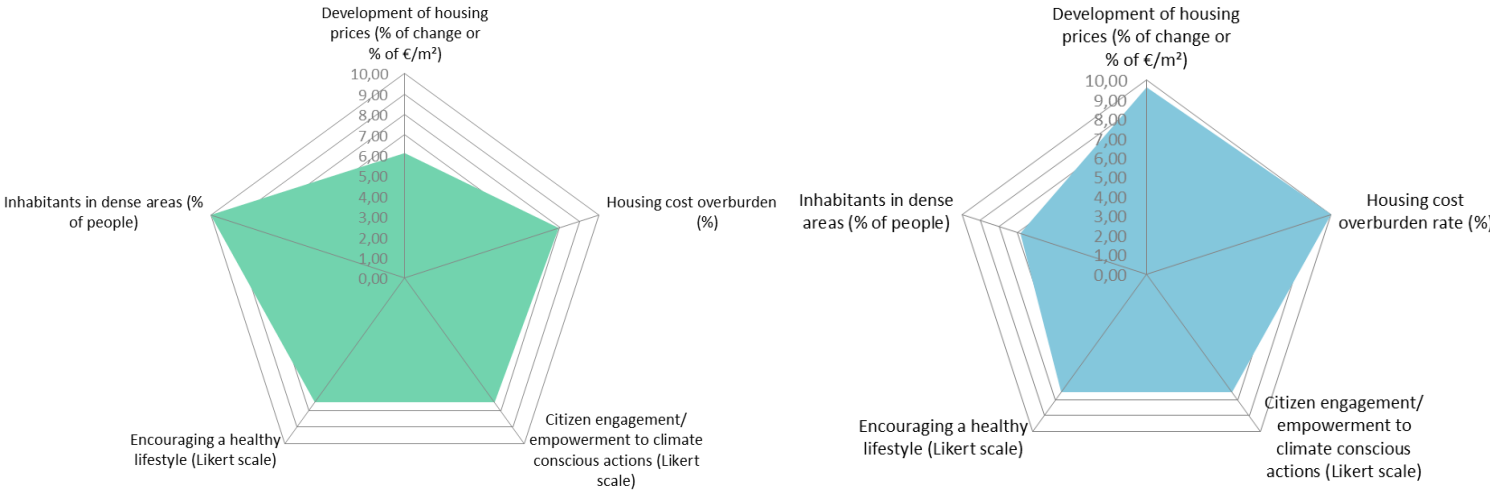


**Figure 13: Normalized values for Society and Citizens indicators (Groningen in green and Oulu in blue)**

## 4.3 Step III: Prioritisation of categories, application fields and indicators for city impact and city characterization

As it has been already mentioned, the prioritization process will be different depending on the objective to be achieved. This section has been divided into two subsections to differentiate the two processes: the first will prioritize the categories, application fields and indicators to evaluate the impact at city level of the actions carried out in the project, and the second will be focused on the city characterization considering the existing city plans, their needs and priorities.

### 4.3.1 Prioritisation for impact evaluation

In order to evaluate the impact that the actions developed in the Project at city level, the indicators defined in the evaluation framework have been analyzed, as well as the application fields and the categories to which they belong, with the objective of prioritizing the most relevant from the point of view of the Positive Energy districts concept.

This task has been carried out by several of the partners involved in the project and which are detailed below:

**Table 28: Experts involved in the prioritization process**

| PARTNER | ORG.TYPE | ROLE IN THE PROJECT |
|---|---|---|
| CARTIF | RTO | Project coordinator. LT Planning and PED method design |
| TECNALIA | RTO | Leader of planning Work Package. LT planning methodology and City Visions 2050 |
| TNO | RTO | Modelling of PEDs for fine design. Baseline definition and monitoring in Groningen. |
| STICHTING ENERGY VALLEY | RTO | Capacity building, guidelines for PED design, business models |
| UNIVERSITY OF GRONINGEN. FACULTY OF SPATIAL SCIENCES | UNIV | Support city planning in Groningen and guidelines for PED design |
| HANZE UNIVERSITY OF APPLIED SCIENCES OF GRONINGEN | UNIV | Monitoring program and evaluation in Groningen demo |
| VTT TECHNICAL RESEARCH CENTRE OF FINLAND | RTO | Leader of evaluation framework definition and Oulu PED design |
| SLOVAK UNIVERSITY OF TECHNOLOGY IN BRATISLAVA | UNIV | Support follower city TN, social innovation and technical design of PED |

The criteria of all experts involved in this prioritization process have been taken into account in order to find the most suitable weights for the definition of the final indices that will be used for the comparison between the city status before and after the interventions.

Considering the structure defined within the Evaluation Framework (Figure 8), several matrixes were created in order to apply the Analytic Hierarchy Process doing a pair-wise comparison between the different available options.

In this comparison analysis, the ratio priorities must be established for each node of the hierarchy through pair-wise comparisons with respect to the importance of the item to the parent node. For this comparison the scale presented in Table 19 has been used.

The weights proposed by each of the experts who have participated in the study are presented in Annex 3 and with that information the final weights have been calculated. On one hand it has been taken into account which of the nodes had more relevance for the experts and on the other hand it has been calculated the arithmetic means of the proposed scores for each of the parent nodes. For the calculation of the final scores it was calculated a pondered mean considering the average score given to the most relevant parent node but also taking into account the inverse one of the opposite node.

Once all pairs have been compared, local weights are aggregated into a composite priority. This is done multiplying local weights by the product of all higher-level priorities. In this way, the local weights are transformed into global weights that measure the importance of each node in the total hierarchy.

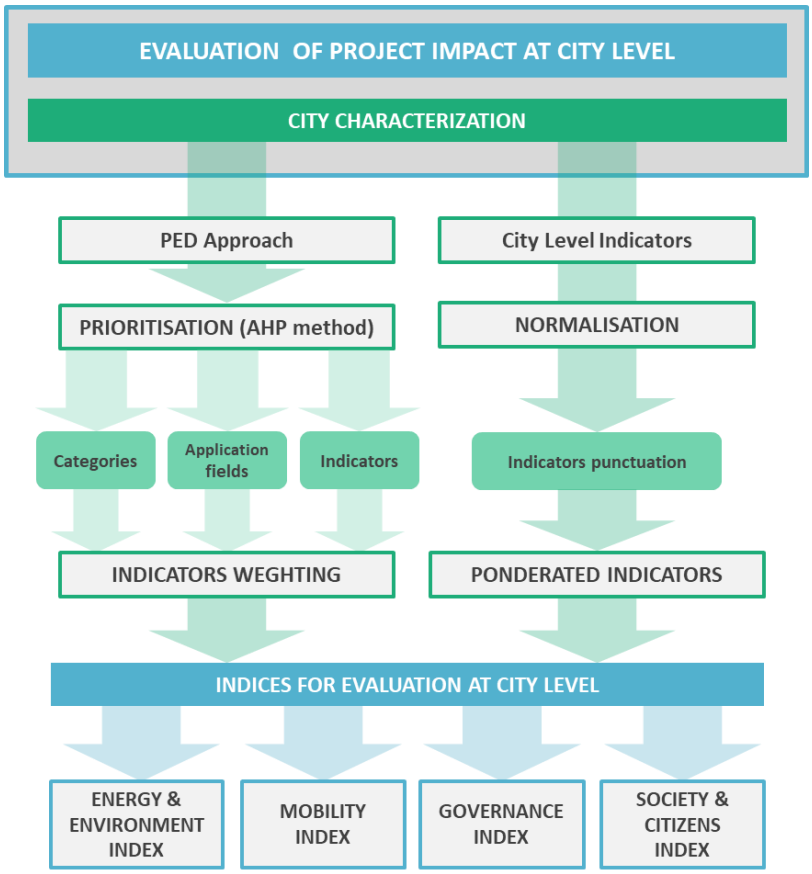


**Figure 14: Evaluation of project impact at city level**

More details about how the method has been applied can be found in the section 3.3, an example of prioritisation exercise is presented in "Annex 2 – Example of prioritisation exercise: Energy and Environment prioritization" and the results of the analysis done by each expert have been included in the Annex 3.

The final prioritization calculated with the information provided by the experts and presented in Annex 3, can be found in following tables:

**Table 29: Category prioritisation**

| CATEGORY PRIORITISATION | | | |
|---|---|---|---|
| A | B | More important (A/B) | Scale (1-9) |
| Energy & Environment | Mobility | A | 5 |
| | Governance | A | 4 |
| | Society & Citizens | B | 2 |
| Mobility | Governance | B | 2 |
| | Society & Citizens | B | 5 |
| Governance | Society & Citizens | B | 3 |

**Table 30: Prioritisation of Energy and Environment Application Fields**

| Energy & Environment prioritisation – Application Fields | | | |
|---|---|---|---|
| A | B | More important (A/B) | Scale (1-9) |
| City Energy Profile | GHG Emissions | A | 2 |
| | Waste Management | A | 3 |
| GHG Emissions | Waste Management | A | 3 |

**Table 31: Prioritisation of Energy and Environment Indicators**

| Energy & Environment prioritisation – Indicators | | | |
|---|---|---|---|
| A | B | More important (A/B) | Scale (1-9) |
| Final energy consumption per capita | Primary energy consumption per capita | B | 3 |
| | Primary energy sources (shares) | B | 3 |
| | Buildings connected to DH-network or renewable energy grid | B | 2 |
| Primary energy consumption per capita | Primary energy sources (shares) | A | 1 |
| | Buildings connected to DH-network or renewable energy grid | B | 3 |
| Primary energy sources (shares) | Buildings connected to DH-network or renewable energy grid | A | 2 |

**Table 32: Prioritisation of Mobility Indicators**

| Mobility – Indicators | | | |
|---|---|---|---|
| A | B | More important (A/B) | Scale (1-9) |
| Modal split | Fuel mix in mobility | B | 2 |
| | Energy use for transportation | A | 3 |
| | Access to public transport | B | 3 |
| | Public infrastructure promoting low-carbon mobility | B | 3 |
| Fuel mix in mobility | Energy use for transportation | A | 2 |
| | Access to public transport | B | 3 |

| Mobility – Indicators | | | |
|---|---|---|---|
| A | B | More important (A/B) | Scale (1-9) |
| | Public infrastructure promoting low-carbon mobility | B | 3 |
| Energy use for transportation | Access to public transport | B | 3 |
| | Public infrastructure promoting low-carbon mobility | B | 3 |
| Access to public transport | Public infrastructure promoting low-carbon mobility | A | 2 |

**Table 33: Prioritisation of Governance Application Fields**

| Governance prioritisation – Application Fields | | | |
|---|---|---|---|
| A | B | More important (A/B) | Scale (1-9) |
| Economy | Initiatives and strategies of the public administration | A | 4 |
| | Public ICT/data | A | 5 |
| Initiatives and strategies of the public administration | Public ICT/data | A | 4 |

**Table 34: Prioritisation of Governance Indicators**

| Governance– Indicators | | | |
|---|---|---|---|
| A | B | More important (A/B) | Scale (1-9) |
| Unemployment rate | GPD (Gross Domestic Product) | A | 2 |

**Table 35: Prioritisation of Social and Citizens Application Fields**

| Society & Citizens prioritisation – Application Fields | | | |
|---|---|---|---|
| A | B | More important (A/B) | Scale (1-9) |
| Affordable housing | Citizen engagement and empowerment | A | 3 |
| | Urban Structure | A | 3 |
| Citizen Engagement and Empowerment | Urban Structure | A | 3 |

**Table 36: Prioritisation of Social and Citizens Indicators**

| Society & Citizens– Indicators | | | |
|---|---|---|---|
| A | B | More important (A/B) | Scale (1-9) |
| Development of housing prices | Housing cost overburden rate | B | 3 |
| | | | |
| Citizen engagement/empowerment to climate conscious actions | Encouraging a healthy lifestyle | A | 3 |

Final weights per category and per application field calculated taking into account the contribution of all experts can be found in Table 37:

**Table 37: Weighting per category and per Application field. Energy and environment**

| ENERGY & ENVIRONMENT | | | | | |
|---|---|---|---|---|---|
| Application field | Indicator | WEIGHT per Category | | WEIGHT per App Field | |
| City Energy Profile | Final energy consumption per capita | 5.53% | 100% | 10.54% | 100% |
| | Primary energy consumption per capita | 12.6% | | 24.02% | |
| | Primary energy sources (shares) | 18.3% | | 34.89% | |
| | Building connected to the DH-network | 16.03% | | 30.55% | |
| GHG Emissions | GHG emissions per capita | 33.38% | | 100% | 100% |
| Waste Management | Recycling rate | 14.16% | | 100% | 100% |

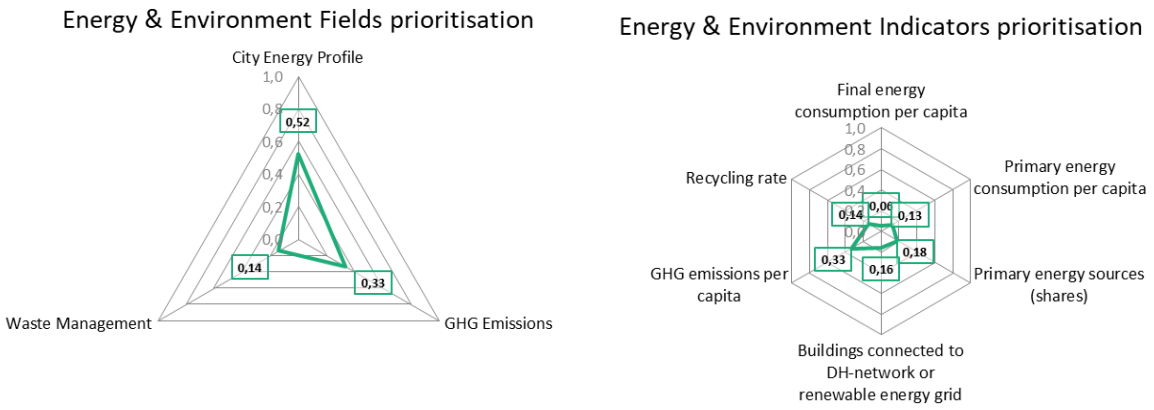


**Figure 15: Energy and environment prioritisation**

**Table 38: Weighting per category and per Application field. Mobility**

| MOBILITY | | | | | |
|---|---|---|---|---|---|
| Application field | Indicator | WEIGHT per Category | | WEIGHT per App Field | |
| City Mobility Profile | Modal Split | 12.73% | 100% | 12.73% | 100% |
| | Fuel mix in mobility | 14.45% | | 14.45% | |
| | Energy use for transportation | 7.96% | | 7.96% | |
| | Access to public transport | 36.93% | | 36.93% | |
| | Public infrastructure promoting low-carbon mobility | 27.93% | | 27.93% | |

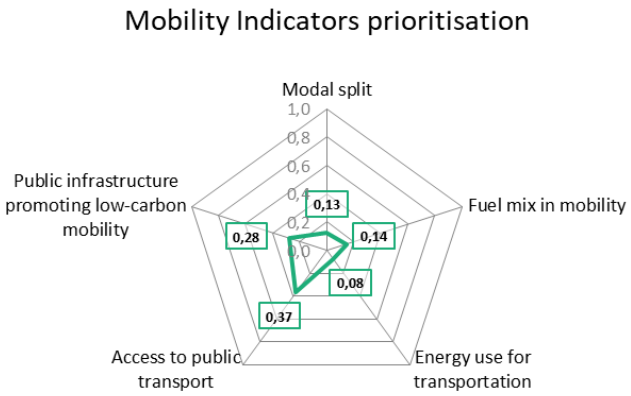


**Figure 16: Mobility prioritisation**

**Table 39: Weighting per category and per Application field. Governance**

| GOVERNANCE | | | | | |
|---|---|---|---|---|---|
| Application field | Indicator | WEIGHT per Category | | WEIGHT per App Field | |
| Economy | Unemployment rate | 43.37% | 100% | 66.66% | 100% |
| | GDP (Gross Domestic Product) | 21.68% | | 33.33% | |
| Initiatives and Strategies of the PA | Smart city factor in a city development strategy | 25.43% | | 100% | 100% |
| Public ICT / Data | Quality of open data | 9.52% | | 100% | 100% |

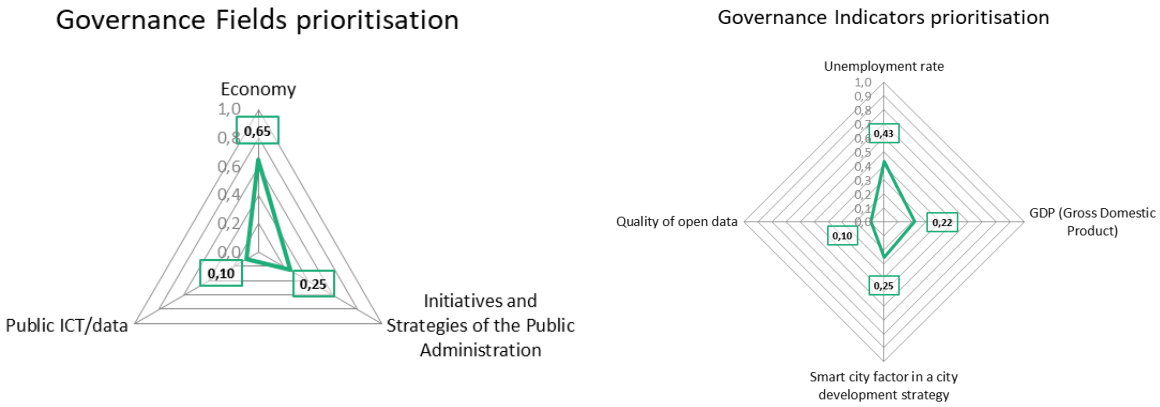


**Figure 17: Governance prioritisation**

**Table 40: Weighting per category and per Application field. Society and citizens**

| SOCIETY & CITIZENS | | | | | |
|---|---|---|---|---|---|
| Application field | Indicator | WEIGHT per Category | | WEIGHT per App Field | |
| Affordable Housing | Development of housing prices | 14.34% | 100% | 25% | 100% |
| | Housing cost overburden rate | 43.02% | | 75% | |
| Citizen Engagement and Empowerment | Citizen engagement/ empowerment to climate conscious actions | 21.48% | | 75% | 100% |
| | Encouraging a healthy lifestyle | 7.16% | | 25% | |
| Urban Structure | Inhabitants in dense areas | 13.99% | | 100% | 100% |

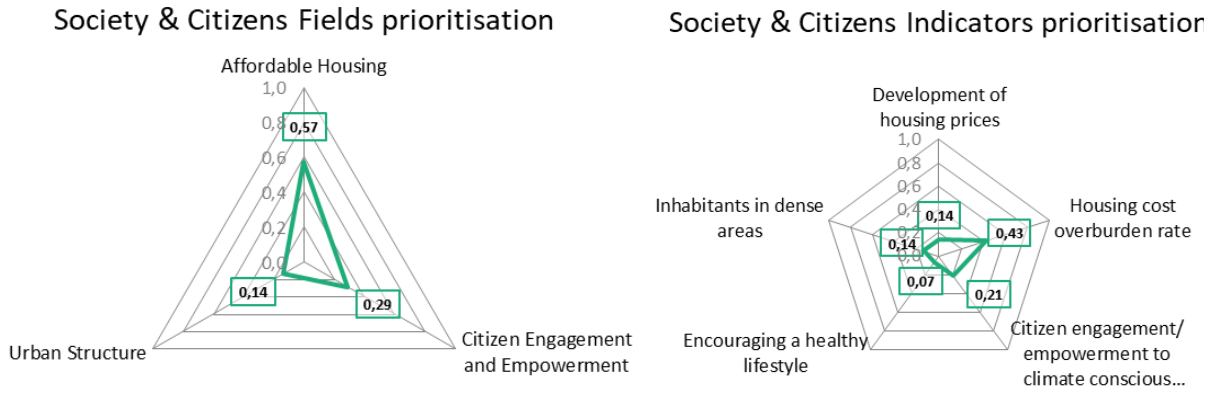


**Figure 18: Society and citizens prioritisation**

## 4.3.2 Prioritisation for city characterization

In this case the final purpose of the methodology is to obtain some city indices to be able to make an own analysis of the cities, showing the categories and application fields that are strong in the city and which of them need improvements and more attention, and also serves to fix future medium and long term goals and objectives.

In this section percentages obtained for the city characterization have been included and as can be seen, different values have been established for each of the lighthouse cities considering their needs and priorities.

Complete information related to the prioritisation for city characterization was presented in the D1.2, so all details can be found in that deliverable.

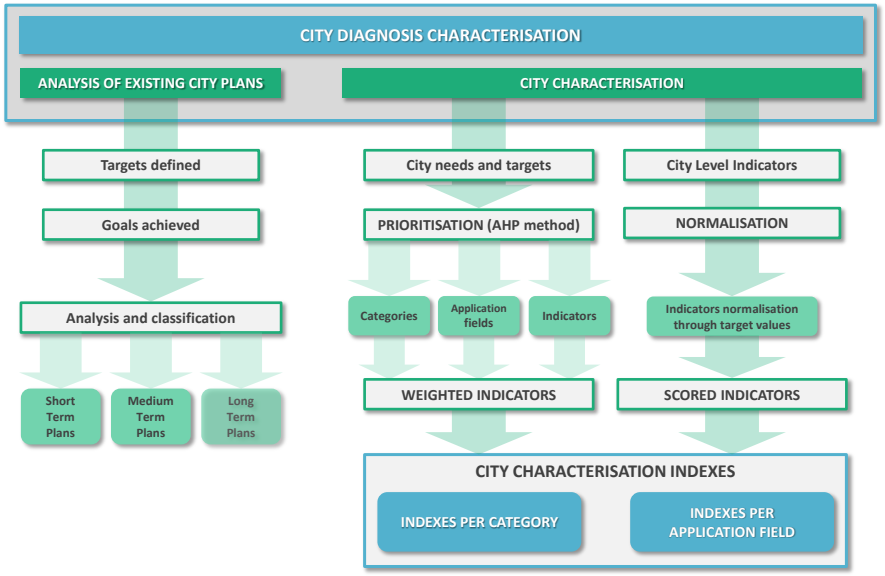


**Figure 19: City diagnosis characterisation**

**Table 41: Weighting per category and per Application field. Energy and environment**

| ENERGY & ENVIRONMENT | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Application field | Indicator | GRONINGEN | | | | OULU | | | |
| | | WEIGHT per Category | | WEIGHT per App Field | | WEIGHT per Category | | WEIGHT per App Field | |
| City Energy Profile | Final energy consumption per capita | 1.15% | 100% | 11.38% | 100% | 1.94% | 100% | 9.28% | 100% |
| | Primary energy consumption per capita | 3.30% | | 32.76% | | 3.33% | | 15.97% | |
| | Primary energy sources (shares) | 2.44% | | 24.19% | | 12.19% | | 58.38% | |
| | Building connected to the DH-network | 3.19% | | 31.66% | | 3.42% | | 16.37% | |
| GHG Emissions | GHG emissions per capita | 46.63% | | 100% | 100% | 70.77% | | 100% | 100% |
| Waste Management | Recycling rate | 43.30% | | 100% | 100% | 8.35% | | 100% | 100% |

**Table 42: Weighting per category and per Application field. Mobility**

| MOBILITY | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Application field | Indicator | GRONINGEN | | | | OULU | | | |
| | | WEIGHT per Category | | WEIGHT per App Field | | WEIGHT per Category | | WEIGHT per App Field | |
| City Mobility Profile | Modal Split | 47.12% | 100% | 47.12% | 100% | 13.88% | 100% | 13.88% | 100% |
| | Fuel mix in mobility | 8.67% | | 8.67% | | 14.17% | | 14.17% | |
| | Energy use for transportation | 5.12% | | 5.12% | | 14.14% | | 14.14% | |
| | Access to public transport | 29.31% | | 29.31% | | 13.80% | | 13.80% | |
| | Public infrastructure promoting low-carbon mobility | 9.78% | | 9.78% | | 44.01% | | 44.01% | |

**Table 43: Weighting per category and per Application field. Governance**

| GOVERNANCE | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Application field | Indicator | GRONINGEN | | | | OULU | | | |
| | | WEIGHT per Category | | WEIGHT per App Field | | WEIGHT per Category | | WEIGHT per App Field | |
| Economy | Unemployment rate | 18,43% | 100% | 87,50% | 100% | 43,81% | 100% | 87,50% | 100% |
| | GDP (Gross Domestic Product) | 2,63% | | 12,50% | | 6,26% | | 12,50% | |
| Initiatives and Strategies of the PA | Smart city factor in a city development strategy | 54,85% | | 100,00% | 100% | 31,02% | | 100,00% | 100% |
| Public ICT / Data | Quality of open data | 24,09% | | 100,00% | 100% | 18,90% | | 100,00% | 100% |

**Table 44: Weighting per category and per Application field. Society and citizens**

| SOCIETY & CITIZENS | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Application field | Indicator | GRONINGEN | | | | OULU | | | |
| | | WEIGHT per Category | | WEIGHT per App Field | | WEIGHT per Category | | WEIGHT per App Field | |
| Affordable Housing | Development of housing prices | 8,73% | 100% | 16,67% | 100% | 6,56% | 100% | 20,00% | 100% |
| | Housing cost overburden rate | 43,64% | | 83,33% | | 26,22% | | 80,00% | |
| Citizen Engagement and Empowerment | Citizen engagement/ empowerment to climate | 15,21% | | 50,00% | 100% | 13,70% | | 33,33% | 100% |
| | Encouraging a healthy lifestyle | 15,21% | | 50,00% | | 27,41% | | 66,67% | |
| Urban Structure | Inhabitants in dense areas | 17,21% | | 100,00% | 100% | 26,11% | | 100,00% | 100% |

## 4.4 Step IV: Calculation of the city indices

As it has been explained in the section 3.4 of this document, the indicators calculated by the cities have been aggregated according to the linear aggregation method. This method was selected because all indicators have been normalized and therefore they are scored on the same scale. This allows that one indicator can be compensated by other better rated that fall within the same category or application field.

On one hand the indicators have been aggregated for generating ten sub-indices, one for each of the ten application fields defined in the evaluation framework and on the other hand, four more general indices represent the aggregated value related to the four categories, energy and environment, mobility, governance and society&citizens

### 4.4.1 Calculation of city indices for impact evaluation

The indicators of Groningen and Oulu have been aggregated according to the linear aggregation method and the results are city indices per category and per application fields, collected within the following Table 45 and Table 46 below.

The calculation of these indices has been carried out considering the same weights for both cities. This allows comparing not only the results for each city before and after the interventions but also it is possible to compare the results between the two lighthouse cities or use this methodology to compare the status of different cities. This is the main different with the application of the evaluation at city level for the city characterization. In that case, each city establishes their own priorities in order to evaluate how the indices improve after the planned actions but it would not be correct to compare the results of two different cities since each of them has used specific weights for the calculation of its indices.

**Table 45: Indices per Category**

| CATEGORIES INDICES | | |
|---|---|---|
| Category | City Index | |
| | GRONINGEN | OULU |
| Energy & Environment | 6.4 | 8.19 |
| Mobility | 8.21 | 4.85 |
| Governance | 8.19 | 7.66 |
| Society & Citizens | 7.84 | 8.79 |

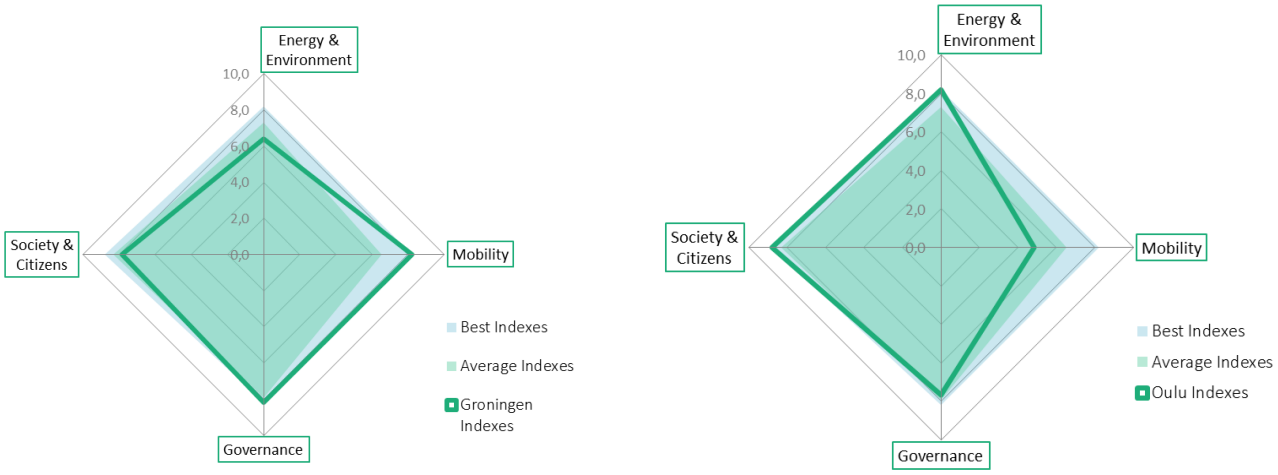


**Figure 20: Radar view of Groningen and Oulu Indices per Category**

Figure 20 and Figure 21 show the graphical representation of the city indices per category and application field for the two lighthouse cities. These are the baseline values calculated with the provided data at the beginning of the project. The same indices will be calculated with the values of the indicators at the end of the project, after the implementation of the actions. The comparison between the indices before and after the interventions will allow measuring the real impact of the implemented actions in the lighthouse cities but also will show how other complementary actions deployed during the development of the project can improve the value of these indices.

For the normalization of the indicators, the values provided by all the project cities have been taken into account in order to establish the thresholds most suitable for the project, nevertheless the average and best values used as reference in the graphs have been calculated only with data of Oulu and Groningen because the city indices for impact evaluation will only be calculated for the two lighthouse cities in order to analyze the impact of the project actions.

In section 4.4.2, city indices for city characterization have been calculated. In that case, the average and best values used as reference have taken into account the value of the indicators calculated by all the project cities.

**Table 46: Indices per Application Field**

| APPLICATION FIELDS INDICES | | | |
|---|---|---|---|
| Category | Application Field | City Index | |
| | | GRONINGEN | OULU |
| ENERGY & ENVIRONMENT | City Energy Profile | 2.41 | 2.02 |
| | GHG Emissions | 2.58 | 5.34 |

| | | | |
|---|---|---|---|
| | Waste Management | 1.42 | 0.84 |
| MOBILITY | City Mobility Profile | 8.21 | 4.85 |
| GOVERNANCE | Economy | 5.81 | 5.04 |
| | Initiatives and Strategies of the PA | 1.91 | 1.91 |
| | Public ICT / Data | 0.48 | 0.71 |
| SOCIETY & CITIZENS | Affordable Housing | 4.29 | 5.68 |
| | Citizen Engagement and Empowerment | 2.15 | 2.15 |
| | Urban Structure | 1.4 | 0.96 |

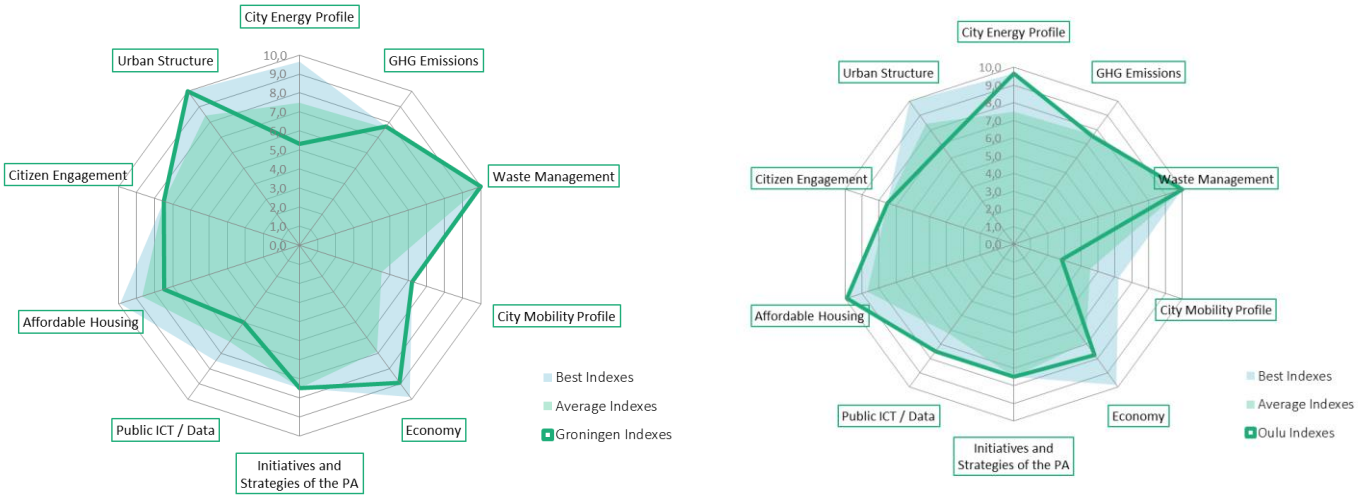


**Figure 21: Radar view of Groningen and Oulu Indices per Application Field**

## 4.4.2 Calculation of city indices for city characterization

In this section the indices calculated for city characterization are presented. These indices are the same included in the previous section but in this case, they have been calculated with the weights established according to the priorities and needs of each of the cities, so they will be used to compare the initial and final results after the project's actions, but it is not possible to compare the results of the two cities. For the comparison of two or more cities it is needed to apply the methodology proposed in previous subsection where common weights are used for the calculation of the indices.

**Table 47: Indices per Category**

| CATEGORIES INDICES | | |
|---|---|---|
| Category | City Index | |
| | GRONINGEN | OULU |
| Energy & Environment | 8.49 | 8.19 |
| Mobility | 8.81 | 6.56 |
| Governance | 7.13 | 7.27 |
| Society & Citizens | 8.00 | 8.13 |

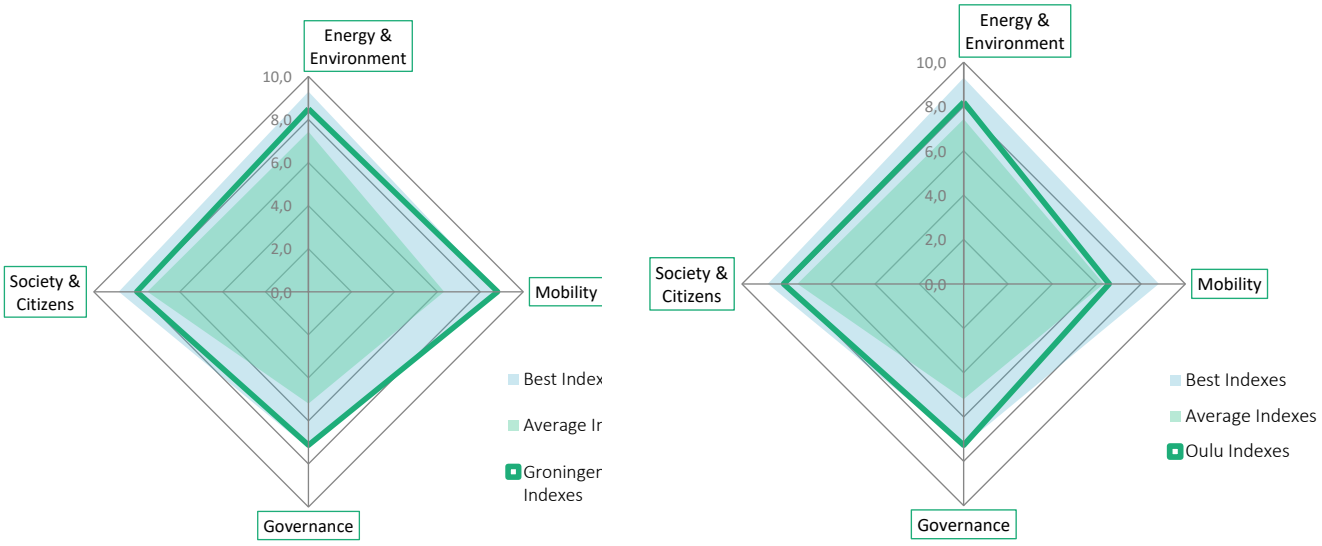


**Figure 22: Radar view of Groningen and Oulu Indices per Category**

**Table 48: Indices per Application Field**

| APPLICATION FIELDS INDICES | | | |
|---|---|---|---|
| Category | Application Field | City Index | |
| | | GRONINGEN | OULU |
| ENERGY & ENVIRONMENT | City Energy Profile | 5.61 | 9.69 |
| | GHG Emissions | 7.72 | 7.54 |
| | Waste Management | 10.00 | 10.00 |
| MOBILITY | City Mobility Profile | 8.81 | 6.56 |
| GOVERNANCE | Economy | 8.59 | 7.05 |
| | Initiatives and Strategies of the PA | 7.50 | 7.50 |
| | Public ICT / Data | 5.00 | 7.50 |
| SOCIETY & CITIZENS | Affordable Housing | 7.63 | 9.93 |
| | Citizen Engagement and Empowerment | 7.50 | 7.50 |
| | Urban Structure | 10.00 | 6.85 |

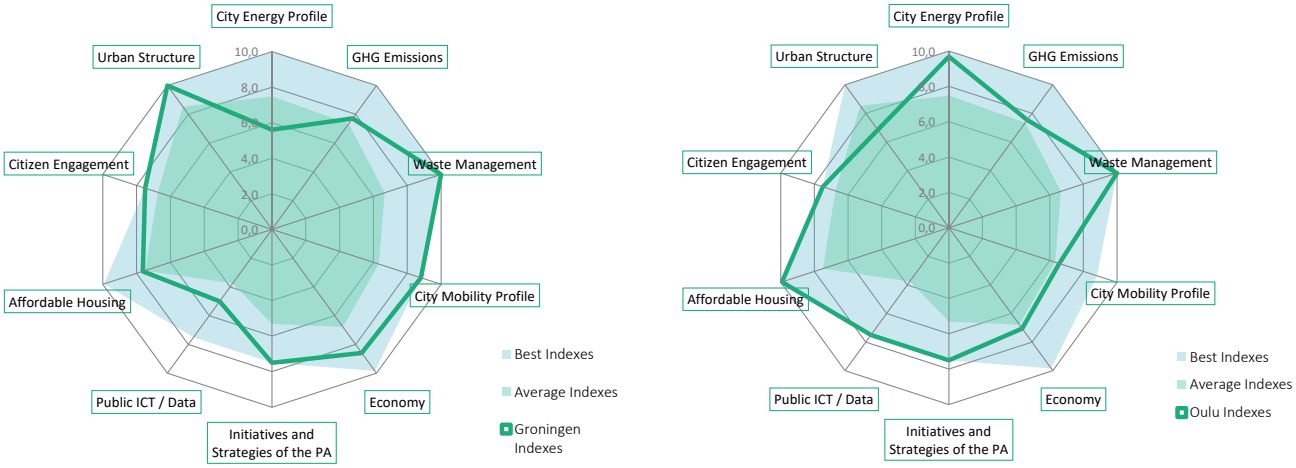


**Figure 23: Radar view of Groningen and Oulu Indices per Application Field**

# Conclusions

This deliverable presents the evaluation methodology at city level developed and applied in MAKING CITY project with two main objectives, on the one hand it has been used for the characterization of the eight cities of the project whose results can be found in detail in the D1.2 and on the other hand this methodology will be applied for the impact evaluation within MAKING-CITY project.

The process consists of four steps based on the city-level indicators defined in the deliverable D5.1. These indicators are normalized and weighted to develop indices that allow us to calculate impacts, compare results and set objectives for cities.

For the establishment of the weights needed for the calculation of the indices two different procedures have been applied. On one hand, for the calculation of the indices that will be used for the evaluation of the project impact at city level, common weights have been established considering the opinion of several experts based on their experience. These weights are common for all cities which want to apply the methodology and therefore it is possible to compare the results of different cities.

On the other hand, the methodology of evaluation at city level can be also used for the characterization of the city. In that case each city establishes its own weights considering their needs and priorities and the information included in its city plans. Since the prioritization is specific for each city, it can be used for the evaluation of the evolution of the city but it is not possible to compare the results of different cities.

The baseline calculated and presented in this deliverable will be used to compare it to the results at the end of the project and thus know the impact on the lighthouse cities of the actions implemented in the project.

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# Annex 1 - City level indicators values

| ENERGY & ENVIRONMENT | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Application field | Indicator | | UNIT | GRONINGEN | OULU | BASSANO DEL GRAPPA | LEÓN | KADIKÖY | TRENČÍN | VIDIN | LUBLIN |
| City Energy Profile | Final energy consumption per capita | | MWh/cap | 24.60 | 23.00 | 18,54 | 25,66 | 14,05 | 19,25 | 7,50 | 9,50 |
| | Primary energy consumption per capita | | MWh/cap | 30.60 | 26.00 | 29,62 | 36,62 | 19,05 | 32,69 | 13,20 | 11,78 |
| | Primary energy sources | Solid fossil fuels | % | 0.00% | 27.00% | 8,00% | 0,00% | 0,00% | 20,00% | 14,00% | 4,52% |
| | | Natural gas | | 51.80% | 0.00% | 38,50% | 28,18% | 20,00% | 24,00% | 1,00% | 31,17% |
| | | Oil and petroleum | | 24.00% | 30.00% | 22,10% | 51,29% | 0,00% | 22,00% | 16,00% | 0,19% |
| | | Renewables and biofuels | | 4.30% | 35.00% | 12,00% | 0,19% | 1,00% | 11,00% | 14,00% | 36,13% |
| | | Electricity from the grid | | 19.90% | 9.00% | 19,40% | 20,34% | 79,00% | 23,00% | 55,00% | 27,99% |
| | | Solid fossil fuels | MWh/cap | 0.00 | 6.67 | 1,52 | 0,00 | 0,00 | 3,85 | 1,51 | 0,53 |
| | | Natural gas | | 15.85 | 0.00 | 7,35 | 7,23 | 0,67 | 4,62 | 0,10 | 3,67 |
| | | Oil and petroleum | | 7.34 | 7.19 | 4,22 | 13,16 | 0,00 | 4,24 | 1,76 | 0,02 |
| | | Renewables and biofuels | | 1.32 | 8.56 | 2,29 | 0,05 | 0,06 | 2,12 | 1,55 | 4,25 |
| | | Electricity from the grid | | 6.09 | 2.11 | 3,70 | 5,22 | 2,68 | 4,43 | 6,08 | 3,30 |
| | Building connected to the DH-network or renewable energy grid | | % of buildings/city | 1% | 61% | 17% | 0% | 0% | 19% | 0% | 75% |
| GHG Emissions | GHG emissions per capita | | Tonnes of CO2 /cap | 5.40 | 5.50 | 4,90 | 6,62 | 3,34 | 5,66 | 3,07 | 8,56 |
| Waste Management | Recycling rate | | % of tonnes | 78% | 99% | 76% | 21% | 6% | 40% | 40% | 94% |

| MOBILITY | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Application field | Indicator | | UNIT | GRONINGEN | OULU | BASSANO DEL GRAPPA | LEÓN | KADIKÖY | TRENČÍN | VIDIN | LUBLIN |
| City Mobility Profile | Modal split | Walk | % | 15% | 22% | 12% | 64% | 49% | 34% | 40% | 24% |
| | | Bike | | 55% | 21% | 10% | 1% | 1% | 7% | 10% | 11% |
| | | Public transport | | 3% | 4% | 6% | 6% | 24% | 17% | 20% | 33% |
| | | Non-car transport | | 73% | 47% | 28% | 71% | 74% | 58% | 70% | 68% |
| | | Car (private motor vehicle) | | 27% | 54% | 72% | 29% | 26% | 42% | 30% | 32% |
| | Fuel mix in mobility | Gas oil and diesel oil | % | 43.20% | 52.00% | 71,00% | 85,45% | 64,00% | 68,80% | 66,00% | 36,30% |
| | | Gasoline | | 54.50% | 32.00% | 20,00% | 14,43% | 10,00% | 28,60% | 27,00% | 47,20% |
| | | Liquefied Petroleum Gases | | 2.10% | 0.00% | 8,00% | 0,10% | 25,00% | 0,30% | 6,00% | 14,30% |
| | | Electricity | | 0.20% | 2.00% | 0,00% | 0,02% | 1,00% | 2,30% | 0,00% | 0,00% |
| | | Other fuels | | 0.00% | 14.00% | 1,00% | 0,00% | 0,00% | 0,00% | 1,00% | 2,20% |
| | Energy use for transportation | | MWh/cap | 6.20 | 7.00 | 7,32 | 7,69 | 3,57 | 5,78 | 1,37 | 6,56 |
| | Access to public transport | | % of people | 98% | 70% | 97% | 100% | 100% | 95% | 100% | 80% |
| | Public infrastructure promoting low-carbon mobility | | Km/100,000 people | 275.00 | 1,000.00 | 112,00 | 24,86 | 3,31 | 55,61 | 112,00 | 51,20 |

| GOVERNANCE | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Application field | Indicator | UNIT | GRONINGEN | OULU | BASSANO DEL GRAPPA | LEÓN | KADIKÖY | TRENČÍN | VIDIN | LUBLIN |
| Economy | Unemployment rate | % of active population | 7,20% | 9,60% | 6,30% | 14,10% | 13,80% | 5,50% | 11,30% | 3,70% |
| | GDP (Gross Domestic Product) | €/cap | 44.800 | 31.300 | 30.800 | 21.700 | 11.500 | 13.400 | 3.900 | 7.700 |
| Initiatives and Strategies of the Public Administration | Smart city factor in a city development strategy | Likert scale | 4 | 4 | 2 | 4 | 2 | 3 | 2 | 4 |
| Public ICT / Data | Quality of open data | Likert scale | 3 | 4 | 2 | 1 | 2 | 3 | 2 | 3 |

| SOCIETY AND CITIZENS | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Application field | Indicator | UNIT | GRONINGEN | OULU | BASSANO DEL GRAPPA | LEÓN | KADIKÖY | TRENČÍN | VIDIN | LUBLIN |
| Affordable Housing | Development of housing prices | % of change or % of €/m² | -4,00% | 1,90% | -9,00% | 5,32% | -3,41% | 7,86% | 5,50% | 8,00% |
| | Housing cost overburden rate | % | 9,40% | 6,60% | 8,20% | 8,90% | 9,50% | 8,40% | 19,70% | 6,70% |
| Citizen Engagement and Empowerment | Citizen engagement/ empowerment to climate conscious actions | Likert scale | 4 | 4 | 4 | 3 | 4 | 3 | 4 | 4 |
| | Encouraging a healthy lifestyle | Likert scale | 4 | 4 | 4 | 3 | 4 | 2 | 3 | 4 |
| Urban Structure | Inhabitants in dense areas | % of people | 95,30% | 56,80% | 94,00% | 87,52% | 100,00% | 20,00% | 90,00% | 81,00% |

# Annex 2 - Example of prioritisation exercise: Energy and Environment prioritization

In order to better understand the pair-wise comparison, below there is an example of how this exercise was developed through an Excel tool.

First, experts or cities depending of the methodology (evaluation of impacts or city characterization) decide which of both categories in the comparison consider most important (A or B) and then, scale the importance of the selection (from 1 to 9 based on the criteria in Table 19).

To obtain all the weights of a category, more than one Matrix will have to be solved. First, one to compare the different application fields of the corresponding category (there are three in the case of Energy & Environment), and secondly, comparisons of the indicators will be established within each application field.

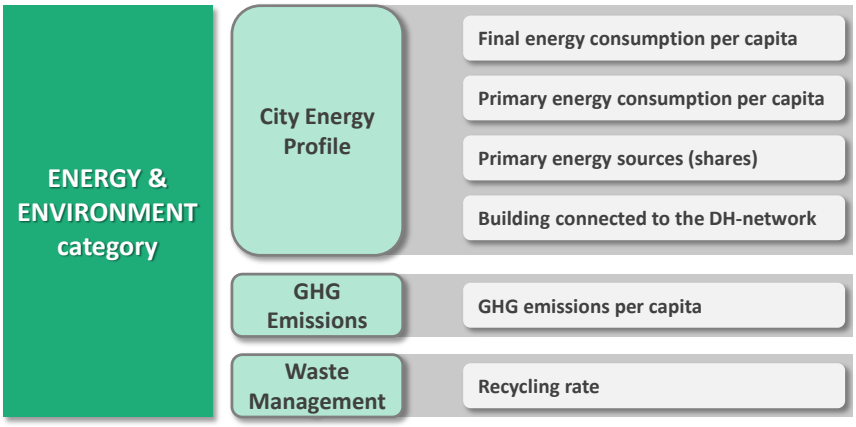


**Figure 24: Energy & Environment structure**

In the case of Energy & Environment category, only one of the application fields has more than one indicator (as shown in Figure 24), so for the other two fields, the weight of its single indicator will be 100%. This first comparison exercise, done through the Excel tool, is shown in tables Table 49 and Table 50 below.

**Table 49: Example of the pair-wise comparison among Energy & Environment application fields**

| ENERGY & ENVIRONMENT application fields | | Comparison | |
|---|---|---|---|
| A | B | More important (A/B) | Scale (1-9) |
| City Energy Profile | GHG Emissions | B | 4 |
| | Waste Management | A | 2 |
| GHG Emissions | Waste Management | A | 5 |

**Table 50: Example of the pair-wise comparison among City Energy Profile indicators**

| CITY ENERGY PROFILE indicators | | Comparison | |
|---|---|---|---|
| A | B | More important (A/B) | Scale (1-9) |
| Final energy consumption per capita | Primary energy consumption per cap | A | 2 |
| | Primary energy sources | A | 2 |

| | | | |
|---|---|---|---|
| | Buildings connected to DH-network | A | 6 |
| Primary energy consumption per capita | Primary energy sources | A | 1 |
| | Buildings connected to DH-network | A | 4 |
| Primary energy sources | Buildings connected to DH-network | A | 5 |

The results of these pair-wise comparison are represented in comparison matrix (tables Table 51 and Table 52), to obtain the weights of each element.

**Table 51: Example of the Energy & Environment application fields comparison MATRIX**

| COMPARISON MATRIX of the Energy & Environment application fields | | | |
|---|---|---|---|
| APPLICATION FIELDS | City Energy Profile | GHG Emissions | Waste Management |
| City Energy Profile | 1 | 1/4 | 2 |
| GHG Emissions | 4 | 1 | 5 |
| Waste Management | 1/2 | 1/5 | 1 |
| SUM | 5.50 | 1.45 | 8.00 |

**Table 52: Example of the City Energy Profile indicators comparison MATRIX**

| COMPARISON MATRIX of the City Energy Profile indicators | | | | |
|---|---|---|---|---|
| INDICATORS | Final energy consumption per cap | Primary energy consumption per cap | Primary energy sources | Buildings connected to DH-network |
| Final energy consumption per cap | 1 | 2 | 2 | 6 |
| Primary energy consumption per cap | 1/2 | 1 | 1 | 4 |
| Primary energy sources | 1/2 | 1 | 1 | 5 |
| Buildings connected to DH-network | 1/6 | 1/4 | 1/5 | 1 |
| SUM | 2.17 | 4.25 | 4.20 | 16.00 |

From the comparison matrix, next step is to compute the priority vector, which is the normalised Eigen vector of the matrix. The normalised matrices below (tables Table 53 and Table 54) are an approximation of Eigen vector (and Eigen value). This approximation works well for small matrix, and it is easy to compute since all that is needed is to normalise each column of the matrix. The normalised principal Eigen vector can be obtained by averaging across the rows, and it is also called priority vector, which shows the relative weights among the categories that are being compared.

**Table 53: Example of the categories normalised matrix and obtaining relative weights**

| NORMALISED MATRIX of the Energy & Environment application fields | | | | WEIGHT |
|---|---|---|---|---|
| APPLICATION FIELDS | City Energy Profile | GHG Emissions | Waste Management | |
| City Energy Profile | 0.18 | 0.17 | 0.25 | 0.20 |
| GHG Emissions | 0.73 | 0.69 | 0.63 | 0.68 |
| Waste Management | 0.09 | 0.14 | 0.13 | 0.12 |
| SUM | 1 | 1 | 1 | 1 |

**Table 54: Example of the categories normalised matrix and obtaining relative weights**

| NORMALISED MATRIX of the City Energy Profile indicators | | | | | WEIGHT |
|---|---|---|---|---|---|
| INDICATORS | Final energy consumption per cap | Primary energy consumption per cap | Primary energy sources | Society & Citizens | |
| Final energy consumption per cap | 0.46 | 0.47 | 0.48 | 0.38 | 0.45 |
| Primary energy consumption per cap | 0.23 | 0.24 | 0.24 | 0.25 | 0.24 |
| Primary energy sources | 0.23 | 0.24 | 0.24 | 0.31 | 0.25 |
| Buildings connected to DH-network | 0.08 | 0.06 | 0.05 | 0.06 | 0.06 |
| SUM | 1 | 1 | 1 | 1 | 1 |

Aside from the relative weight, consistency needs to be checked. The comparison matrix is considered to be adequately consistent if the corresponding consistency ratio (CR) is less than 10% (Saaty, 1980 [10]). The CR coefficient is calculated from the consistency index (CI), which is estimated by adding the rows in the comparison matrix and multiply the resulting vector of priorities obtained earlier. This yields an approximation of the maximum Eigen value, denoted $\lambda_{MAX}$. Then, the CI value is calculated by using the formula: $CI = (\lambda_{MAX} - n) / (n - 1)$, where *n* is the matrix size. Next, the consistency ratio (CR) is obtained by dividing the CI value by the Random Index (RI): $CR = CI / RI$, as given in the following Table 55.

**Table 55: Random Index (RI) for the different *n* matrix**

| RANDOM INDEX (RI) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| *n* | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| RI | 0 | 0.58 | 0.90 | 1.12 | 1.24 | 1.32 | 1.41 | 1.45 | 1.51 |

For the Energy & Environment application fields: CI = 0.01; and RI = 0.58; so CR = 0.02; what meets **CR < 0.1**; and therefore the matrix and prioritization is consistent.

For the City Energy Profile indicators: CI = 0.01; and RI = 0.90; so CR = 0.01; what meets **CR < 0.1**; and therefore the matrix and prioritization is consistent.

Final weights per category and per application field within the Energy & Environment category would be as follows (Table 56).

**Table 56: Energy & Environment Indicators Weighting per Category and per Application field**

| ENERGY & ENVIRONMENT | | | | | |
|---|---|---|---|---|---|
| Application field | Indicator | WEIGHT per Category | | WEIGHT per App Field | |
| City Energy Profile | Final energy consumption per capita | 8.98% | 100% | 44.58% | 100% |
| | Primary energy consumption per capita | 4.80% | | 23.85% | |
| | Primary energy sources (shares) | 5.12% | | 25.42% | |
| | Building connected to the DH-network | 1.24% | | 6.15% | |
| GHG Emissions | GHG emissions per capita | 68.06% | | 100% | 100% |
| Waste Management | Recycling rate | 11.79% | | 100% | 100% |

As in the example, the AHP method is applied in the same way to calculate the weights of the application fields and indicators of the rest of the MAKING-CITY categories, obtaining the corresponding weights as reflected in previous Table 56 for all the categories.

# Annex 3 - Pair-wise comparison carried out by MAKING-CITY experts

The comparison scale used has been included in Table 57

**Table 57: Comparison scale**

| Scale | Definition | Comments |
|---|---|---|
| 1 | Equal importance | Element A is just as important as element B |
| 3 | Moderate importance | Experience and judgement slightly favour element A over B |
| 5 | Essential importance | Experience and judgement strongly favour element A over B |
| 7 | Very strong importance | Element A is much more important than element B |
| 9 | Extreme importance | The greater importance of element A over B is beyond doubt |
| 2, 4, 6, 8 | Intermediate values | |

# Annex 3.1 - CARTIF

## Category Prioritisation

| CATEGORY PRIORITISATION | | | |
|---|---|---|---|
| A | B | More important (A/B) | Scale (1-9) |
| Energy & Environment | Mobility | A | 7 |
| | Governance | A | 3 |
| | Society & Citizens | B | 2 |
| Mobility | Governance | A | 1 |
| | Society & Citizens | B | 3 |
| Governance | Society & Citizens | A | 1 |

| CATEGORY PRIORITISATION | | | |
|---|---|---|---|
| A | B | More important (A/B) | Scale (1-9) |
| Energy & Environment | Mobility | A | 8 |
| | Governance | A | 5 |
| | Society & Citizens | A | 4 |
| Mobility | Governance | B | 5 |

| | | | |
|---|---|---|---|
| | Society & Citizens | B | 7 |
| Governance | Society & Citizens | B | 2 |

## Energy & Environment Prioritization

| Energy & Environment prioritisation – Application Fields | | | |
|---|---|---|---|
| A | B | More important (A/B) | Scale (1-9) |
| City Energy Profile | GHG Emissions | A | 2 |
| | Waste Management | A | 3 |
| GHG Emissions | Waste Management | A | 1 |

| Energy & Environment prioritisation – Indicators | | | |
|---|---|---|---|
| A | B | More important (A/B) | Scale (1-9) |
| Final energy consumption per capita | Primary energy consumption per capita | B | 3 |
| | Primary energy sources (shares) | B | 3 |
| | Buildings connected to DH-network or renewable energy grid | B | 5 |
| Primary energy consumption per capita | Primary energy sources (shares) | A | 1 |
| | Buildings connected to DH-network or renewable energy grid | B | 5 |
| Primary energy sources (shares) | Buildings connected to DH-network or renewable energy grid | A | 1 |

| Energy & Environment prioritisation – Application Fields | | | |
|---|---|---|---|
| A | B | More important (A/B) | Scale (1-9) |
| City Energy Profile | GHG Emissions | A | 3 |
| | Waste Management | A | 7 |
| GHG Emissions | Waste Management | B | 2 |

| Energy & Environment prioritisation – Indicators | | | |
|---|---|---|---|
| A | B | More important (A/B) | Scale (1-9) |

| | | | |
|---|---|---|---|
| Final energy consumption per capita | Primary energy consumption per capita | B | 5 |
| | Primary energy sources (shares) | B | 8 |
| | Buildings connected to DH-network or renewable energy grid | A | 6 |
| Primary energy consumption per capita | Primary energy sources (shares) | B | 6 |
| | Buildings connected to DH-network or renewable energy grid | A | 7 |
| Primary energy sources (shares) | Buildings connected to DH-network or renewable energy grid | A | 3 |

## Mobility Prioritization

| Mobility – Indicators | | | |
|---|---|---|---|
| A | B | More important (A/B) | Scale (1-9) |
| Modal split | Fuel mix in mobility | B | 5 |
| | Energy use for transportation | A | 7 |
| | Access to public transport | B | 2 |
| | Public infrastructure promoting low-carbon mobility | B | 1 |
| Fuel mix in mobility | Energy use for transportation | A | 8 |
| | Access to public transport | B | 6 |
| | Public infrastructure promoting low-carbon mobility | B | 6 |
| Energy use for transportation | Access to public transport | B | 6 |
| | Public infrastructure promoting low-carbon mobility | B | 6 |
| Access to public transport | Public infrastructure promoting low-carbon mobility | A | 1 |

| Mobility – Indicators | | | |
|---|---|---|---|
| A | B | More important (A/B) | Scale (1-9) |
| Modal split | Fuel mix in mobility | B | 5 |

| | | | |
|---|---|---|---|
| | Energy use for transportation | B | 6 |
| | Access to public transport | A | 1 |
| | Public infrastructure promoting low-carbon mobility | B | 3 |
| Fuel mix in mobility | Energy use for transportation | B | 5 |
| | Access to public transport | A | 4 |
| | Public infrastructure promoting low-carbon mobility | B | 3 |
| Energy use for transportation | Access to public transport | A | 6 |
| | Public infrastructure promoting low-carbon mobility | A | 6 |
| Access to public transport | Public infrastructure promoting low-carbon mobility | B | 4 |

## Governance Prioritization

| Governance prioritisation – Application Fields | | | |
|---|---|---|---|
| A | B | More important (A/B) | Scale (1-9) |
| Economy | Initiatives and strategies of the public administration | B | 7 |
| | Public ICT/data | A | 2 |
| Initiatives and strategies of the public administration | Public ICT/data | A | 7 |

| Governance– Indicators | | | |
|---|---|---|---|
| A | B | More important (A/B) | Scale (1-9) |
| Unemployment rate | GPD (Gross Domestic Product) | B | 3 |

| Governance prioritisation – Application Fields | | | |
|---|---|---|---|
| A | B | More important (A/B) | Scale (1-9) |
| Economy | Initiatives and strategies of the public administration | A | 6 |
| | Public ICT/data | A | 7 |

| | | | |
|---|---|---|---|
| Initiatives and strategies of the public administration | Public ICT/data | A | 5 |

| Governance– Indicators | | | |
|---|---|---|---|
| A | B | More important (A/B) | Scale (1-9) |
| Unemployment rate | GPD (Gross Domestic Product) | B | 4 |

## Society & Citizens Prioritization

| Society & Citizens prioritisation – Application Fields | | | |
|---|---|---|---|
| A | B | More important (A/B) | Scale (1-9) |
| Affordable housing | Citizen engagement and empowerment | A | 1 |
| | Urban Structure | B | 2 |
| Citizen Engagement and Empowerment | Urban Structure | A | 2 |

| Society & Citizens– Indicators | | | |
|---|---|---|---|
| A | B | More important (A/B) | Scale (1-9) |
| Development of housing prices | Housing cost overburden rate | B | 3 |
| Citizen engagement/empowerment to climate conscious actions | Encouraging a healthy lifestyle | A | 5 |

| Society & Citizens prioritisation – Application Fields | | | |
|---|---|---|---|
| A | B | More important (A/B) | Scale (1-9) |
| Affordable housing | Citizen engagement and empowerment | B | 6 |
| | Urban Structure | B | 7 |

| | | | |
|---|---|---|---|
| Citizen Engagement and Empowerment | Urban Structure | A | 7 |

| Society & Citizens– Indicators | | | |
|---|---|---|---|
| A | B | More important (A/B) | Scale (1-9) |
| Development of housing prices | Housing cost overburden rate | B | 5 |
| | | | |
| Citizen engagement/empowerment to climate conscious actions | Encouraging a healthy lifestyle | A | 2 |

# Annex 3.2 - TECNALIA

## Category Prioritisation

| CATEGORY PRIORITISATION | | | |
|---|---|---|---|
| A | B | More important (A/B) | Scale (1-9) |
| Energy & Environment | Mobility | A | 7 |
| | Governance | A | 7 |
| | Society & Citizens | A | 7 |
| Mobility | Governance | B | 3 |
| | Society & Citizens | B | 3 |
| Governance | Society & Citizens | A | 2 |

## Energy & Environment Prioritization

| Energy & Environment prioritisation – Application Fields | | | |
|---|---|---|---|
| A | B | More important (A/B) | Scale (1-9) |
| City Energy Profile | GHG Emissions | | 1 |
| | Waste Management | A | 5 |
| GHG Emissions | Waste Management | A | 7 |

| Energy & Environment prioritisation – Indicators | | | |
|---|---|---|---|
| A | B | More important (A/B) | Scale (1-9) |
| Final energy consumption per capita | Primary energy consumption per capita | A | 7 |
| | Primary energy sources (shares) | A | 7 |
| | Buildings connected to DH-network or renewable energy grid | A | 7 |
| Primary energy consumption per capita | Primary energy sources (shares) | A | 3 |
| | Buildings connected to DH-network or renewable energy grid | B | 5 |
| Primary energy sources (shares) | Buildings connected to DH-network or renewable energy grid | B | 7 |

## Mobility Prioritization

| Mobility – Indicators | | | |
|---|---|---|---|
| A | B | More important (A/B) | Scale (1-9) |
| Modal split | Fuel mix in mobility | A | 2 |
| | Energy use for transportation | B | 3 |
| | Access to public transport | B | 9 |
| | Public infrastructure promoting low-carbon mobility | B | 5 |
| Fuel mix in mobility | Energy use for transportation | B | 5 |
| | Access to public transport | B | 2 |
| | Public infrastructure promoting low-carbon mobility | B | 3 |
| Energy use for transportation | Access to public transport | A | 5 |
| | Public infrastructure promoting low-carbon mobility | A | 5 |
| Access to public transport | Public infrastructure promoting low-carbon mobility | B | 3 |

## Governance Prioritization

| Governance prioritisation – Application Fields | | | |
|---|---|---|---|
| A | B | More important (A/B) | Scale (1-9) |
| Economy | Initiatives and strategies of the public administration | A | 5 |
| | Public ICT/data | A | 5 |
| Initiatives and strategies of the public administration | Public ICT/data | B | 9 |

| Governance– Indicators | | | |
|---|---|---|---|
| A | B | More important (A/B) | Scale (1-9) |
| Unemployment rate | GPD (Gross Domestic Product) | B | 8 |

## Society & Citizens Prioritization

| Society & Citizens prioritisation – Application Fields | | | |
|---|---|---|---|
| A | B | More important (A/B) | Scale (1-9) |
| Affordable housing | Citizen engagement and empowerment | A | 3 |
| | Urban Structure | A | 3 |
| Citizen Engagement and Empowerment | Urban Structure | A | 3 |

| Society & Citizens– Indicators | | | |
|---|---|---|---|
| A | B | More important (A/B) | Scale (1-9) |
| Development of housing prices | Housing cost overburden rate | A | 3 |
| | | | |
| Citizen engagement/empowerment to climate conscious actions | Encouraging a healthy lifestyle | A | 7 |

# Annex 3.3 - TNO

## Category Prioritisation

| CATEGORY PRIORITISATION | | | |
|---|---|---|---|
| A | B | More important (A/B) | Scale (1-9) |
| Energy & Environment | Mobility | A | 5 |
| | Governance | B | 1 |
| | Society & Citizens | B | 1 |
| Mobility | Governance | B | 5 |
| | Society & Citizens | B | 3 |
| Governance | Society & Citizens | A | 4 |

## Energy & Environment Prioritization

| Energy & Environment prioritisation – Application Fields | | | |
|---|---|---|---|
| A | B | More important (A/B) | Scale (1-9) |
| City Energy Profile | GHG Emissions | B | 1 |
| | Waste Management | A | 3 |
| GHG Emissions | Waste Management | A | 3 |

| Energy & Environment prioritisation – Indicators | | | |
|---|---|---|---|
| A | B | More important (A/B) | Scale (1-9) |
| Final energy consumption per capita | Primary energy consumption per capita | B | 3 |
| | Primary energy sources (shares) | A | 3 |
| | Buildings connected to DH-network or renewable energy grid | B | 4 |
| Primary energy consumption per capita | Primary energy sources (shares) | A | 3 |
| | Buildings connected to DH-network or renewable energy grid | B | 4 |
| Primary energy sources (shares) | Buildings connected to DH-network or renewable energy grid | B | 1 |

## Mobility Prioritization

| Mobility – Indicators | | | |
|---|---|---|---|
| A | B | More important (A/B) | Scale (1-9) |
| Modal split | Fuel mix in mobility | B | 2 |
| | Energy use for transportation | A | 2 |
| | Access to public transport | B | 1 |
| | Public infrastructure promoting low-carbon mobility | B | 1 |
| Fuel mix in mobility | Energy use for transportation | A | 3 |
| | Access to public transport | B | 2 |
| | Public infrastructure promoting low-carbon mobility | A | 5 |
| Energy use for transportation | Access to public transport | B | 3 |
| | Public infrastructure promoting low-carbon mobility | A | 2 |
| Access to public transport | Public infrastructure promoting low-carbon mobility | A | 7 |

## Governance Prioritization

| Governance prioritisation – Application Fields | | | |
|---|---|---|---|
| A | B | More important (A/B) | Scale (1-9) |
| Economy | Initiatives and strategies of the public administration | A | 5 |
| | Public ICT/data | A | 5 |
| Initiatives and strategies of the public administration | Public ICT/data | A | 3 |

| Governance– Indicators | | | |
|---|---|---|---|
| A | B | More important (A/B) | Scale (1-9) |
| Unemployment rate | GPD (Gross Domestic Product) | A | 3 |

## Society & Citizens Prioritization

| Society & Citizens prioritisation – Application Fields | | | |
|---|---|---|---|
| A | B | More important (A/B) | Scale (1-9) |
| Affordable housing | Citizen engagement and empowerment | A | 1 |
| | Urban Structure | A | 7 |
| Citizen Engagement and Empowerment | Urban Structure | A | 7 |

| Society & Citizens– Indicators | | | |
|---|---|---|---|
| A | B | More important (A/B) | Scale (1-9) |
| Development of housing prices | Housing cost overburden rate | B | 1 |
| | | | |
| Citizen engagement/empowerment to climate conscious actions | Encouraging a healthy lifestyle | A | 1 |

# Annex 3.4 - STICHTING ENERGY VALLEY

## Category Prioritisation

| CATEGORY PRIORITISATION | | | |
|---|---|---|---|
| A | B | More important (A/B) | Scale (1-9) |
| Energy & Environment | Mobility | A | 3 |
| | Governance | A | 7 |
| | Society & Citizens | B | 4 |
| Mobility | Governance | A | 3 |
| | Society & Citizens | B | 7 |
| Governance | Society & Citizens | B | 8 |

## Energy & Environment Prioritization

| Energy & Environment prioritisation – Application Fields | | | |
|---|---|---|---|
| A | B | More important (A/B) | Scale (1-9) |
| City Energy Profile | GHG Emissions | B | 7 |
| | Waste Management | B | 5 |
| GHG Emissions | Waste Management | A | 5 |

| Energy & Environment prioritisation – Indicators | | | |
|---|---|---|---|
| A | B | More important (A/B) | Scale (1-9) |
| Final energy consumption per capita | Primary energy consumption per capita | A | 6 |
| | Primary energy sources (shares) | A | 2 |
| | Buildings connected to DH-network or renewable energy grid | B | 2 |
| Primary energy consumption per capita | Primary energy sources (shares) | B | 4 |
| | Buildings connected to DH-network or renewable energy grid | B | 7 |
| Primary energy sources (shares) | Buildings connected to DH-network or renewable energy grid | B | 7 |

## Mobility Prioritization

| Mobility – Indicators | | | |
|---|---|---|---|
| A | B | More important (A/B) | Scale (1-9) |
| Modal split | Fuel mix in mobility | B | 4 |
| | Energy use for transportation | B | 4 |
| | Access to public transport | B | 7 |
| | Public infrastructure promoting low-carbon mobility | B | 5 |
| Fuel mix in mobility | Energy use for transportation | A | 1 |
| | Access to public transport | B | 3 |
| | Public infrastructure promoting low-carbon mobility | B | 2 |
| Energy use for transportation | Access to public transport | B | 2 |
| | Public infrastructure promoting low-carbon mobility | B | 2 |
| Access to public transport | Public infrastructure promoting low-carbon mobility | A | 1 |

## Governance Prioritization

| Governance prioritisation – Application Fields | | | |
|---|---|---|---|
| A | B | More important (A/B) | Scale (1-9) |
| Economy | Initiatives and strategies of the public administration | A | 7 |
| | Public ICT/data | A | 5 |
| Initiatives and strategies of the public administration | Public ICT/data | A | 4 |

| Governance– Indicators | | | |
|---|---|---|---|
| A | B | More important (A/B) | Scale (1-9) |
| Unemployment rate | GPD (Gross Domestic Product) | A | 3 |

## Society & Citizens Prioritization

| Society & Citizens prioritisation – Application Fields | | | |
|---|---|---|---|
| A | B | More important (A/B) | Scale (1-9) |
| Affordable housing | Citizen engagement and empowerment | A | 4 |
| | Urban Structure | A | 1 |
| Citizen Engagement and Empowerment | Urban Structure | B | 4 |

| Society & Citizens– Indicators | | | |
|---|---|---|---|
| A | B | More important (A/B) | Scale (1-9) |
| Development of housing prices | Housing cost overburden rate | B | 9 |
| | | | |
| Citizen engagement/empowerment to climate conscious actions | Encouraging a healthy lifestyle | B | 3 |

# Annex 3.5 - University of Groningen. Faculty of Spatial Sciences

## Category Prioritisation

| CATEGORY PRIORITISATION | | | |
|---|---|---|---|
| A | B | More important (A/B) | Scale (1-9) |
| Energy & Environment | Mobility | A | 3 |
| | Governance | A | 5 |
| | Society & Citizens | B | 2 |
| Mobility | Governance | A | 3 |
| | Society & Citizens | B | 4 |
| Governance | Society & Citizens | B | 3 |

## Energy & Environment Prioritization

| Energy & Environment prioritisation – Application Fields | | | |
|---|---|---|---|
| A | B | More important (A/B) | Scale (1-9) |
| City Energy Profile | GHG Emissions | B | 4 |
| | Waste Management | A | 2 |
| GHG Emissions | Waste Management | A | 5 |

| Energy & Environment prioritisation – Indicators | | | |
|---|---|---|---|
| A | B | More important (A/B) | Scale (1-9) |
| Final energy consumption per capita | Primary energy consumption per capita | B | 7 |
| | Primary energy sources (shares) | B | 7 |
| | Buildings connected to DH-network or renewable energy grid | A | 3 |
| Primary energy consumption per capita | Primary energy sources (shares) | A | 1 |
| | Buildings connected to DH-network or renewable energy grid | A | 4 |

| | | | |
|---|---|---|---|
| Primary energy sources (shares) | Buildings connected to DH-network or renewable energy grid | A | 3 |

## Mobility Prioritization

| Mobility – Indicators | | | |
|---|---|---|---|
| A | B | More important (A/B) | Scale (1-9) |
| Modal split | Fuel mix in mobility | A | 9 |
| | Energy use for transportation | A | 5 |
| | Access to public transport | A | 4 |
| | Public infrastructure promoting low-carbon mobility | A | 4 |
| Fuel mix in mobility | Energy use for transportation | B | 3 |
| | Access to public transport | A | 1 |
| | Public infrastructure promoting low-carbon mobility | A | 1 |
| Energy use for transportation | Access to public transport | B | 4 |
| | Public infrastructure promoting low-carbon mobility | B | 2 |
| Access to public transport | Public infrastructure promoting low-carbon mobility | A | 4 |

## Governance Prioritization

| Governance prioritisation – Application Fields | | | |
|---|---|---|---|
| A | B | More important (A/B) | Scale (1-9) |
| Economy | Initiatives and strategies of the public administration | A | 3 |
| | Public ICT/data | A | 4 |
| Initiatives and strategies of the public administration | Public ICT/data | A | 3 |

| Governance– Indicators | | | |
|---|---|---|---|
| A | B | More important (A/B) | Scale (1-9) |

| | | | |
|---|---|---|---|
| Unemployment rate | GPD (Gross Domestic Product) | A | 7 |

## Society & Citizens Prioritization

| Society & Citizens prioritisation – Application Fields | | | |
|---|---|---|---|
| A | B | More important (A/B) | Scale (1-9) |
| Affordable housing | Citizen engagement and empowerment | A | 3 |
| | Urban Structure | A | 5 |
| Citizen Engagement and Empowerment | Urban Structure | A | 2 |

| Society & Citizens– Indicators | | | |
|---|---|---|---|
| A | B | More important (A/B) | Scale (1-9) |
| Development of housing prices | Housing cost overburden rate | B | 5 |
| | | | |
| Citizen engagement/empowerment to climate conscious actions | Encouraging a healthy lifestyle | A | 1 |

# Annex 3.6 - Hanze Univesity of Applied Sciences of Groningen

## Category Prioritisation

| CATEGORY PRIORITISATION | | | |
|---|---|---|---|
| A | B | More important (A/B) | Scale (1-9) |
| Energy & Environment | Mobility | A | 5 |
| | Governance | B | 1 |
| | Society & Citizens | B | 5 |
| Mobility | Governance | B | 1 |
| | Society & Citizens | B | 5 |
| Governance | Society & Citizens | B | 3 |

## Energy & Environment Prioritization

| Energy & Environment prioritisation – Application Fields | | | |
|---|---|---|---|
| A | B | More important (A/B) | Scale (1-9) |
| City Energy Profile | GHG Emissions | B | 5 |
| | Waste Management | B | 5 |
| GHG Emissions | Waste Management | A | 1 |

| Energy & Environment prioritisation – Indicators | | | |
|---|---|---|---|
| A | B | More important (A/B) | Scale (1-9) |
| Final energy consumption per capita | Primary energy consumption per capita | B | 3 |
| | Primary energy sources (shares) | B | 1 |
| | Buildings connected to DH-network or renewable energy grid | B | 3 |
| Primary energy consumption per capita | Primary energy sources (shares) | B | 1 |
| | Buildings connected to DH-network or renewable energy grid | B | 3 |

| | | | |
|---|---|---|---|
| Primary energy sources (shares) | Buildings connected to DH-network or renewable energy grid | B | 3 |

## Mobility Prioritization

| Mobility – Indicators | | | |
|---|---|---|---|
| A | B | More important (A/B) | Scale (1-9) |
| Modal split | Fuel mix in mobility | A | 1 |
| | Energy use for transportation | A | 5 |
| | Access to public transport | B | 5 |
| | Public infrastructure promoting low-carbon mobility | B | 5 |
| Fuel mix in mobility | Energy use for transportation | A | 5 |
| | Access to public transport | B | 5 |
| | Public infrastructure promoting low-carbon mobility | B | 3 |
| Energy use for transportation | Access to public transport | B | 3 |
| | Public infrastructure promoting low-carbon mobility | B | 5 |
| Access to public transport | Public infrastructure promoting low-carbon mobility | A | 3 |

## Governance Prioritization

| Governance prioritisation – Application Fields | | | |
|---|---|---|---|
| A | B | More important (A/B) | Scale (1-9) |
| Economy | Initiatives and strategies of the public administration | A | 5 |
| | Public ICT/data | A | 5 |
| Initiatives and strategies of the public administration | Public ICT/data | A | 5 |

| Governance– Indicators | | | |
|---|---|---|---|
| A | B | More important (A/B) | Scale (1-9) |

| | | | |
|---|---|---|---|
| Unemployment rate | GPD (Gross Domestic Product) | B | 3 |

## Society & Citizens Prioritization

| Society & Citizens prioritisation – Application Fields | | | |
|---|---|---|---|
| A | B | More important (A/B) | Scale (1-9) |
| Affordable housing | Citizen engagement and empowerment | A | 5 |
| | Urban Structure | B | 5 |
| Citizen Engagement and Empowerment | Urban Structure | A | 3 |

| Society & Citizens– Indicators | | | |
|---|---|---|---|
| A | B | More important (A/B) | Scale (1-9) |
| Development of housing prices | Housing cost overburden rate | B | 1 |
| | | | |
| Citizen engagement/empowerment to climate conscious actions | Encouraging a healthy lifestyle | A | 1 |

# Annex 3.7 - VTT Technical Research Centre of Finland

## Category Prioritisation

| CATEGORY PRIORITISATION | | | |
|---|---|---|---|
| A | B | More important (A/B) | Scale (1-9) |
| Energy & Environment | Mobility | A | 5 |
| | Governance | A | 3 |
| | Society & Citizens | A | 1 |
| Mobility | Governance | B | 3 |
| | Society & Citizens | B | 4 |
| Governance | Society & Citizens | B | 1 |

## Energy & Environment Prioritization

| Energy & Environment prioritisation – Application Fields | | | |
|---|---|---|---|
| A | B | More important (A/B) | Scale (1-9) |
| City Energy Profile | GHG Emissions | A | 1 |
| | Waste Management | A | 3 |
| GHG Emissions | Waste Management | A | 3 |

| Energy & Environment prioritisation – Indicators | | | |
|---|---|---|---|
| A | B | More important (A/B) | Scale (1-9) |
| Final energy consumption per capita | Primary energy consumption per capita | B | 3 |
| | Primary energy sources (shares) | B | 2 |
| | Buildings connected to DH-network or renewable energy grid | B | 3 |
| Primary energy consumption per capita | Primary energy sources (shares) | A | 1 |
| | Buildings connected to DH-network or renewable energy grid | B | 5 |
| Primary energy sources (shares) | Buildings connected to DH-network or renewable energy grid | A | 1 |

## Mobility Prioritization

| Mobility – Indicators | | | |
|---|---|---|---|
| A | B | More important (A/B) | Scale (1-9) |
| Modal split | Fuel mix in mobility | B | 3 |
| | Energy use for transportation | A | 3 |
| | Access to public transport | B | 3 |
| | Public infrastructure promoting low-carbon mobility | B | 1 |
| Fuel mix in mobility | Energy use for transportation | A | 3 |
| | Access to public transport | B | 3 |
| | Public infrastructure promoting low-carbon mobility | A | 2 |
| Energy use for transportation | Access to public transport | B | 3 |
| | Public infrastructure promoting low-carbon mobility | A | 2 |
| Access to public transport | Public infrastructure promoting low-carbon mobility | A | 5 |

## Governance Prioritization

| Governance prioritisation – Application Fields | | | |
|---|---|---|---|
| A | B | More important (A/B) | Scale (1-9) |
| Economy | Initiatives and strategies of the public administration | A | 3 |
| | Public ICT/data | A | 5 |
| Initiatives and strategies of the public administration | Public ICT/data | A | 4 |

| Governance– Indicators | | | |
|---|---|---|---|
| A | B | More important (A/B) | Scale (1-9) |
| Unemployment rate | GPD (Gross Domestic Product) | A | 3 |

## Society & Citizens Prioritization

| Society & Citizens prioritisation – Application Fields | | | |
|---|---|---|---|
| A | B | More important (A/B) | Scale (1-9) |
| Affordable housing | Citizen engagement and empowerment | A | 3 |
| | Urban Structure | A | 3 |
| Citizen Engagement and Empowerment | Urban Structure | B | 2 |

| Society & Citizens– Indicators | | | |
|---|---|---|---|
| A | B | More important (A/B) | Scale (1-9) |
| Development of housing prices | Housing cost overburden rate | B | 3 |
| | | | |
| Citizen engagement/empowerment to climate conscious actions | Encouraging a healthy lifestyle | A | 1 |

# Annex 3.10 – Slovak University of Technology in Bratislava

## Category Prioritisation

| CATEGORY PRIORITISATION | | | |
|---|---|---|---|
| A | B | More important (A/B) | Scale (1-9) |
| Energy & Environment | Mobility | A | 3 |
| | Governance | A | 7 |
| | Society & Citizens | A | 5 |
| Mobility | Governance | A | 7 |
| | Society & Citizens | B | 5 |
| Governance | Society & Citizens | B | 5 |

## Energy & Environment Prioritization

| Energy & Environment prioritisation – Application Fields | | | |
|---|---|---|---|
| A | B | More important (A/B) | Scale (1-9) |
| City Energy Profile | GHG Emissions | A | 9 |
| | Waste Management | A | 5 |
| GHG Emissions | Waste Management | B | 5 |

| Energy & Environment prioritisation – Indicators | | | |
|---|---|---|---|
| A | B | More important (A/B) | Scale (1-9) |
| Final energy consumption per capita | Primary energy consumption per capita | A | 3 |
| | Primary energy sources (shares) | B | 5 |
| | Buildings connected to DH-network or renewable energy grid | A | 5 |
| Primary energy consumption per capita | Primary energy sources (shares) | B | 7 |
| | Buildings connected to DH-network or renewable energy grid | A | 5 |
| Primary energy sources (shares) | Buildings connected to DH-network or renewable energy grid | A | 7 |

## Mobility Prioritization

| Mobility – Indicators | | | |
|---|---|---|---|
| A | B | More important (A/B) | Scale (1-9) |
| Modal split | Fuel mix in mobility | A | 3 |
| | Energy use for transportation | A | 5 |
| | Access to public transport | B | 3 |
| | Public infrastructure promoting low-carbon mobility | B | 7 |
| Fuel mix in mobility | Energy use for transportation | A | 3 |
| | Access to public transport | B | 5 |
| | Public infrastructure promoting low-carbon mobility | B | 7 |
| Energy use for transportation | Access to public transport | B | 5 |
| | Public infrastructure promoting low-carbon mobility | B | 7 |
| Access to public transport | Public infrastructure promoting low-carbon mobility | B | 3 |

## Governance Prioritization

| Governance prioritisation – Application Fields | | | |
|---|---|---|---|
| A | B | More important (A/B) | Scale (1-9) |
| Economy | Initiatives and strategies of the public administration | A | 5 |
| | Public ICT/data | A | 7 |
| Initiatives and strategies of the public administration | Public ICT/data | A | 5 |

| Governance– Indicators | | | |
|---|---|---|---|
| A | B | More important (A/B) | Scale (1-9) |
| Unemployment rate | GPD (Gross Domestic Product) | A | 5 |

## Society & Citizens Prioritization

| Society & Citizens prioritisation – Application Fields | | | |
|---|---|---|---|
| A | B | More important (A/B) | Scale (1-9) |
| Affordable housing | Citizen engagement and empowerment | A | 5 |
| | Urban Structure | A | 3 |
| Citizen Engagement and Empowerment | Urban Structure | A | 3 |

| Society & Citizens– Indicators | | | |
|---|---|---|---|
| A | B | More important (A/B) | Scale (1-9) |
| Development of housing prices | Housing cost overburden rate | B | 5 |
| | | | |
| Citizen engagement/empowerment to climate conscious actions | Encouraging a healthy lifestyle | A | 7 |