MatchUP

D1.1: Indicators tools and methods for advanced city modelling and diagnosis

WP1, T1.1.

Date of document

June, 2018 *(M9)*

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Technical References

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Project Coordinator	Ernesto Faubel Ajuntamiento de Valencia efaubel@valencia.es
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[1] PU = Public
PP = Restricted to other programme participants (including the Commission Services)
RE = Restricted to a group specified by the consortium (including the Commission Services)
CO = Confidential, only for members of the consortium (including the Commission Services)

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Versions

Version	Person	Partner	Date
0.1	Estefanía Vallejo	CAR	04 December 2017
0.2	Lara Mabe	TEC	03 January 2018
0.3	Lara Mabe	TEC	28 March 2018
0.4	Barbara Branchini	KVEL	09 April 2018
0.5	Lara Mabe	TEC	21 May 2018
0.6	Cristina de Torre	CAR	24 May 2018
0.7	Sebastian Pretzsch	FHG	04 June 2018
0.8	Ana Quijano	CAR	05 June 2018
0.9	Habib Gultekin	SAM	05 June 2018
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1.3	Ana Quijano	CAR	12 June 2018
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Abbreviations and Acronyms

Acronym	Description
AHP	Analytic Hierarchy Process
BAU	Business-As-Usual
CET	Citizens engagement tools
CMG	Coordination and Management Group
CoM	Covenant of Mayors
DG	Driving Group
DWG	Diagnosis Working group
EASW	European Awareness Scenario Workshops
EE	Energy efficiency
EPBD	Energy Performance of Building Directive
EU	European Union
GHG	Greenhouse gases
IAP2	Association for Public Participation
MP	Meeting Point
NGO	Non-governmental organization
PAR	Participatory Action Research
PG	Participatory groups
RES	Renewable Energy Sources
SEAP	Sustainable Energy Action Plan
SECAP	Sustainable Energy and Climate Action Plan
SrV	System of representative traffic surveys
SUMO	Simulation of Urban MObility
SUMP	Sustainable Urban Mobility Plans
SWOT	Strengths, Weaknesses Opportunities, Threats)
TWG	Thematic working group
WBCSD	World Business Council for Sustainable Development

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0 Abstract

The objective of WP1 “Urban Transformation” is the maximization of the upscaling and replication of the demonstrated actions using relevant urban planning mechanisms, the definition of pragmatic models to upscale and replicate, with special focus on transferability of business models. Organizational capability and a strong emphasis on citizen and stakeholder engagement will be essential dimensions to ensure this replication planning process.

Commitment of lighthouse and follower cities in the project is clear. These interventions should be part of a city strategy where a number of goals, actions, etc. are gathered. Therefore, the alignment of interventions with current urban plans is very important but far more important will be to study the alignment of upscaling and replication strategies with these plans. The methodology that will be developed will help not only participating cities but will also be of value for Covenant of Mayors Office and Compact of Mayors in evaluating performance of cities according their planning based on impacts.

The main objective of Task 1.1 “Advanced city diagnosis: identification and review of city challenges and priorities” is to baseline the real city situation and to prioritise its needs and demands in the main fields of energy, mobility, ICTs and citizens fields. The goal is to provide methods and tools to characterise the demanding elements and also to have information about the city supply side. Furthermore, within this task specific methods to analyse information from existing plans will be developed.

The methods and tools developed will be adapted to the casuistry of each city and will be used to obtain and Advanced City Diagnosis, mandatory input for the development of scenarios, Smart City strategic and Replication plans.

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1 Introduction

1.1 Purpose and target group

This report constitutes Deliverable "*D1.1. Report on indicators, tools and methods for advanced city modelling and diagnosis*", which is one of the main outcomes of task "*T1.1: Advanced city diagnosis: identification and review of city challenges and priorities*".

One of the core objectives of this document is to describe the methods and tools selected to carry out the Advanced City Diagnosis of Lighthouse and Follower cities. However, based on these methods and using this document, cities have started their diagnosis (see Figure 2.1) since city diagnosis will be the other main outcome of task T1.1.

The second section of this document "MAtchUP Advanced City Diagnosis approach" describes the process to be followed by cities and how to implement it through specific workshops or meetings.

Furthermore, within this document, the different steps to carry out the Advanced City Diagnosis are described: Citizen-centric approach, Analysis of city plans and city indicators, City performance characterization and City needs and priorities identification.

Finally, Annex I describes the MAtchUP city indicators framework.

1.2 Contribution of partners

The following Table 1.1. depicts the main contributions from participant partners in the development of this deliverable.

Participant short name	Contributions
TEC	Task and deliverable responsible. "MAtchUP Advanced City Diagnosis approach" responsible and definition. "Methodology for energy characterization" responsible and definition of "Methods for city needs and priorities" identification. Check the methodology with the Lighthouse and Follower cities. Selection of the energy indicators.
CAR	"Analysis of city plans" responsible and definition. Coordination of the "City level evaluation framework". Coordinate with the Lighthouse and Follower cities the assessment of Plans. Definition of city indicators and coordination with partners and cities for the selection of final set.
KVEL	"Citizen-centric approach" responsible and definition. Responsible of the selection of social indicators. "Methodology/tools for Social characterization" responsible and definition. Assessment of the Participatory Process defined by each city.
SAM	Responsible of the selection of ICT indicators. "Methodology for ICT characterization" responsible and definition.
TUD	Validation of ICT indicators.
FHG	Responsible of the selection of Mobility indicators. "Methodology for mobility characterization" responsible and definition.

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Participant short name	Contributions
VAL	Deliverable review. Adapt the Diagnosis process to Valencia Municipality and recommendations. Assessment of City Plans and indicators availability.
INN	Collaborate in the Diagnosis process of Valencia.
DRE	Adapt the Diagnosis process to Dresden Municipality and recommendations. Assessment of City Plans and indicators availability.
ANT	Adapt the Diagnosis process to Antalya Municipality and recommendations. Assessment of City Plans and indicators availability.
DEM	Collaborate in the Diagnosis process of Antalya. Participate in the selection of the energy indicators.
HER	Adapt the Diagnosis process to Herzliya Municipality and recommendations. Assessment of City Plans and indicators availability.
OST	Adapt the Diagnosis process to Ostend Municipality and recommendations. Assessment of City Plans and indicators availability.
SKOP	Adapt the Diagnosis process to Skopja Municipality and recommendations. Assessment of City Plans and indicators availability.
KER	Adapt the Diagnosis process to Kerava Municipality and recommendations. Assessment of City Plans and indicators availability.

Table 1.1. Contribution of partners

1.3 Relation to other activities in the project

The following Table 1.2 depicts the main relationship of this deliverable to other activities (or deliverables) developed within the MAtchUP Project and that should be considered along with this document for further understanding of its contents.

Deliverable Number	Relation
D1.2	The Advanced City Diagnosis and the Advanced Integrating planning will share the method for citizen engagement, participatory process and city strategy.
D1.4 – D1.5	The Advanced City Diagnosis will be the base for the definition of demand and supply scenarios.
D1.6 – D12	The Advanced City Diagnosis of each city will be part of the Smart City strategic plan of each city.
D1.13 – D1.19	The Advanced City Diagnosis will serve to assess the impact of the Replication of intervention in each city.
D1.20	The Advanced City Diagnosis will be the base to update SEAPs/SECAPs

Table 1.2. Relation to other activities in the project

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2 MAtchUP Advanced City Diagnosis approach

For an advanced city diagnosis, several steps are necessary, and the involvement of various stakeholders at each step is also needed.

A preliminary step of this Diagnosis process is therefore creating a "Diagnosis Working Group" (M8) in each city, which will be the core team that will *navigate* through the diagnosis process and must involve different stakeholders as needed for each step.

The three key steps to be followed by the Diagnosis Working Group can be summarized as follows:

- Step 0: Citizen-centric approach
- Step 1: Analysis of city plans and city indicators
- Step 2: City performance characterization
- Step 3: City needs and priorities identification

These steps have been defined between the MAtchUP technical partners. However, the process must be adapted to the context of each city. In order to adapt it, the cities must develop their own "Advanced diagnosis plan". This document will be a working document that will be updated during the Diagnosis process.

TEC and CAR, as responsible of WP1 have developed a process to monitor the work of each city.

	LIGHTHOUSES			FOLLOWERS			
	VALENCIA	DRESDEN	ANTALYA	KERAVA	OSTEND	SKOPJE	HERZLIYA
Advanced diagnosis plan	✔	✔	✔	✔	✔	✔	✔
Gantt	✖	✔	✔	✖	✔	✖	✖
Participatory process	✔	✔	✔	✔	✔	✔	✔
Diagnosis working group	✔	✔	✔	✔	✔	✔	✔
WS1 defined	✔	✔	✖	✔	✖	✖	✖
Analysis of city plans	✔	✔	✔	✔	✔	✔	✔
Analysis of city indicators availability	✔	✔	✔	✔	✔	✖	✔
Review of D1.1. methodology	✖	✖	✖	✖	✖	✖	✖
Energy working group	✖	✖	✔	✖	✖	✖	✖
Energy characterization in progress	✖	✖	✖	✖	✖	✖	✖
Mobility working group	✖	✖	✔	✖	✖	✖	✖
Mobility characterization in progress	✖	✖	✖	✖	✖	✖	✖
ICT working group	✖	✖	✔	✖	✖	✖	✖
ICT characterization in progress	✖	✖	✖	✖	✖	✖	✖
Social working group	✖	✖	✔	✖	✖	✖	✖
Social characterization in progress	✖	✖	✖	✖	✖	✖	✖
WS2 defined	✖	✖	✖	✔	✖	✖	✖
WS3 defined	✖	✖	✖	✔	✖	✖	✖
Relevants events in your city	✖	✖	✖	✖	✖	✔	✖
Analisys of city plan & strategies	✖	✖	✖	✖	✖	✖	✖
WS1 report	✖	✖	✖	✖	✖	✖	✖
City Indicators	✖	✖	✖	✖	✖	✖	✖

Figure 2.1. Method to monitor the diagnosis process of each city

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2.1 Gantt of the Diagnosis Process

The Advanced City Diagnosis should be carried out by the cities in 2018 and finished in December 2018 (M15) in order to be able to characterize and evaluate the scenarios before M18 (March 2019).
This Advanced City Diagnosis process is based on research and technical work. However, the organisation of specific workshops with relevant participants is proposed as a method to obtain the desired outcomes. Depending on the city's casuistic, workshops can be replaced by specific meetings.
The timing presented below has been recommended by Tecnalia, however each city is working on its adaptation.

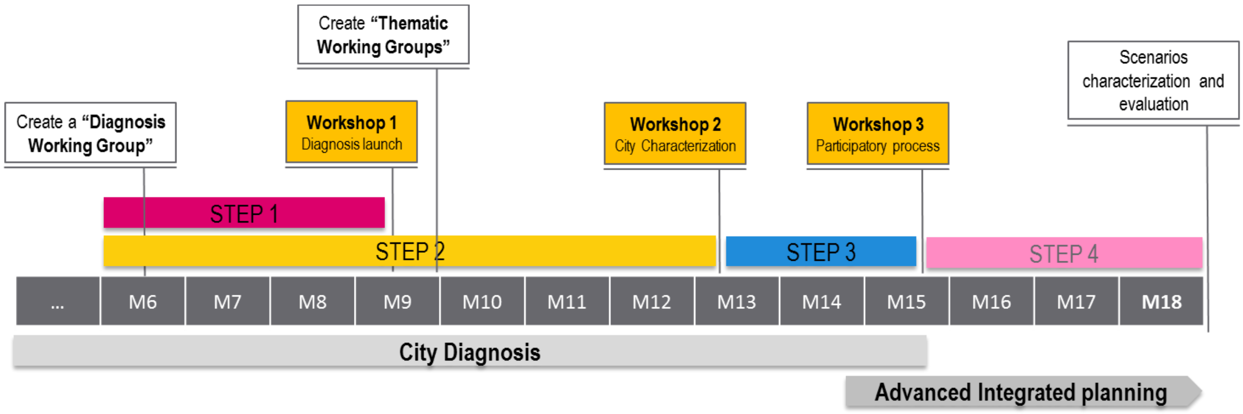

Figure 2.2. Gantt for the Diagnosis Process

2.2 Step 0. Citizen-centric approach

The city characterization of cities should have a **citizen-centric approach** and should combine the perspective of experts, stakeholders and citizens.

Although in the 60's participation linked to urban development was not much more than an intellectual intrepidity of spirited authors like Lefebvre (1967), currently in the OECD countries or in Latin America, it is assumed that, somehow, the citizens should be part of the design of cities, insomuch that some authors refer to it as an ethical "obligation". The V World Urban Forum held in Rio de Janeiro in March 2010 gave priority to participation and, for a long time, in different documents, the EU points out that **the development of cities must be sustainable and governed by participatory processes**[2].

The MAtchUP project aims at strengthening the planning processes for urban transformation, consolidating the benefits of deploying large scale demonstration projects of innovative technologies in the energy, mobility, ICT sectors, promoting the social and human capital and assuming that a citizen-centric approach, in terms of citizen engagement and co-creation strategies, is essential to reach relevant results.

[2] Azorín, Raga, González, Catalá y Caparrós. SOCIOLOGIADOS. Revista de Investigación Social. Vol. 1, n.º 1, 2016, pp. 119-140. DOI: 10.14198/SOCDOS.2016.1.1.05

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In fact, only the active and binding participation of citizens allows to build integrated urban environments and to deploy sustainable actions with which the neighbours feel identified, making possible the empowerment of citizens and the improvement of their quality of life.

The recommended features of a **citizens' engagement strategy** are:

- Direct participation, multilevel governance and co-management
- Co-decision
- Social inclusion
- Synergy with existing initiatives

Participation. From this point of view, it is urgent to take another step and overcome the participation merely consultative, and aspire to innovative approaches and systems of direct participation and multilevel governance (co-management or self-management), and with a self-organization of citizenship in networks around their activities. Participation should go through the backbone of the MAtchUP actions (in line with the philosophy of the *Community Driven Development* which is getting imperative across Europe), starting from the process design and the decision-making (participatory planning, proposals, consultation) to the actions execution, through co-management.

Co-decision. This approach ultimately moves towards more ambitious citizens' participation models, that is to say, models open to the active collaboration and the co-decision by citizens or their social or economic agents. Creating specific, regulated and defined terms of participation, the policy makers can respond more effectively to the real needs of citizens, increasing the impact and benefits.

Social inclusion. The citizens' engagement process should be inclusive allowing and encouraging the participation of vulnerable people living in the area of intervention, ensuring that their voice is heard along the planned urban actions deployment. In many of the working areas, the innovations implemented through the MAtchUP actions must make possible the recovery and enhancement, from a social, cultural, environmental and economic point of view, about the identity and diversity of the area, as an integrating element of the actions and empowerment of the citizens, avoiding processes of gentrification or revaluation exclusively economic. From this point of view, we must understand the field of work in a flexible manner, without losing sight of the urban perspective and responding to the different scales in which the different problems and dimensions can be addressed (neighbourhood - city - metropolitan area).

Synergy with existing initiatives. It is also important to build on existing resources in the area of interest (programs, initiatives, networks, platforms, collectives, associations, etc) to avoid duplicating efforts and achieve an innovation of major importance. It would be important to systematize all the data collected from the pilot sites, as they will contribute to the understanding of the behaviour of the citizens and will offer the possibility of filling the gaps in training and awareness on innovation and sustainability.

The features of participation, co-decision, social inclusion and synergies with existing initiatives shall nurture the MAtchUP processes, both at the city and the project level. The several participatory activities scheduled along the Project should be understood

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as a continuous process and the synergies among the citizens' engagement actions, and between them and the existing initiatives under the planning, demonstration and replication actions should be identified, put in value and strengthen.

In order to clarify the **common participatory environment**, the following figure (Figure 2.3) shows the citizens' engagement infrastructures and processes planned along the Project at different levels, allowing to conceptualize them as parts of one common framework. The figure highlights the specific and common paths followed along the engagement actions:

- under WP1 along the characterization (T1.1) and strategic planning (T1.2-5) phases
- under WP2, WP3, WP4 along the citizens' engagement actions
- under WP5 through the social evaluation to be deployed

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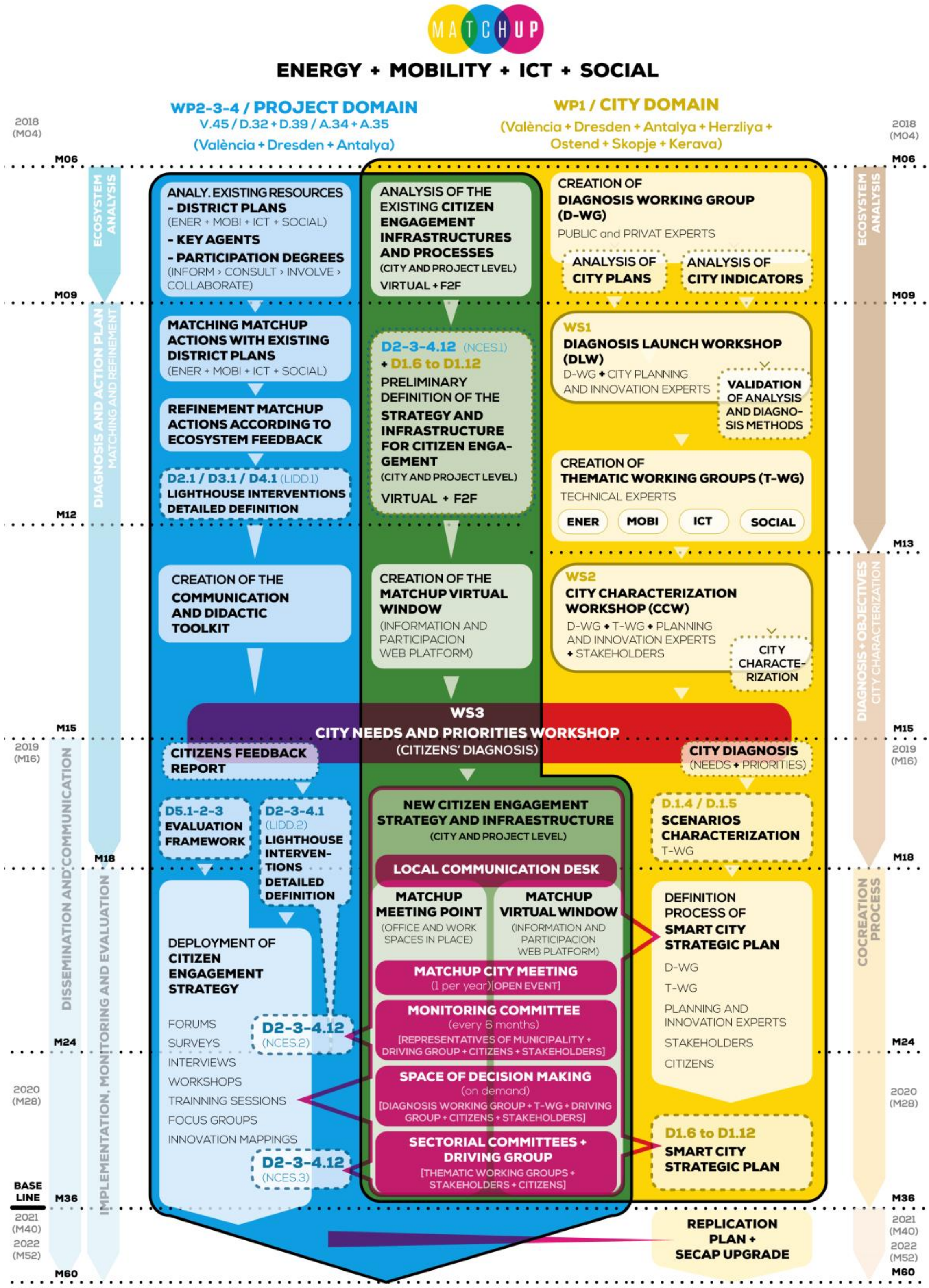

Figure 2.3. MAtchUP Citizens' Engagement Strategies

2.3 Step 1. Analysis of city plans and city indicators

In this first step, different existing studies analysing the **city, the region and its country** will be reviewed by the Diagnosis Working Group and relevant information and figures will be extracted in a structured way.

At minimum the following aspects will be gathered from existing documents:

Information to be extracted from the plans	
Name and brief description of the study /plan/strategy	If one plan has sections related to different fields (energy, mobility, ICT or citizens), include description of at least a line per area.
Current status of the plan	Description (active, outdated, replaced by, etc.)
Who was responsible for the study?	(eg. local government department, private entities, research centers, etc.)
What was the objective of the study?	(eg. respond to legislation, signature to network as CoM, actual planning, etc.)
Application fields	energy, mobility, ICT, social or other (specify)
Implementation Period	Implementation period of the plan
Status of implementation	Status of implementation of the plan
Measurable objectives	Include measurable and strategic objectives for each plan
Strategic Objectives	
Relevant figures	Relevant data that can be useful for the characterization of the city
Intervention areas of the City	Which are the intervention areas of the city identified in the plan? What are the actions that will be carried out in each area?
Current Status of implementation	Status of implementation for each action
Financial Schemes	Financial schemes for each action
Municipal department responsible of implementation	Specify

Table 2.1. Information to be extracted from plans

Additionally, the final list of indicators (see Annex A1) availability will be assessed. Regarding the characterisation methods described in Section 4 they should be also assessed and adapted to the city needs and capacities.

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Conclusions of this first analysis should be reviewed in a first workshop, the "Diagnosis Launch Workshop". This first meeting will be essential so as to get acquainted with the overall city perspective, and identify potential missing studies or information to characterise each MAtchUP fields and their interrelations.

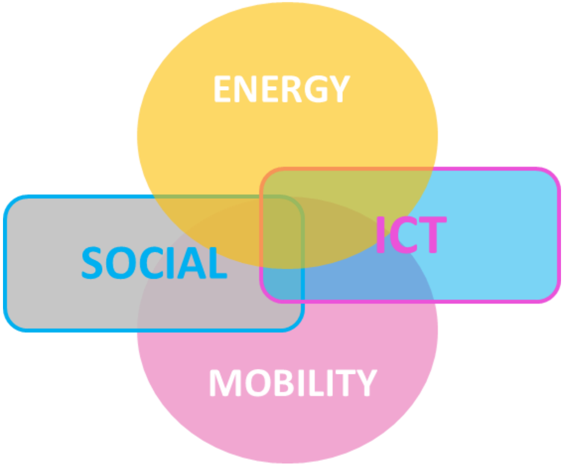

Figure 2.4. MAtchUP fields and their relations

This first workshop will also serve as a key meeting to identify information and data ownership, necessary for the following steps of **Advanced City Diagnosis.** Furthermore, the participatory process of the city will be assessed.

Diagnosis Launch Workshop (1st Workshop) – m9	
Participants	▪ "DIAGNOSIS WORKING GROUP" ▪ City departments and other entities responsible of the different studies and plans (definition and application) ▪ Other public entities relevant to city planning divided by MAtchUP fields (e.g. public energy company, public transport company, etc)
Objectives	▪ First summary and analysis of existing plans and studies ▪ Identify missing points/aspects to be analysed ▪ Gather different perspectives ▪ Discuss and agree on characterization methods proposed for the different fields (D1.1) ▪ Discuss about a participatory process to be followed in the city, to gather wider stakeholders and citizen perspective and develop city needs and priorities.
Outcomes	▪ Feedback on the initial analysis of plans and indicators useful to complete the City Diagnosis ▪ Further inputs needed for the City Diagnosis ▪ Identification of relevant stakeholders and data owners ▪ Defined approach for a participatory process

Table 2.2. Diagnosis Launch Workshop structure

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2.4 Step 2. City performance characterization

To evaluate and characterize city performance, and whenever possible benchmark this performance with other relevant references, it is important to use a recognized Evaluation framework for city characterization.

Within MATCHUP project, this framework for city characterization has been developed having as reference previous experiences in Smart city projects and initiatives supported by the EC such as Smart Cities Systems, CITYkeys and EXPRESSO projects. The framework methodology includes a number of indicators for city characterization in energy, mobility, ITC and social fields (see Annex A1).

Apart from the set of indicators, the **characterization methodologies** for each field described below will be **needed to provide additional information** for a more **detailed diagnosis of the city**. *For example, heat maps of the buildings could help energy planners to get a more accurate picture and diagnosis of building stock energy performance throughout the city, and mobility distribution maps could help identifying key problems in specific areas of the city.*

In order to carry out the performance characterisation of each main field, different "Thematic Working Groups" (TWG) will be set by the Diagnosis Working Group:

- Energy Working Group
- Mobility Working Group
- ICT Working Group
- Social Working Group

Stakeholders to be invited to those TWG include, for each theme, the relevant technical department(s) of the local authority, and public or even private companies if deemed necessary (identified at the "Diagnosis Launch Workshop"). **Technical personnel** are expected to participate in these working groups, and collaborate on providing the necessary data for characterising the city.

The TWG will be in contact with the **technical partners from the MAtchUP project** (TEC - Energy, FHG – Mobility, SAM, TUD - ICT and KVEL - Social) in order to carry out the City Characterisation:

- Complete list of indicators: Energy, Mobility, ICT, Social
- Define the Energy System of the City
- Characterise the Building Stock
- Characterise the Mobility
- Define the main drivers that affects the evolution of each field
- Define the BAU (Business As Usual) for each field
- Participatory process to define needs and priorities
- Etc.

After an initial characterization for each thematic area has been prepared by these TWG, a "City Characterization Workshop" will be held, which could involve the same stakeholders as the "Diagnosis Launch Workshop", plus **additional key stakeholders** identified within the TWG.

The idea of this second workshop is to really get an understanding from a multidisciplinary perspective and considering all different interests from the

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stakeholders of what is the **overall situation of the city, in relation to both other cities and with existing plans, strategies and objectives identified in Step 1.**

CITY CHARACTERIZATION WORKSHOP (2nd Workshop) – m13	
Participants	▪ DIAGNOSIS WORKING GROUP ▪ At least one representative of each TWG ▪ City departments and other entities responsible of different studies and plans ▪ Other public entities relevant to city planning (e.g. public energy company, public transport company, etc.) ▪ Key stakeholders identified by each TWG
Objectives	▪ Presentation of city characterization for each theme (energy, mobility, ICT & social) ▪ Analysis of overall city situation ▪ Benchmarking with other cities ▪ Compare with city objectives ▪ Gather first view on needs and priorities from the city perspective ▪ If not already in progress, launch participatory process, to further develop city needs and priorities from a wider perspective
Outcomes	▪ Detailed city characterization for each dimension ▪ Initial view on needs and priorities from city perspective ▪ Participatory process launched to further develop city needs and priorities from a wider perspective

Table 2.3. City Characterisation Workshop structure

2.5 Step 3. City needs and priorities identification

This step will build on the previous work on characterization, but will have as a fundamental added value that it will consider the interest, opinions, and wishes from a broader stakeholder group (private companies and citizens, should also be taken into account).

This process should therefore **necessarily include a participatory element**, through which the different inputs can be considered to identify city's needs (and most importantly citizens' needs) and include a structured methodology for prioritization.

The procedure to carry this third step might vary between cities, and depending how the participatory process, which has been discussed on the previous steps, has been *organized (e.g. consultations, surveys, interviews, open sessions & debates, etc.).*

Table below describes the process in a format of a third workshop "City needs and Priorities Workshop", which would involve a wide range of stakeholders, and serve to share different views and perspectives.

This Step 3 should include two separate phases, one for gathering as much inputs as possible on needs and wishes, and a second to follow a prioritization method, which can be based on structured methodologies (eg. SWOT, AHP, PESTLE, etc.).

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CITY NEEDS AND PRIORITIES WORKSHOP (3rd Workshop) – m15	
Participants	▪ "DIAGNOSIS WORKING GROUP" ▪ At least one representative of each TWG ▪ Industrial associations ▪ Citizen associations ▪ Private companies ▪ NGOs ▪ Education and research institutions ▪ Etc.
Objectives	▪ Presentation of summary of city characterization and diagnosis to broader group of stakeholders ▪ Present results of participatory actions carried (if available) ▪ Gathering as much info as possible about wishes and needs of the participants ▪ Perform a prioritization exercise with participants
Outcomes	▪ Collection of city and citizen needs ▪ First results of the prioritization analysis to generate scenarios

Table 2.4. City needs and priorities Workshop structure

The Diagnosis Working Group will document the analysis of information and the results of the workshops and the participatory process, reporting all the inputs gathered and processing into the following documents:

- Advanced Diagnosis Plan
- Workshops' reports
- Analysis of existing plans and strategies
- Characterization of city performance
- Identification of city needs and priorities

These documents will serve as a starting point for the development of **City Scenarios (D1.4 & D1.5)** and to start the process of defining the **Smart City Strategic Plan (D1.6 to D1.12)**.

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3 Step 0. Citizen-centric approach

The city characterization of cities should have a **citizen-centric approach** and should combine the perspective of experts, stakeholders and citizens. The process and infrastructures for the citizens' engagement are described in the following paragraphs.

3.1 Citizens' Engagement process

The citizens' engagement strategy is a four-steps process, including:

1. Ecosystem analysis
2. Diagnosis and objectives
3. Action plan and indicators design
4. Implementation and monitoring

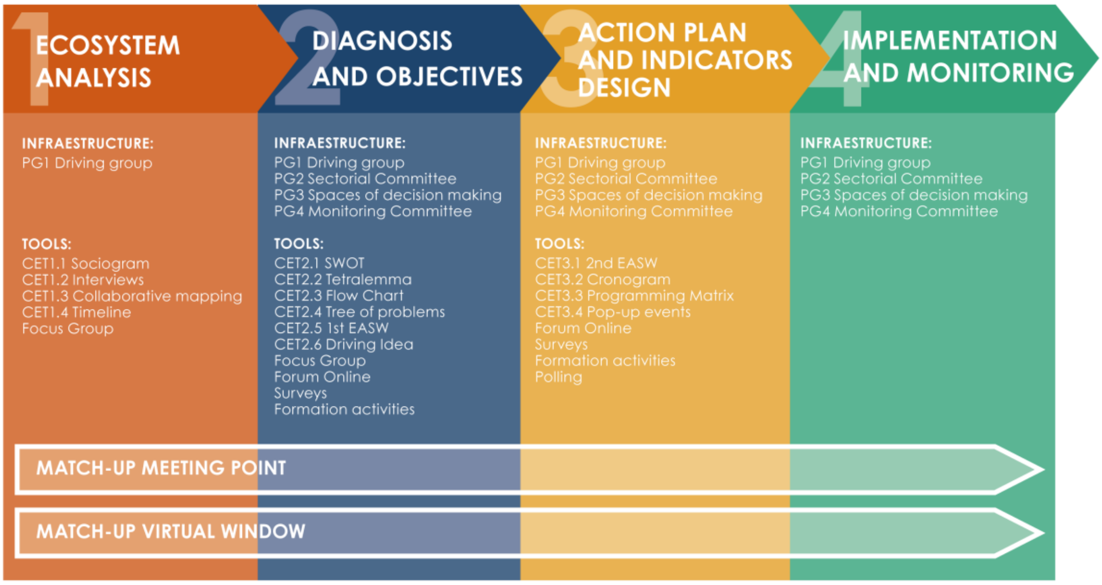

Figure 3.1. Citizens' Engagement process

The MAtchUP Advanced City Characterization will be based on the ecosystem analysis and diagnosis, while the Strategic Planning and Implementation should be co-designed and monitored.

Within this Deliverable D1.1, for the convenience of cities, only the participatory steps accompanying the Advanced City Characterization are described, namely the Phase 1. Ecosystem analysis and the Phase 2. Diagnosis. However, as mentioned above, the citizens' engagement shall be seen as an integrated and continuous process thorough the whole project.

The whole process is modelled and described in detail within the MAtchUP Deliverable *D1.2 Indicators tools and methods for advanced integrated planning: city strategy, financial model and organisational capability* (Defining a Strategy for citizen engagement, p. 33-46). Moreover, a Repository of Citizens' Engagement Tools is included as *Annex A2 of Deliverable 1.2*, as practical supporting tools suggested for the implementation of the engagement actions. The Citizens' Engagement Tools will be

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referred within this document as practical tools that may be used during the actions under Phase 1 and Phase 2.

3.1.1 Ecosystem analysis

The initial phase of the Ecosystem Analysis includes gathering information on existing resources both in terms of relevant strategies and networks. Cities should identify and connect with existing and planned resources and strategies that are complementary to the MAtchUP strategy, in order to establish synergies and not to overlap. The collaboration with private initiatives working in line with the MAtchUP goals is encouraged and should be promoted and disseminated.

This first stage is used to start generating trust between the technical team of coordination and management and the different key actors in the area of action, gathering the information and different points of view present in the field of action. The main actions to perform within the ecosystem analysis are listed below.

- **Collection of information and data crossing**. Cities should collect information generated with a participatory approach in the four MAtchUP fields (Energy, Mobility, ICT, Social), by different actors and from different perspectives (academic information, press news, morphological studies, etc.), as well as initiatives. The collection task will allow also to detect those aspects that were not taken into account or on which there is not enough research, identifying missing points and contradictions. Moreover, shortcomings may be identified along the data collection with respect to the point of view of specific groups, especially the most vulnerable. The analysis will thus identify missed perspectives, and it will ensure the full inclusion of all the relevant actors on the territory. The data collection will be iterative and analysis and studies necessary and relevant for a good definition and implementation of the planned strategies will be generated. It is recommended to perform the analysis using a **Participatory Action Research (PAR)**, in a collaborative way and with relevant actors.
- **Analysis of previous initiatives linked to urban regeneration**, through interviews and group meetings.
- Analysis of existing **participation infrastructures and citizens' involvement** in the field.
- Analysis of existing **platforms and digital networks**.
- **Communication** with the Project partners.
- **Identification of key actors.** Cities should identify relevant local actors and target groups at the municipal level and in the fields under study (Energy, Mobility, ICT, Social) in order to involve them in the diagnosis at different level and to different extents. Key actors include: experts, technicians, policy makers, stakeholders, citizens' representatives, vulnerable groups, Civil Society Organizations. For each key actor and activity, the degree of participation should be clarified (information, consultation, participation, involvement, collaboration, empowerment[3]).

The ecosystem analysis will proceed in parallel to the analysis of the city plans and indicators (*City Advanced Characterization, Step 1*) and they will be mutually nurtured.

3 The levels of participation according to the IAP2's Public Participation Spectrum.

To perform the Ecosystem Analysis, the following bodies shall be already operational:

- Coordination and Monitoring Group
- Sectorial Committees

The following Citizens' Engagement Tools can be used in the 1st step of the process (See Annex 2 of Deliverable 1.2):

- Sociogram (Citizen Engagement Tool (CET)_01.1)
- Individual and group interviews (Consult part 6: CET_01.2)
- Collaborative mapping (CET_01.3)
- Lines of Time (CET_01.4)

3.1.2 Diagnosis and objectives

During this phase, **cities should identify the main needs and priorities collectively** and they will establish the objectives that must be addressed with the city strategy. A participatory diagnosis is about returning to people the technical interpretation made with the information collected in the previous phase and to build collaboratively with citizens and stakeholders objectives and actions. The data should be crossed among key actors and action fields in order to complete the information and build through different perspectives.

Citizens and relevant stakeholders, identified as key actors along the ecosystem analysis, will be involved in the collaborative diagnosis with the aim of prioritizing needs. This should be done through a participatory event, such as a participatory workshop, supported by an online consultation, if needed.

The steps listed below should be followed.

1. Preliminary technical diagnosis. The *City Performance Characterization* will be elaborated by the Diagnosis Working Group, with the support of Sectorial Committees, and validated by key local actors and stakeholders.

2. Creation of didactic and comprehensible material. An important task to do during this phase is the disclosure of the information that is generated. As a preparatory task previous to the participatory event, a **didactic toolkit** should be prepared, including Layman reports and summaries based on the preliminary results of the city characterization; the toolkit will be easily understandable by general public and will be used as working material for the prioritization by participating citizens.

3. Participatory workshop. Return of the technical conclusions and self-diagnosis workshop with the key actors identified during the ecosystem analysis phase. The participants will be involved in the participatory session, aimed to reach consensus on needs and priorities within the city characterization.

To perform the Collaborative Diagnosis, the following bodies shall be already operational (see section 3.2.3):

- Coordination and Monitoring Group
- Sectorial Committees
- Driving Group

The following Citizens' Engagement Tools can be used in the 2nd step of the process:

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- SWOT (CET_02.1)
- Tetralemma (CET_02.2)
- Flow Chart (CET_02.3)
- Tree of problems (CET_02.4)
- 1st EASW (CET_02.5)
- Driving Idea (CET_02.6)
- Focus Groups, Forum online, Surveys, Training activities.

3.2 Citizens' Engagement Infrastructures

A co-design process can be understood as an attempt to help users, researcher, designers and people with diverse backgrounds and skills to cooperate creatively and to jointly explore and envision ideas, make and discuss sketches and explore with mock-up future ideas (Niemi et al., 2015). To do this, we need to understand which actors are more likely to participate, for what reasons and when they choose to engage, and how the engagement process takes place and produces desirable outcomes (UNDP, 2016).

Therefore, cities should **set up the infrastructures for the citizens' engagement**, considered as the working spaces and working groups, as well as the bodies for the coordination and management. The infrastructures will be aligned to existing bodies and initiatives: to this end, relevant synergies will be mapped through the ecosystem analysis before the infrastructures set up. The citizens' engagement infrastructures should include a meeting point, both physical and virtual; coordination, monitoring, communication and dissemination groups; and sectorial bodies and spaces for decision-making.

Participatory bodies and spaces may support both the city planning (city level) and the pilot actions (project level). Indeed, synergies shall be identified and overlapping avoided, as well as citizens' overburden. It is also recommended to maintain the created infrastructures beyond the project life-cycle, along any further action in the urban transformation domain.

The following figure visualizes the Citizens' Engagement Infrastructures described below.

3.2.1 MAtchUP Meeting Point

It is recommended to set up a specific site in the cities for the involvement of citizens. The MAtchUP Meeting Point (MP) will be the point of reference and development of the programme and it will serve as:

- The working place of the group in charge of the coordination and management of the citizens' engagement strategy;
- The central office for the communication and dissemination of the activities developed. The Local Communication Desk may be located here;
- The meeting point and debate among the sectorial committees (such as the Thematic Working Groups), technicians, the citizens, research institutions and the experts from the municipality;
- The site for the development of assemblies, workshops and meetings.

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This physical space will be complemented by a virtual interaction space, which will serve as a support platform (information, documentation, dissemination, participation . of the process.

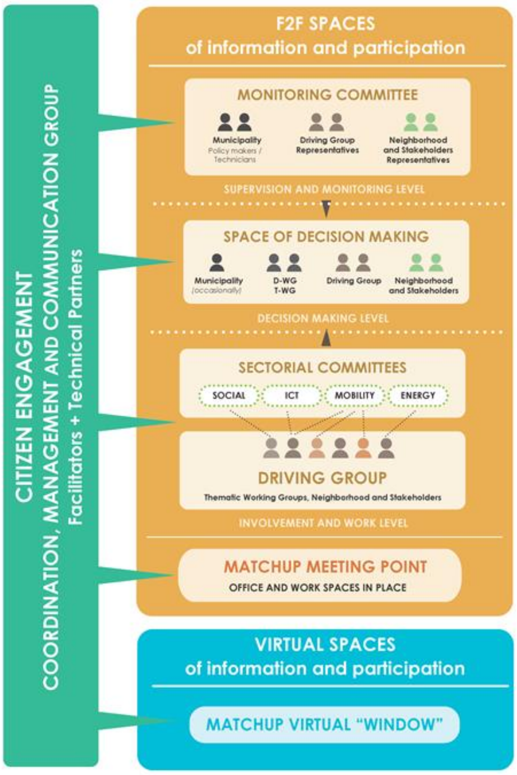

Figure 3.2: CItizens' Engagement infrastructures

The MAtchUP Meeting Point can be a permanent site or it can be set on a rotating basis. In the demo cities, it is recommended to set up the MAtchUP MP in the district where the intervention is planned, where possible. Moreover, where a highly organized associations' network is active in the MAtchUP pilot district, its spaces can be used as Meeting Point if available. In fact, in many contexts the use of own sites of the entities and the citizens and the respect for their dynamics allows a more effective participation.

The MAtchUP MP may be used also as a training center (formal and informal), on energy innovations, ICT and mobility at the city and the project level. The training of "MAtchUP agents" can be considered in each area of action or the different entities that can serve as a link between the programme and the citizens.

3.2.2 Coordination and management group

The citizens' engagement infrastructures should include a Coordination and Management Group (CMG), composed by facilitators and technical partners who will be responsible of the contents and methodology throughout the whole process. The CMG establishes, since the beginning of the process, agile and flexible governance systems that will allow good communication and coordination towards citizens, policy makers and stakeholders.

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It coordinates the different bodies and groups created for the engagement process. It also acts as a mediation team maintaining fluid communication and a close and continuous collaboration with the social and economic agents, addressing the problems that arise from the confluence of divergent interests.

The Diagnosis Working Group may take over the Coordination and Management group tasks; should this be the case, the Diagnosis Working Group should include one representative in charge of the Citizens' Engagement.

3.2.3 **Participatory Groups**

PG_1: DRIVING GROUP

CITIZENS + COORDINATION & MANAGEMENT TEAM.

It is a mix people team, constituted by the citizens and volunteers; and the technical group of management and coordination. The Driving Group (DG) is active along the whole process, is composed by people really engaged and who take on responsibility part of the process. This group of people is at the same time source of information and the centre of the process. The Driving Group is flexible, and new members can be invited whenever specific issues and themes require it. The DG may support in the data collection on their referring environments, on existing networks and relationships. The DG is able to self-manage many of the actions and initiatives that arise from the process.

PG_2: SECTORIAL COMMITTEES

CITIZENS + COORDINATION AND MANAGEMENT TEAM + TECHNICIANS

These commissions work in specific domains and they are composed by technicians, expert in the field. The Thematic Working Groups are an example of Sectorial Committees and they may well support both the city diagnosis and planning, and the pilot implementation in the lighthouse cities, strengthening synergies and avoiding overlapping. Further Working Commissions may be created around a specific MAtchUP performance, or depending on other needs or interests linked to the program.

The Communication and Dissemination Group is also a specific sectorial committee, dedicated to ensuring a correct connection with the citizens of the field and the transparency of the process. Taking advantage of the own citizenship means of communication is encouraged, regardless of whether our MAtchUP projects generate their own media, as a greater impact and effects may be achieved.

PG_3: SPACES OF DECISION MAKING

CITIZENS + COORDINATION AND MANAGEMENT TEAM + TECHNICIANS + POLICY MAKERS.

When working groups and sectorial committees make proposals that need an open space of decision for all the citizens, specific spaces of decision making need to be set up. In these spaces, the proposals are legitimized and priority is given to the most urgent actions and proposals to work in the medium and long term.

PG_4: MONITORING COMMITTEE

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CITIZENS + COORDINATION AND MANAGEMENT TEAM + TECHNICIANS + POLICY MAKERS.

The monitoring committee is integrated by:

- Policy makers.
- Process Promoters.
- Representative associations.
- Driving Group.

This commission is informed during all the participative processes. It is an essential part of the participatory process of the strategy definition, working as a supervisor of the negotiation in some pivotal moment and ensuring the transparency and the proper functioning of the citizens' involvement process.

A fluid and continuous communication should be guaranteed between all the agents of the monitoring committee and in addition, control and information meetings are to be established.

3.2.4 **Dissemination & Communication**

It is important to communicate in a clear way during all the process of citizens' involvement both the objective of the process and the way in which it is planned to carry out; the reasons why, "for who", "with whom" and "how" we will work. The cities Local Communication Desks will deploy the dissemination and communication actions in coordination with the WP8 Leader (ICE).

As general recommendations, online platforms and/or social networks should be enabled to promote participation, communication and information about the process of citizens' involvement. It may also be valued the complementary use of virtual tools such as Cyber-Forums or Virtual Cafes for the promotion of debates, properly conducted so that the inputs can contribute to reinforce and amplify the participatory process started.

Other aspects that should be taken into account along the development of the strategy of citizens' engagement are:

- Regular contact with the Administrations.
- Constant citizens' participation from the beginning.
- Establishment of communication and transparency systems.
- Use of information and communication technologies to interact with citizens.
- Creation of a corporative image.
- Links in European networks and initiatives that allow to access to knowledge and the possibility of adding to joint activities side with the set goals.

3.2.5 **Monitoring and Assessment mechanisms**

In every processes of citizen involvement, the mechanisms for monitoring the actions and evaluation of their physical, social, economic and financial results should be established. To do it, they will be used and if it is necessary will be defined the appropriate indicators. Agents who are already evaluating these indicators will be identified to collaborate with them.

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4 Step 1. Analysis of city plans and city indicators

The urban population in 2016 accounted for 54% of the total global population, up from 34% in 1960, and continues to grow[4]. It is expected that it will reach 66% by 2050. The forecasts are that the combined effects of urbanization, together with the world's population overall growth may add 2.5 billion people to current urban populations by 2050[5].

In Europe three quarters of the population (approximately 359 million people) live in cities and urban areas of more than 5,000 inhabitants, being Europe the most urbanized continent[6]. Cities consume 78% of the world's energy and produce more than 60% of all carbon dioxide and significant amounts of other greenhouse gas emissions, mainly through energy generation, vehicles, industry and biomass use[7]. Therefore, cities are a key element to fight climate change.

European cities have a clear commitment of reducing GHG emissions, of increasing the quality of life of their citizens, of decreasing energy demand and associated economic costs. This commitment is underpinned in the urban plans which have been developed by the city councils.

Plans establish the priorities and articulate the public policy so that the programs translate those priorities into concrete actions and determined deadlines. These plans are defined by local, regional and national authorities considering the targets established by the EU.

In this section, the method for analysis of existing city plans is going to be defined. The analysis of the plans will be divided in three parts: on one hand, city and regional plans will be analysed in order to detect if they are aligned with the European targets, if they are sufficiently ambitious or if the city or region is achieving the proposed objectives and on the other hand, they will be used to obtain information and relevant figures that will be useful for the city diagnosis, its characterization and for the generation of scenarios that will allow to quantify the energy needs and the mobility profile in the future. Moreover, the data gathered in the plans and also in other studies of the city will be relevant for the calculation of the city indicators.

These analyses will be done by all MAtchUP European cities but also by those that are not part of the European Union. Although cities like Herzliya (Israel), has not an official commitment to accomplish the European targets, its objectives and plans will be reviewed in order to adapt them to these European targets.

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[4] http://www.who.int/gho/urban_health/situation_trends/urban_population_growth_text/en/
[5] http://www.un.org/en/development/desa/news/population/world-urbanization-prospects-2014.html
[6] Urbact II Capitalisation, April 2015
[7] https://unhabitat.org/urban-themes/climate-change/

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4.1 Analysis of existing city plans: current status of the plans, alignment with European targets and improvement possibilities

The analysis of existing plans is a very good first step before the development of the Smart City Strategic Plans that will be carried out in the framework of the WP1 but also for obtaining relevant information that can be very useful for completing the diagnosis of the MAtchUP cities.

A first exercise for the identification of plans has been done by the MAtchUP Cities. They have started to review national, regional and city plans, as well as other initiatives and programs whose information can be useful for the city characterization.

	PLANS IDENTIFIED			
	ENERGY	MOBILITY	ICT	SOCIAL / OTHER
Valencia	▪ SEAP ▪ SECAP (under development) ▪ Mapping of fuel poverty ▪ Adaptation Plan	▪ Innovation Plan for transport and infrastructures ▪ Strategic Plan for Infrastructures and transport ▪ Comunidad Valenciana Mobility ▪ Valencia Urban Mobility Plan ▪ Traffic Ordinance	▪ Management Plan for electronic administration ▪ Smart City Strategy of Valencia ▪ Municipal Ordinance for the Installation, Modification and Operation of the Elements and Telecommunication Equipment that Use the Radioelectric Space ▪ Guide to transparency for the Local Public Sector ▪ Guide to the right of access to public information ▪ Guide Procedure to enforce the right to public information ▪ Regulation of transparency and citizen participation	▪ Citizens' engagement model ▪ Social Inclusion
Dresden	▪ Climate Action Plan 2050 ▪ Regional plan	▪ Federal Transport Plan 2030 ▪ Regional plan	▪ Netzallianz Digitales Deutschland	▪ Development Plan Saxony ▪ SECAP - Part II:

	PLANS IDENTIFIED			
	ENERGY	MOBILITY	ICT	SOCIAL / OTHER
	Oberes Elbtal/Osterzgebirge 2009 ▪ Energy and Climate Program Saxony ▪ SECAP - Part I: Integrated Energy and Climate Protection Concept	Oberes Elbtal/Osterzgebirge 2009 ▪ Transport Plan Saxony ▪ Sustainable Urban Mobility Plan	▪ Digital Strategy Saxony	Climate Adaptation Program ▪ Plan on municipal IT Architecture ▪ Integrated Urban Development Concept ▪ Open City Dresden]t
Antalya	▪ Energy Efficiency Strategy Paper 2014-2023 ▪ Energy Efficiency Action Plan 2017-2023 ▪ National Climate Change Action Plan ▪ National Renewable Energy Action Plan ▪ Energy Efficiency Law ▪ Renewable Energy Law ▪ BAKA Biomass Report ▪ BAKA Solar Energy Report ▪ Antalya SEAP	▪ National Smart Transportation Systems Strategy ▪ Antalya Transportation Master Plan	▪ National interoperability strategy ▪ E-government strategy ▪ Western Mediterranean region dev. Plan ▪ Organized Industrial Zones ▪ Municipality performance plan ▪ Municipality strategy plan ▪ Irrigation unions	▪ 10th Development Plan ▪ BAKA Regional Development Plan ▪ BAKA Economic Indicators Report ▪ Antalya-Isparta-Bursa Region 1/100.000 Scale Environment Regulation Master Plan ▪ Antalya Metropolitan Municipality Strategic Plan ▪ Antalya 1/25.000 Scale Structure Plan ▪ Antalya Environmental Status Report ▪ Antalya Statistic Report ▪ Antalya ecotourism Master Plan
Herzliya	▪ National Plan for Energy Efficiency ▪ Plan for energy saving	▪ Transportation Plan	▪ Smart City Plan	▪ Forum-15 Cities Alliance ▪ Green House reduction master plan
Keraba	▪ National goals for land use	▪ Finland's Energy and Climate		▪ Kerava Housing

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	PLANS IDENTIFIED			
	ENERGY	MOBILITY	ICT	SOCIAL / OTHER
	▪ Strategic climate program for Central Uusimaa ▪ Transportation system plan for the Helsinki metropolitan area (HLJ)	Strategy ▪ Regional plans for Uusimaa ▪ Kerava Master Plan 2035 (YK6) ▪ Kerava Transportation Policy Program		Policy Program
Oostende	▪ Climate Neutral Ostend 2050 ▪ LED-lighting		▪ Statistics: 'Facts & Figures of the Province of West-Flanders' ▪ Statistics: SWING	▪ Co-creation 'East Bank' Ostend ▪ Kom Uit Je Schelp ▪ Overall Greening of City Centre ▪ Smart Society Network
Skopje	▪ SEAP (Action plan of the City of Skopje ▪ Energy efficiency Program of City of Skopje	▪ SUMP		▪ Spatial plan of Republic of Macedonia ▪ LEAP 2 ▪ Resilient Skopje ▪ GUP (General urban plan of City of Skopje)

Table 4.1: Preliminary list of plans identified at city scale

The main objectives of this analysis are:

- to evaluate current targets of the cities in order to detect if they are aligned with European targets or if those targets could be more ambitious.
- to achieve data that will be used for the calculation of the city level indicators.
- to obtain relevant information for the city diagnosis and for the generation of scenarios

Moreover, MAtchUP project is going to work with lighthouse and follower cities in the adaptation of their Sustainable Energy Action Plans to Sustainable Energy and Climate Action Plans. For this, the current SEAP and SECAPs will be analysed in order to evaluate their improvement possibilities and to adapt them to the 2030 targets taking into account not only the mitigation actions but also the adaptation to climate change.

4.1.1 European Targets

European policies have been decreed to fight against the world's biggest environmental issue, the global warming. These policies aim at working to cut EU greenhouse gas emissions and for this, several targets have been established in the last years.

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The first set of EU targets for the year 2020 were established in 2007 and enacted in legislation in 2009 and consisted to cut in 20% the greenhouse gas emissions compared with 1990, to increase 20% of total energy consumption from renewable energy and to increase 20% the global energy efficiency. They are also headline targets of the Europe 2020 Strategy developed in 2010. These targets were modified and the new current EU targets for 2030 are more ambitious. The goals for 2030 are to cut at least 40% the greenhouse gas emissions compared with 1990, increase at least 27% of total energy consumption from renewable energy sources and to increase at least 27% the energy efficiency. Moreover, the EU climate action polities establish global goals with a longer time-horizon by 2050. For this year, EU aims to cut its emissions by 80-95% compared to 1990 levels and turning EU into a highly energy efficient and low-carbon economy.

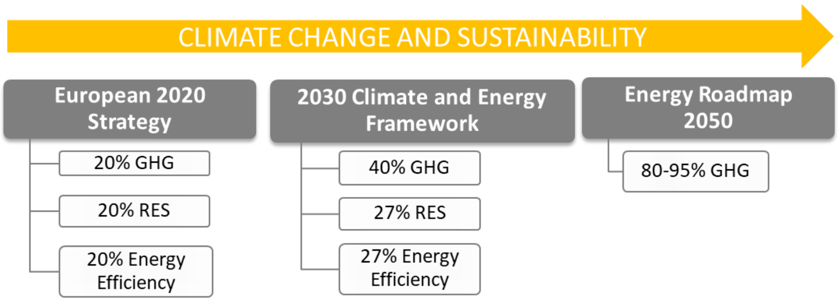

Figure 4.1: European energy targets

Furthermore, the Europe 2020 strategy emphasises smart, sustainable and inclusive growth in order to improve Europe's competitiveness and productivity and underpin a sustainable social market economy. In addition to the sustainable objectives just mentioned, other goals related to smartness and inclusive growth were established divided among different thematic areas:

- Research and development: 3% of GDP to be invested in R&D sector
- Education: share of early schools leavers to be reduced under 10% and at least 40% of 30 to 34 years old to have completed tertiary or equivalent education
- Employment: 75% of the population aged 20 to 64 years to be employed
- Poverty and social exclusion: at least 20 million fewer people in (or at risk of) poverty/social exclusion

To foster the achievement of the environmental goals, the **EU regulation** supports these objectives, with initiatives like the EU's emissions trading system, regulations to support the deployment of renewable energy in the EU territory (RES Directive transposed as National Action Plans) or some regulations to increase the Energy Efficiency like the Energy Efficiency Directive or Energy Performance of Building Directive (EPBD)

In line with these, in April of 2013 the European Commission adopted an EU strategy on adaptation to climate change which has been welcomed by the EU Member States. The strategy aims to make Europe more climate-resilient.

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4.1.2 Covenant of Mayors for Climate and Energy[8]

Regarding cities, Global Covenant of Mayors for Climate and Energy is the most important world-wide initiative, with a special focus at EU level, committed to fight against the climate change. It is an international alliance of cities and local governments with a shared long-term vision of promoting and supporting voluntary action to commit to EU climate targets, principally the reduction of CO_2 emissions and to combat climate change and move to a low emission and resilient society. EU Covenant of Mayors merged with the United Nations Mayors Compact to launch the new combined Global Covenant of Mayors for Climate and Energy.

Local governments committed to Covenant of Mayors pledge to implement policies and undertake measures to:

- Reduce or limit greenhouse gas emissions
- Prepare for the impacts of climate change
- Increase access to sustainable energy
- Track progress toward these objectives

When officially joining the Covenant of Mayors, signatories commit to developing a Sustainable Energy (and Climate) Action Plan within two years. SEAP (Sustainable Energy Action Plan) includes commitments related to 2020 targets and adaptation to climate change.

In October 2015, the European Commission launched the new integrated Covenant of Mayors for Climate and Energy which goes beyond the objectives set for 2020. From 2016, signatories are required to submit a SECAP (Sustainable Energy and Climate Action Plan) with new commitments for 2030 and an additional focus on climate change impact mitigation. The new 2030 Covenant of Mayors has meant that new signatories now commit to a 40% CO_2 emission reduction target by 2030.

4.1.3 National, Regional and Local Plans

Since each European country has different resources and energy markets, they have to follow different paths when it comes to meeting their obligations under the Renewable Energy Directive, including their legally binding 2020 targets.

National plans, that must be drew up every three years under Energy Efficiency Directive, set out estimated energy consumption, planned energy efficiency measures and those improvements that EU countries expect to achieve.

The plans cover:

- individual renewable energy targets for the electricity, heating and cooling, and transport sectors
- the planned mix of different renewables technologies
- policy measures to achieve national targets including cooperation between local, regional, and national authorities
- any planned statistical transfers and/or joint projects with other countries
- national policies to develop biomass resources

[8] https://www.globalcovenantofmayors.org/

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- measures to ensure that biofuels used to meet renewable energy targets are in compliance with the EU's sustainability criteria

MAtchUP cities will analyse their national, regional and local plans considering the targets established for the different key fields of the project.

In the following table can be seen some of the targets that will be taken into account in the analysis of the national, regional and local plans.

Energy Targets	Mobility Targets	ICT Targets	Social Targets	
% Reduction of Energy Demand / Base Year	Future Modal Split	Nº of users of services / year	Improve education ratio	Number of interactive social media initiatives
% Improve Energy Efficiency / Base Year	% Use of Public Transport	Nº online government services / citizens	Improve GDP	Encourage the use of ICT in society
% RES	% Electric Vehicles in the city fleet	Improve interoperability	Eradicate Fuel poverty	Institutions more transparent for the citizens
% Reduction of CO_2 emissions / Base Year			Open government dataset	Access to public free Wi-Fi

Table 4.2: Targets that will be analysed from the national, regional and local plans

4.1.4 Sustainable Energy Action Plan (SEAP) and Sustainable Energy and Climate Action Plan (SECAP)

The Sustainable Energy Action Plan is a key document that shows how the Covenant of Mayors signatory will reach its commitment by 2020. It uses the results of the Baseline Emissions Inventory (BEI) that provides knowledge of the nature of the entities mitting CO2 on the cities and will thus help select the appropriate actions, identify the best fields of action and opportunities for reaching the local authority's CO2 reduction target.

SECAP is the upgrade version of the SEAP and therefore it maintains the same procedure. The main differences between both action plans are their targets and timeframes.

SEAP was aimed at defining mitigation actions that allowed cutting down at least 20 of CO_2 emissions by the year 2020 and SECAP defines actions for reducing at least 40% of those emissions by 2030. Moreover, SECAP has to include not only mitigation actions but also the adaptation to climate change. Therefore, existing SEAP actions taking into account the new reduction targets could be the mitigation actions of the new SECAP.

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MatchUP City	Year of adhesion to CoM	Baseline Year	SEAP/SECAP	Overall CO_2 emission reduction target		Monitoring
				2020	2030	
Valencia	10/02/2009	2007	2010	20%	-	2015
Dresden	24/06/2016	2005	2017	-	41%	-
Antalya	08/01/2013	2012	2014	23%	-	-
Oostende	23/01/2010	2007	2013	20%	-	2015
Skopje	29/03/2010	2009	2011	21%	-	-
Kerava	-	-	-	-	-	-
Herzliya	-	-	-	-	-	-

Table 4.3. MAtchUP cities status related to the signature of Covenant or Mayors.

Dresden, one of the MAtchUP cities, was the first European city with more than 250,000 inhabitants to have submitted a SECAP. **The MAtchUP project will establish a close link with the Covenant of Mayors framework,** by supporting the cities involved in the project like Valencia, Antalya, Oostende and Skopje to upgrade their existing 2020 Covenant action plans (SEAPs) to 2030 SECAPs. Dresden will be able to improve its existing SECAPs or even develop a new SECAP and on the other hand Kerava and Herzliya will commit to the 2030 objectives of the Covenant during the project lifetime and be accompanied in the creation of their SECAPs.

4.1.5 **Sustainable Urban Mobility Plans**

Sustainable Urban Mobility Plans (SUMP) were promoted by the European Commission in the White Paper on Transport (2011) and the Urban Mobility Package (2013). These plans are one of the main tools to tackle transport and mobility in urban areas.

The SUMP is a strategic plan with the main objective of providing integrated solutions to transport and mobility needs of people and goods, guaranteeing technical, economic, environmental and social sustainability.

The Sustainable Urban Mobility Plan concept considers the functional urban area and foresees that plans are developed in cooperation across different policy areas and sectors, across different levels of government and administration and in cooperation with citizens and other stakeholders.

As can be seen in the Table 4.4 some of the MAtchUP cities already have Sustainable Urban Plans that will be analysed during the project. In other cases, cities are working in the development of their mobility plans and MAtchUP project will collaborate with them in these tasks.

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MAtchUP City	Mobility plans	Period
Valencia	Sustainable Urban Mobility Plan of Valencia	Since 2013
	Circulation Ordinance	Since 2010
Dresden	Sustainable Urban Mobility Plan Dresden 2025 plus	2014-2025
Antalya	Antalya Transportation Master Plan	2017-2040
Oostende	-	-
Skopje	Sustainable Urban Mobility Plan	
Kerava	Kerava Master Plan 2035	2016-2035
	Kerava Transportation Policy Program	2018-2025
Herzliya	Transportation Plan	Since 2018

Table 4.4: Mobility Plans in the MAtchUP cities

4.2 Analysis of the existing city plans I: current targets

Within MAtchUP project, the most relevant plans, programs and strategies developed by regional and urban governments to contribute to the national objectives and therefore to the European targets will be analysed. This analysis will be carried out taking into account the key areas of the project, so plans will analyse the energy, mobility, ICT and citizens /social fields under a sustainable approach which cover environment, social and economic aspects.

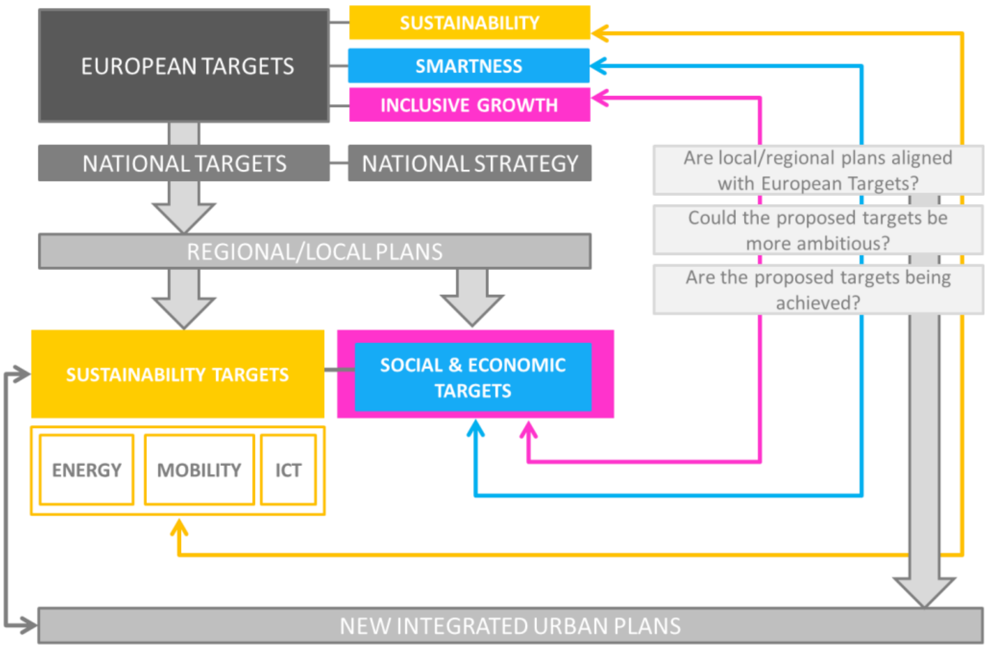

Figure 4.2: Analysis of plans

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The Europe 2020 strategy emphasises smart, sustainable and inclusive growth as a way to overcome the structural weaknesses in Europe's economy, improve its competitiveness and productivity and underpin a sustainable social market economy. The result of the analysis of the plans from the point of view of the MAtchUP key fields will be linked with these three key categories defined by European Union.

Therefore, a continuous top-down deployment of the plans is expected, while a continuous bottom-up monitoring and evaluation to update the plans from the results of the lower level will be implemented.

A global and integrated vision of the city targets and of the city status is essential to achieve the expected success, so the plans will be analysed to detect lack of integrated vision in order to propose improvements for the new generation of plans.

4.3 Analysis of the existing city plans II: data for indicators calculation

Indicators are a useful diagnosis tool to know the starting point of the cities revealing areas of the city in which it is performing well and those in which a significant improvement is needed. They are also a helpful decision-making tool that can be used to establish a priority order among the areas for action and are a valuable monitoring tool.

Some of the indicators included in the MAtchUP evaluation framework can be obtained from the current city plans or in some cases, those data will have been previously calculated to the development of those plans. For this reason, not only is necessary to analyse the plans but also other documents, analysis or studies made in the city will be very useful for the characterization of the city demand, for the definition of the needs and priorities and for the calculation of those indicators that will help to evaluate the current status ant the improvements of the city.

Therefore, each city will take advantage of previous studies and plans for the calculation of the required indicators within MAtchUP evaluation framework. MAtchUP city level indicators will link the objectives of the plans and those European targets above mentioned. Thus, cities will be able to check if they are accomplishing with the requirements established by the European Union. In some cases, the indicators will not be exactly the same than those used for the calculation of European targets, but they will allow evaluating if the city is evolving in the right direction.

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STRATEGY 2020			MAtchUP Evaluation Framework	
KEY PRIORITIES	THEMATIC AREAS	TARGETS	SUSTAINABLE DEVELOPMENT DIVISION	INDICATORS
SMARTNESS	Research and development	3% EU's GDP invested in R&D	Equitable	R&D expenditure as percentage of city's GDP
	Education	Early school leavers under 10% 40% younger generation with tertiary degree	Equitable	Early school leaving, number of high education degrees per 100,000 population, access to educational resources
SUSTAINABILITY	Climate change and energy	20/20/20	Viable & Bearable	GHG Emissions per capita and per sector, Renewable energy generated within the city, Renewable heat generated, Renewable electricity generated
INCLUSIVE GROWTH	Employment	75% Population aged 20-63 employed	Equitable	Unemployment rate, youth unemployment rate, employment rate in vulterable groups (age)
	Poverty and social exclusion	20 million less people at risk of poverty	Equitable	Fuel poverty, people at risk of poverty or social exclusion

Figure 4.3: Relation between plans and indicators

4.3.1 Governance Indicators related to city plans

Within the MAtchUP evaluation framework, there is a list of indicators related to Governance where they are classified into several domains like Local government support, civic engagement and governance, local government support or governance collaboration.

Some of these indicators within Local Government Support domain are related to city plans and will give an idea of the involvement of the city in its transformation towards a smarter and more sustainable city.

Domain	Indicator	
Local Government Support	Existence of an Agenda 21	Signature and compliance of the Covenant of Mayors
	Level of correspondence with national regulation	Smart city policy
	Existence of local sustainability plans	Existence of regulations for development of energy efficient districts
	Existence of plans/programs to promote sustainable mobility	Existence of Smart Cities strategies
	Climate resilience strategy	
Governance collaboration	Cross-departmental integration	Multilevel government

Table 4.5: Governance Indicators related to city plans

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4.4 Analysis of the existing city plans III: Information and relevant figures for the city characterization

Last but not least, the third objective of the analysis of the existing city plans is to obtain information to characterize the demand of the city, identify its needs and priorities and obtain useful information for the generation of scenarios.

The development of national, regional and city plans to accomplish the European targets means a hard work for the city that has to collect data and carried out calculations that can be very useful for the characterization of its current situation.

In some cases, the needed information will not be available at city scale, so that information will be extracted from Regional or National Plans. For this reason, it is important to reference all the figures.

The analysis of the plans for finding useful information will be made taking into account the four main fields of the project: energy, mobility, ICT and social. Some of the most relevant data that cities could extract from their plans or previous studies have been included in the Table 4.6.

Energy Characterization	Mobility Characterization	ICT Characterization	Social Characterization
Energy Demand & Supply city profile	Mobility City Profile	Urban platforms features	Demographic profile
Energy Consumption per sector and carrier	Trips characterization	ICT in society	Economic development of the city
Energy Production per sector and carrier	Public transport and other clean alternatives to private vehicles	ICT for the urban infrastructure management	Citizens profile
Local Energy Resources	Road network	WIFI Access within the City	Living conditions (Housing cost overburden rate, fuel poverty, population dependency ration)
CO2 emissions	Electric transport		Civic engagement
	Mobility Platform		Unemployment rate

Table 4.6: Information that will be extracted from the city plans for the city characterization

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4.4.1 Actuation Areas

In some cases, actuation areas will have been already selected within the cities. It will be necessary to identify if city has started to act in these areas or if, on the contrary, although those areas have been identified because of their needs, no actuations have been planned so far.

These areas will be identified within a map of the city and into a list and they will be related with the fields of the project (Energy, Mobility, ICT and Social).

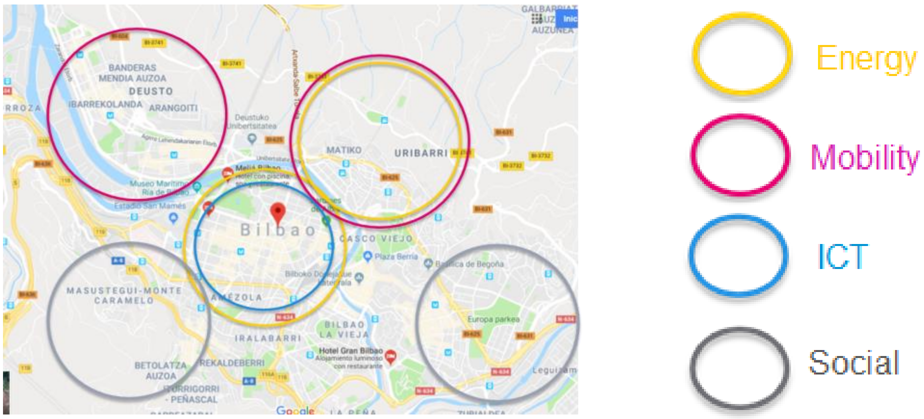

Figure 4.4. Example of actuation areas identified in a city map

4.4.2 Actions and timeline

Cities will identify the main actions planned to be implemented and their timelines.

Before the definition of actuation areas or actions to be implemented within MAtchUP project, it is necessary to know not only the actuation areas that have been identified previously by the city but also those actions that have been planned or at least been considered to be implemented.

When available, Business As Usual will be also presented at city, regional or national scale.

The status of the interventions will be reported as well as a description of the monitoring systems in case the actions are being monitored.

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5 Step 2. City performance characterization

The initial approach to city performance characterization will be through the calculation of the city level indicators included in the city evaluation framework described in *City level evaluation framework*. Cities will have the support of the technical partners for a more detailed characterization of the performance related to energy, mobility, ICT and social. The methodologies are for this detailed characterization are described in sections 5.2 to 5.5

5.1 City level evaluation framework. Priorities pre-identification

An evaluation framework is an effective approach which enables cities to determine whether is achieving its objectives.

Sustainable development is a common and contemporary goal of many urban development policies in various countries and cities. Thus, an Evaluation Framework based in sustainability is a key point to establish a way to rate the sustainable features of the urban development of cities and can help cities to identify strengths and weaknesses and consequently set priorities for the selection of actions to be implemented to transform a city into a sustainable city.

MAtchUP project is defining its evaluation framework based on the concept of sustainable development and in indicators that will help to the cities to evaluate their current status and the improvements that are being achieved during their transformation process.

Figure below represents the evaluation framework and how indicators have been classified under the three dimensions that comprise the term sustainability: environment, economy and social. This figure also includes how these indicators are grouping in the fields, which cover the technical solutions to be implemented in MAtchUP projects: Energy in Sustainable buildings and districts, City infrastructures, and Mobility and transport, ICT and Urban Platform and Non-Technical actions for the solution related to Citizens and Society.

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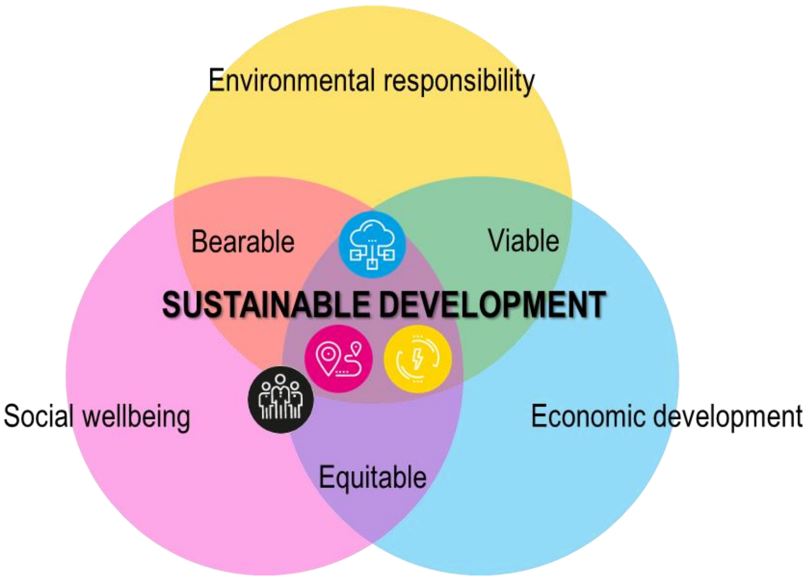

Figure 5.1. Classification of the MAtchUP indicators at city level

As a result of the collaboration of experts and cities involved in the project, a total of 188 indicators have been defined and distributed through domains. Figure below represents the evaluation framework developed for advanced city diagnosis.

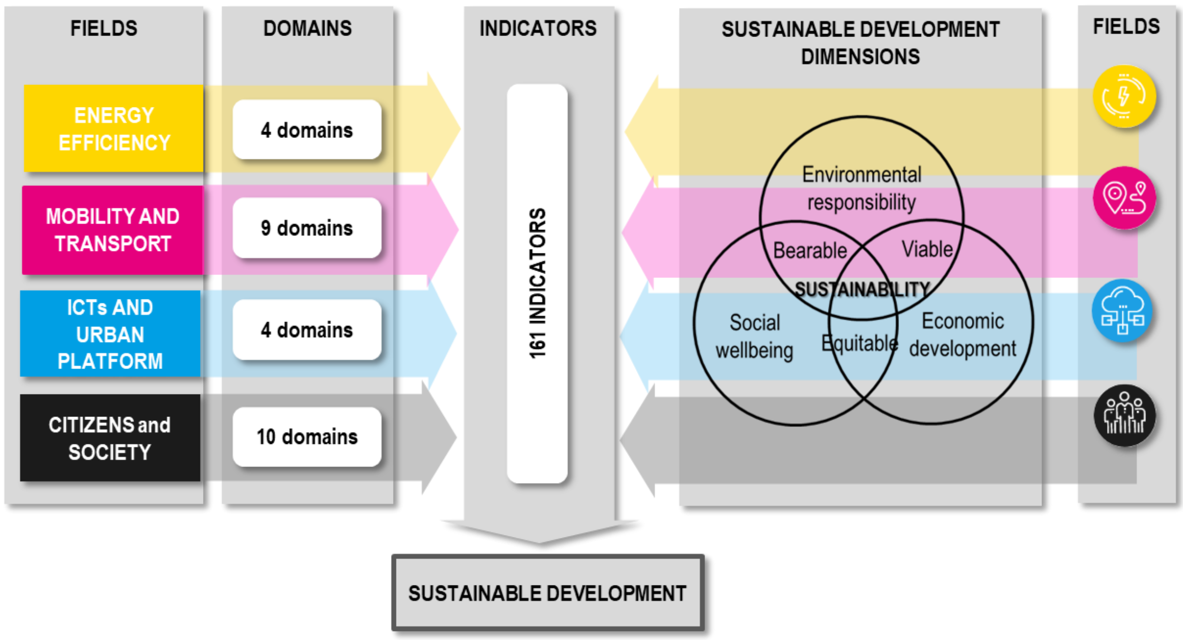

Figure 5.2. MAtchUP evaluation framework

Under this scheme, MAtchUP intends to build indexes that are formed when individual indicators are compiled into a single index through the application of mathematical models. As a result, the cities can rate the sustainability of the urban development of the cities.

Further information of this evaluation framework and the definition of indicators selected for the city characterization can be found in Annex1.

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5.2 Methodology for energy characterization

Energy security and climate change are driving a future that will require significant improvements in the energy performance of the building sector. The 28 Member States of the European Union (EU) have set an **energy saving target of 30% by 2030**[9], which will need to be reached mainly through energy efficiency measures. The EU has also committed to reduce **greenhouse gas (GHG) emissions by 80–95% by 2050**[10], as part of its roadmap for moving to a competitive low-carbon economy in 2050. **Buildings** are one of the world's largest energy-consuming sectors. Considering the residential and service sectors buildings **account for nearly 33% of the final global energy consumption**[11] **and reaching 40% in the EU**[12]. In order to support the energy transition of Europe towards a low carbon economy, **municipalities have a key role to play**. For example, thousands of local and regional authorities launched the **Covenant of Mayors for Climate & Energy**[13], which brings a voluntarily commitment to achieve EU climate and energy objectives on their territory. Other cities focused their effort defining environmental plans or developing building energy efficiency regulations.

5.2.1 State of the art

Energy models are used to portray the present and future energy use of a system. Thus, they are a useful tool for policy-makers, in order to achieve the above-mentioned measures and targets. Present energy modelling methods can be classified into two approaches: **Top-Down** and **Bottom-Up** models.

5.2.2 Top-Down

The first option (top-down) is based on defining an overall value of demand and supply for the whole evaluated area.

Top-Down models focus on an aggregate level and deal with the effects of energy consumption under an economy-wide approach[14]. They are usually described as general equilibrium models. These models lay down econometric correlations between energy and macroeconomic variables (GDP, income, GVA, fuels prices, etc.) based on historical data. Hence, energy use of end-use sectors is represented through production functions which relate the dependent variable (energy consumption or GHG emissions for which scenarios and trends want to be known) with a combination of independent variables (macroeconomic variables for which trends and forecasts are known). These relationships can be set up through simple functions like growth-rate

[9] European Commission, "Proposal for a directive of the European Parliament and of the council amending directive 2012/27/EU on energy efficiency", 2016

[10] European Commission, "A Roadmap for moving to a competitive low carbon economy in 2050", 2011

[11] IEA, "Key World Energy Statistics", 2017

[12] European Commission, "EU energy in figures. Statistical Pocketbook 2017", 2017

[13] https://www.covenantofmayors.eu/en/

[14] C. Böhringer and T. F. Rutherford, "Combining bottom-up and top-down," *Energy Econ.*, vol. 30, no. 2, pp. 574–596, 2008.

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based methods or elasticity-based demand forecasting, through more complicated ones like translog cost or logit models for the industry sector; non-linear functions for the transport sector (e.g. Gompertz model); regression models, cointegration, and error correction methods for the residential and tertiary sectors[15].

Top-Down models have however some limitations: as they do not represent with detail actual and future technologies and do not distinguish energy consumption between final end-uses and areas of the city.

5.2.3 Bottom-Up

Bottom-Up models are engineering-based methods which focus on a disaggregate level and rely on micro-level data such as detailed consumption of different buildings, uses, technologies, equipment efficiencies, or consumers' behaviour[16] hence describing the energy sector with detail.

In the residential or tertiary sectors, a valuable input for a Bottom-Up model is the diagnosis of building stock energy consumption. Currently, there are several commercial dynamic energy simulation tools (e.g. Design Builder, Trnsys, Simergy, EnergyPlus, etc.) that calculate accurately the energy demand of each building. The quality of this data can be very accurate. However, to obtain the results, the end user has to define the values of many parameters of each building.

Bottom-up models poorly represent economic interactions and are not able to take into account feedback effects of technical changes on the economic system. Another drawback of this kind of models is that the disaggregation level of the data which is needed is hard to obtain.

Finally, it should be noted that hybrid models are arising in the last years with the purpose of combining the two above mentioned approaches, each one balancing the flaws of the other[17].

As an example, some of the actual energy demand forecasting models are now described:

- **PRIMES[18]:** hybrid model used by the E.U. It is a partial equilibrium model, unless linked with macroeconomic model GEM-E3. The demand of each end-use sector is calculated in a specific sub-model which in turn are linked together through an algorithm which determines equilibrium prices.
- **NEMS[19]:** hybrid model used by the U.S. government. It has an econometric approach (top-down) combined with a rich technology representation and demand disaggregation (bottom-up).

[15] S. C. Bhattacharyya and G. R. Timilsina, "Energy Demand Models for Policy Formulation A Comparative Study of Energy Demand Models," Energy, vol. 4866, no. March, p. 151, 2009.

[16] The World Bank Group, "Planning for a Low Carbon Future," 2012.

[17] C. Böhringer and T. F. Rutherford, "Integrated assessment of energy policies: Decomposing top-down and bottom-up," *J. Econ. Dyn. Control*, vol. 33, no. 9, pp. 1648–1661, 2009.

[18] https://ec.europa.eu/clima/sites/clima/files/strategies/analysis/models/docs/primes_model_2013-2014_en.pdf

[19] https://www.eia.gov/outlooks/aeo/nems/overview/pdf/0581(2009).pdf

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- **POLES[20]:** hybrid model used by the E.U. and French government for long-term energy policies analysis. Demand is analysed at a disaggregate level (bottom-up) while incorporating price variable as a demand driver, thus modelling price-related policies (top-down).
- **TIMES-MARKAL[21]:** partial-equilibrium model with a bottom-up approach. It has been used in a widely number of studies across the world, and for the assessment of future energy scenarios at city scale. The TIMES-MARKAL model has an optimization purpose and calculates the least-cost solution.
- **LEAP[22]:** modelling tool following an engineering-based accounting method. Widely use due to its ease-of-use and flexibility. LEAP is able to conduct energy plans and policies assessment at a local, regional or national level and supports both bottom-up and top-down approaches. LEAP has an optimization tool in order to identify the least cost capacity expansion and dispatch of supply side processes.

As it can be seen, the vast majority of them focus on a national level. New or adapted models should be developed in order to characterize the energy use at a city scale.

5.2.4 Methods selected and origin of data

In order to carry out the energy characterization of the MAtchUP lighthouse and follower cities a **hybrid model** will be developed for each one defining in detail their **energy system**.

Local authorities keep and manage different sources of information of their municipality for the elaboration of energy plans and public works.

5.2.4.1 Energy system modelling

For the baseline assessment **demand** and **supply** side information is required. Nowadays much information is available within open data bases and surveys carried out by the municipality. However, cities should provide information as much disaggregated as possible within sectors and subsectors, in order to better assess technological changes and better evaluate new resources potentials.

Concerning **demand side**, information related with energy uses at sector level, devices' ownership and saturation, fuel shares and technologies consumption are needed. Apart from the city's data, this kind of information could be obtained via surveys or consulting the utilities companies working within the city. Electricity and heat demand load profiles would also be useful to characterize some sectors like the residential or tertiary ones. The level of detail and characterization of the different sectors (residential, tertiary, transport and industry) will rely on the quantity and quality of the data supplied. At this point it is interesting to remark that information from other plans and projects carried out in the city could be integrated into the model.

For the **supply side**, data of the energy generation of the process/plants within the boundaries of the city is needed. This information ranges from fuel consumption and

[20] http://publications.jrc.ec.europa.eu/repository/bitstream/JRC107387/kjna28728enn.pdf

[21] https://iea-etsap.org/index.php/documentation

[22] https://www.energycommunity.org/default.asp?action=introduction

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power and/or heat generation, to load factor, plant's installed capacity, etc. Cities usually have information related to energy generation within their boundaries. For more details, the generation plants' owner companies could be consulted. It also would be useful to know data related to self-consumption like PV panels or micro-CHP generation or any other on-site generation devices.

Apart from that, other information needed is:

- **Energy resources:** fossil fuel reserves, renewable sources yield, fixed import/export fuels values, etc.
- **Energy network:** power grid and DH networks characteristics (electric and heat losses, capacities, lengths, etc)
- **Macroeconomic data:** socioeconomic data to characterize the city's social and economic activity (e.g. nº of inhabitants, nº of buildings, income per capita, m^2 or GVA of the industrial/tertiary sector, nº of vehicles, transport modal split, etc...). If some of this information is not available at city scale it could be extrapolated from regional or country level data. This kind of data is required to link both economic and energy aspects, and also to project the future energy usage.

5.2.4.2 Diagnosis of building stock energy consumption

In order to complete the energy system model, a relevant input will be the **building stock energy consumption characterization.**

The Municipality can have different sources of information characterizing building energy consumption or that can be used to characterize energy consumption.

1. Real energy consumption of each building monitored
2. Building stock energy consumption already characterized
3. Real energy consumption of some buildings monitored
4. Representative buildings simulated with dynamic simulations
5. CityGML of the city with Energy ADEs (Application Domain Extensions) *[CityGML is an open data model based on XML format for storage and exchange of virtual models of 3D city defined by the OGC. The aim of the development of CityGML was to reach a common definition and understanding of the basic entities, attributes, and relations within a 3D city model. What is especially important, since it allows the reuse of the same data in different fields of application. It has been designed to store both types of information, allows storing 3D information, considering both urban scale and building level. CityGML is a standard widely used in Europe.]*
6. Cadaster of the city (and LIDAR if needed)

If Municipalities don't provide real energy consumption or building stock characterized, **Tecnalia** proposes an innovative easy way to carry out the diagnosis of buildings' energy consumption.

Among the available information sources, one of the most widespread and interesting is the cadastre. The **cadastre** is an information register describing the physical characteristics of urban properties. There is no homogeneous cadastral model at European level, but although each one has its own structure, all countries have this information since it remains the tool used to collect taxes.

Another data source is the **LiDAR** data: a system that generates a point cloud of the ground by means of an airborne laser scanner. From the LIDAR data a Digital Surface

Model (DSM) and a Digital Terrain Model (DTM) can be derived. DSM and DTM are a 3D representation of topography, stored as a matrix of points with heights. The DSM represents the elevation of the natural and built features on the earth surface, while the DTM represents the elevation of the earth surface. LiDAR data is increasingly available, in particular for urban areas. These data should also be available for the municipality.

In order to simplify the assessment, **static equations** will be used to determine hourly demands following the **Energy Performance of Buildings Directive.** In order to calculate the energy demand of buildings using the cadaster as an input the following information must be at least integrated in a unique shape:

- Geometry
- Year of Construction
- Use
- Height (or number of floors or LIDAR)

The objective will be to simulate the whole city or at least the city center. If the quality of the cadaster is not adequate for the whole city, the study will be focused in representative district/s.

5.2.5 Energy City Indicators

Within the project MAtchUP the consortium worked out a list of 26 indicators. The indicators relevant for energy characterization are summarised in Table 5.1. More information is included in Annex I.

Domain	Indicators				
Air quality	GHG emissions per sector: residential	GHG emissions per sector: tertiary	GHG emissions per sector: municipal	GHG emissions per sector: lighting	GHG emissions per sector: industry
City energy profile	Final energy consumption per capita	Primary energy consumption in the city	Final energy per sector and per energy carrier	Renewable energy per carrier	
	Renewable heat and electricity generated within the city		Renewable energy generated within the city		
Smart buildings	Buildings with green/sustainable certificate	Integrated Building Management Systems in Public Buildings		Smart energy meters	Number of connections to a district heating network
Local	Existence of		Existence of regulations for development of		

Domain	Indicators	
government support	plans/programs to promote energy efficient buildings	energy efficient districts

Table 5.1. Energy city indicators (See Annex A1)

5.2.6 **Energy characterization step by step**

The structure and energy characterization of the city will depend on the data available. Therefore, energy and non-energy related sectors will be as much detailed and specified (and hence scenarios accurate) as information is accessible.

The city will be characterized for the baseline year and disaggregated into four modules:

- Demand side
- Supply side
- City resources

The information available by the City and needed to develop the Energy Model should be a main output of the "Diagnosis Launch Workshop". This information must be assessed by the Energy Working Group and shared with **the technical partners in MAtchUP related to the Energy Characterisation.**

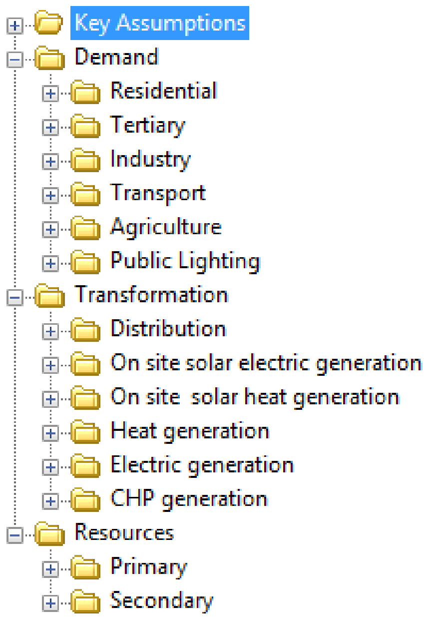

Figure 5.3. Example of city characterization in LEAP

5.2.6.1 Demand side

This module defines the **energy consumption of the end-use sectors** within the city: residential, tertiary, industry and transport. Each of one is divided into subsectors (e.g. apartment blocks and single-family houses for the residential sector; offices buildings, educational buildings, healthcare buildings, etc. for the tertiary sector; siderurgy, chemical, consumer goods, etc. for the industry sector; public/private, road/non- road for the transport sector) which in turn are characterized by their final energy uses (e.g.

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heating and cooling, lighting, appliances, etc…). For each final energy use many technologies/devices are available (e.g. boiler, solar collectors, heat pumps, DH network, etc…). Finally, every technology/device is defined by their fuel consumption. Thus, the city's energy consumption is determined through a bottom-up approach, with a detailed description of the energy uses and technologies employed to meet them.

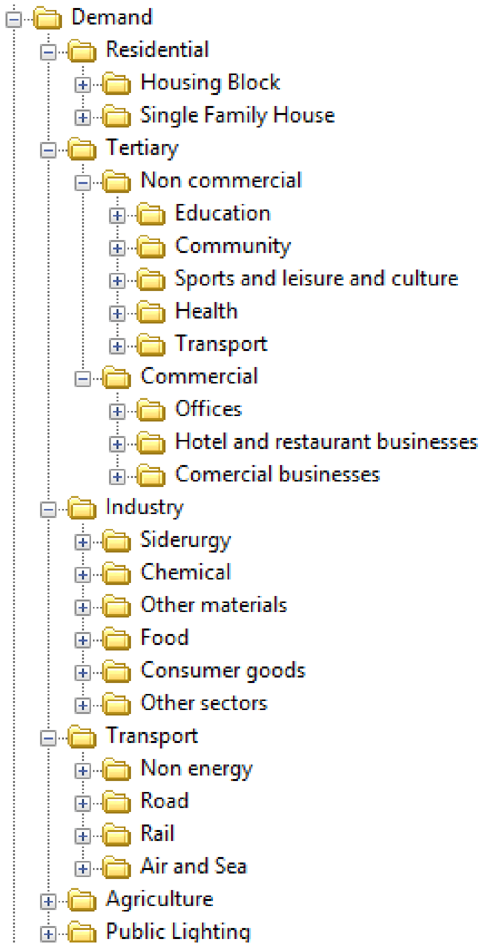

Figure 5.4. Example of demand side disaggregation in LEAP

In the table below an example of the disaggregation within final energy uses and technologies is described for the residential's subsector of apartment blocks.

Subsector	Final Energy Use	Technology	Fuel
Apartment blocks	Heating	Boiler	Natural gas
		District Heating	Heat
		Heat pump	Electricity
	DHW	Electric heater	Electricity
	Lighting	Conventional lamps	Electricity
		LED lamps	Electricity
	Home appliances	TV	Electricity
		Dishwasher	Electricity
		Washing machine	Electricity

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Table 5.2. Apartment blocks subsector disaggregation

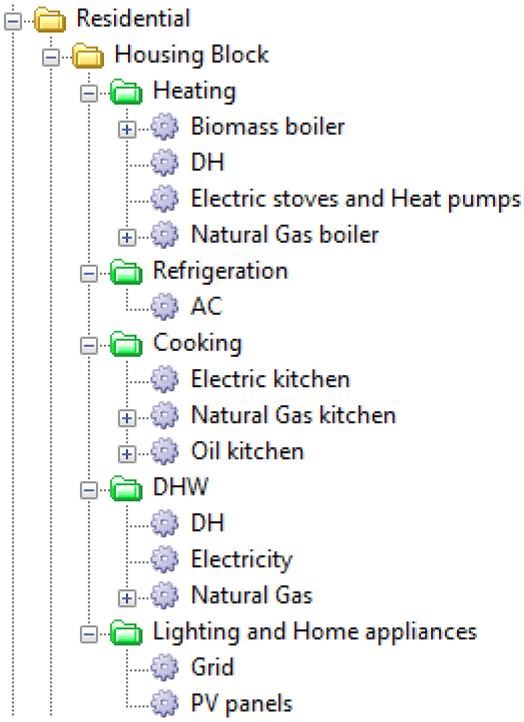

Figure 5.5. Example of residential final uses and devices disaggregation in LEAP

Cases where energy from on-site generation (e.g. solar PV, solar collectors, micro-CHP, etc) is used (and hence self-consumption occurs) should be considered and described apart: installed capacity and historical production should be indicated, and the final use (e.g. heating, DHW, lighting, etc) of the produced energy (electricity or heat) specified. If this information is not available, an estimation should be made on how much of the energy consumed for a final energy use comes from the on-site generation equipment.

5.2.6.1.1 Diagnosis of building stock energy consumption

Datasets containing the cartographic and cadastral information should be available as open data or provided by the Municipality in order to begin with the process. The accuracy of the results provided will depend on availability of data, its level of detail and veracity.

Whatever the data source, is necessary to delete all the irrelevant information in order to simplify and focus in the required one. Therefore, all this information should be adapted, cleaned an organized in an initial data pre-process step by the Municipality and/or by the Energy Working Group.

Following some common problems have been identified:

- The information is not included in a unique layer.
- Information that comes from different sources does not have a shared identifier.
- The coordinate reference systems are different.
- There is not a common agreement on the representation of some of the properties.
- The geometry of the buildings is too complex and requires simplification.
- The semantic information is not complete for all the buildings.

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- Inconsistencies in the data.

When the height of the buildings is not defined by the cadastre, another required data source is the LiDAR. LiDAR data usually comes in huge files. Therefore, in order improve the performance of the data; LIDAR data should be limited to the area of the study.

After this pre-processing step, a shape file with a unique geometry for each building and the following mandatory parameters needs to be created by the end-user building ID, geometry of the building, building footprint area, year of construction, use and building height. However, the height of the building could be defined directly as an input of the cadastral data or be calculated using the provided LiDAR data.

The methodology needs for calculating the energy demand of the district the following information: flat geometry, height (or number of floors), use and age. This information is extracted automatically from the pre-processing of the cadastral map of the city. After this pre-processing step, a shape file with a unique geometry for each building is created. Table 15 includes the most relevant information used for the analysis. In the case of the height, if the information is not available, it can be directly calculated using the LiDAR data when it is available.

Parameter	Mandatory or Optional
Building ID	Mandatory
Building Geometry	Mandatory
Footprint area	Mandatory
Height 1	Mandatory
Height 2	Optional
Number of floors 2	Mandatory
Number of floors 1	Optional
Hourly outside air temperature	Mandatory
Year of construction	Mandatory
Building Use	Mandatory
Gross floor area	Optional
Roof area	Optional

Table 5.3. Inputs for the energy modelling phase obtained from the 3D model information pre-processing.

Additional non mandatory parameters such as gross floor area, number of floors or roof area can also be an input; however, in case they are not, they will be estimated in the data process step.

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5.2.6.1.2 Calibration of the model

Once that the relevance of each of the evaluated parameters of the energy calculation equations has been evaluated for each case study. In the calibration the modeler will try to obtain real information that can be useful to define these parameters as realistic as possible. This will allow to reduce the error obtained with the energy modelling respect to actual values.

Normally, the information of the energy demand or consumption from monitoring is not available. In this case, the calibration phase needs to be flexible enough to adapt to the model.

Therefore, the calibration of the energy model can follow differ approaches. Based on the Tecnalia's experience, the most common approaches could be described as follows; The list is organized from the most desirable situation to the less desirable situation.

- At least in one specific district, data related to the energy demands and consumptions is available for each of the building uses and ages. Besides, specific information parameters used to generate the model are also available **(U values, Schedules, internal gains, ventilation losses, solar gains and % of windows)**. This situation would allow a good adjustment of the main parameters of the model which would allow an optimum upscaling of the model to the whole city.
- Data from monitoring is available for some buildings of the city and for some of the periods. Besides, specific information parameters used to generate the model are also available. This situation would allow a reasonable adjustment of the main parameters of the model which would allow a good replication of the modelling in other districts of the city.
- Data from monitoring is available but aggregated for the entire district. Besides, theoretical but city particularized information related to the main parameters are also available. This situation would allow a good adjustment of the district which would allow a reasonable replication of the modelling in other districts of the city. However, the specific results per building would have a higher error.
- Data from monitoring is not available, but results of simulation of the energy demand/consumption of the buildings of the city are available and theoretical values of the main modelling parameters particularized for the city are available. This situation would allow a reasonable adjustment of the main parameters of the model. This situation would be more reasonable for an assessment of a large where more detailed analysis of each building is not needed.

More situations would be possible depending on each of the case study evaluated. In any case, the most relevant is to describe in a transparent way the information used for the modelling and for the calibration of the model describing in detail the hypothesis that have been adopted in each case. This will allow a good understanding of the accuracy of the results provided by the model.

5.2.6.1.3 Results obtained by the model

After processing the cadastral information, the model will allow calculating energy demand and energy consumption per building and for the selected area under study.

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Parameter	Unit
Building generic data	
Building ID	
Centroid of the building	Coordinates
Use	Name
Footprint area	m^2
Height	Number
Number of floors	Number
Gross floor area	m^2
External opaque facade area	m^2
Roof area	m^2
Window area	m^2
Volume	m^3
Year of construction	Number
Building energetic data calculated	
Annual heating demand	$kWh{\cdot}year^{-1}$
Annual cooling demand	$kWh{\cdot}year^{-1}$
Annual DHW demand	$kWh{\cdot}year^{-1}$
Annual heating demand per square meter	$kWh{\cdot}m^{-2}{\cdot}year^{-1}$
Annual cooling demand per square meter	$kWh{\cdot}m^{-2}{\cdot}year^{-1}$
Annual DHW demand per square meter	$kWh{\cdot}m^{-2}{\cdot}year^{-1}$
Peak heating demand	kW
Peak cooling demand	kW
Peak DHW demand	kW

Table 5.4. Outputs of the building stock simulation

This task will provide two type of results: (1) geo-referenced information of each building, which will be represented through a CSV file (Table 16) and a SHAPE file (Figure 5.6); and (2) CSV file with information on the demand and energy consumption of the entire study area classified according to the use and age of the buildings.

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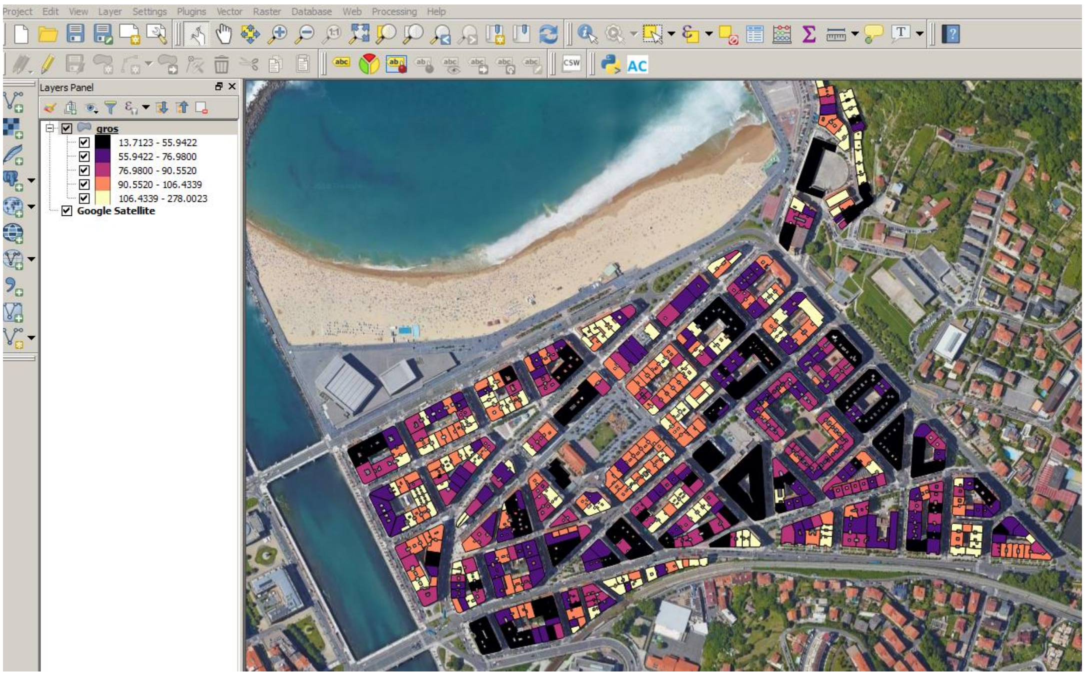

Figure 5.6. Display of heating demand per square meter. Example: San Sebastian district study case

5.2.6.2 Other demand side sectors diagnosis

For the city energy characterization the rest of end-use sectors must be also considered. The diagnosis of the building stock is useful for the description of the energy use in the residential and tertiary sectors. However, mobility, industry and agriculture (if relevant) sectors should be taken into account in the energy analysis at a city scale.

Energy consumption disaggregated by subsector, usage and fuel should be given for the industry and agriculture sectors. In addition, the electric consumption for public lighting should be considered too.

For the mobility sector a methodology for its characterization will be developed in the next sections and could be a useful input for the characterization of the city's energy use as a whole.

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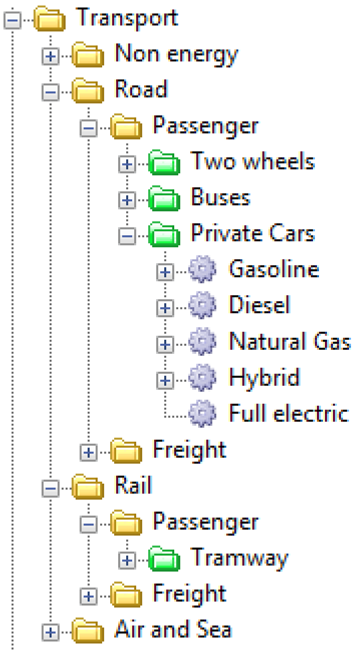

Figure 5.7. Example of transport energy uses disaggregation in LEAP

5.2.6.3 Supply side

This module defines the energy production (and consumption) of all the transformation processes/plants within the city's boundaries where primary energy is converted into final energy. The supply side produces part of the energy consumed by the end-use sectors described above.

This module includes:

- Electricity generation processes: PV plants, hydro plants, wind farms, other non-renewable processes for electricity production, etc.
- Thermal generation processes: heat only boiler plants, heat pump plants, etc.
- CHP plants
- On-site generation processes: as mentioned in the demand side, when data is available, on-site generation plants are here defined among the rest of the "large-scale" production processes connected to the (electric or heat) grid.
- Other conversion processes: refineries, biomass treatment plants, biofuel production plants, etc.
- Import/export: primary energy required by the transformation processes to work which is not found among the city's primary energy reserves, and final energy demanded by the end-use sectors which is not meet by the supply side; as well as energy surpluses which are exported.
- Heat and electricity networks: characteristics of the city's heat and power grids.

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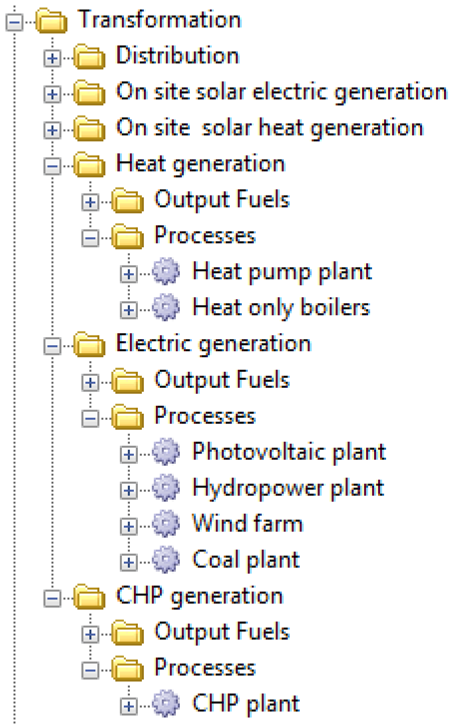

Figure 5.8.Example of supply side disaggregation in LEAP

Based on the final energy demanded by the end-use sectors and in the characteristics of the supply side (i.e. processes efficiencies, plants capacities, DH and power networks losses, etc.), the final energy which is required to be produced is calculated, as well as the primary energy consumed in the transformation processes in order to produce the mentioned final energy. If energy requirements remain unmet, the quantity of energy to be imported is calculated. Additionally, if there is a surplus of energy in the city's production, an export policy can be adopted.

5.2.6.4 City resources

In this module are characterized the city's energy reserves and renewable energy yields, as well as fixed import/export targets which are not defined in the supply side module. Hence, the possibilities of using alternative resources and the availability of local energy resources can be assessed.

5.3 Methodology/tools for mobility characterization

Mobility characterization is needed for several city level **planning processes**, mainly for:

- city development planning (industrial areas, leisure areas, structure of residential areas, etc.),
- transport and infrastructure planning (lanes per road, speed limits, traffic lights timings, road equipment, etc.),
- public transport planning (lines, schedules, fares, means of transportation, vehicle equipment), as well as

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- mobility planning, integrating all aspects (can transport infrastructure fulfil new mobility demands of new planned buildings/companies/sport stadiums, etc).

Furthermore, mobility characterization and detailed monitoring of changes is used to **measure the impacts** of transport planning. To this end, certain **indicators** are defined and are compared over time (typically before and after a certain modification).

One main step within the characterization process is the identification of indicators and data necessary to determine the indicators. Based on this, an analysis of potential data sources has to be performed and gaps in the data availability have to be identified. Subsequently, a process has to be established which allows to close the gaps as far as possible. The characterization can start as soon as the data base is appropriate for the relevant questions. It combines all relevant data, calculates the indicators and draws a picture of the situation based on these evaluations.

5.3.1 State of the art

5.3.1.1 Data collection sources

The fusion of various data pools maintained for example by local and regional municipalities, transport operators, or suppliers of car and bike sharing can serve as a basis. Statistic database, such as Eurostat[23] can be used to supplement this data by appending global data, or guesses based on comparable cities. Some more information can be added by combining the available data with environmental data, such as geographical or meteorological data.

Nevertheless, for most cities the available data describes facts. It covers aspects that are countable and documented in lists, maps or plans. Data describing the **mobility demand** that is based on soft criteria such as behaviour patterns or even purposes and intentions are much rarer or not available at all. However, such data is equally important to underpin the planning processes with data. Therefore, a methodology for mobility characterization needs to yield a detailed analysis of the current mobility demand, which includes details such as

- origin-destination relations and their frequency normalized by the basic population
- the reasons of travel
- used transport modes

From these details, a **digital traffic model** can be calculated (for example in SUMO[24] or PTV Visum[25]) to answer certain planning questions.

The mentioned **traffic models** and **indicators** are calculated from facts and **empirically collected data**, based on the **mobility behaviour** of a **representative sample** of the city's population. In order to create this data set, state-of-the-art methodologies use **surveys** and **interviews** with citizen to collect data ordinarily during a **study** that's is conducted over a sufficiently long period (for example **one year)** in order to include **seasonal variations**.

[23] Eurostat database: http://ec.europa.eu/eurostat/en/data/database

[24] SUMO: Simulation of Urban MObility http://sumo.dlr.de/index.html

[25] PTV Vissim: http://vision-traffic.ptvgroup.com/de/produkte/ptv-visum/

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Typically for interview-based methodologies on mobility behaviour, a **single person** is randomly chosen from a database and requested to recall all journeys from his/her own and all people of his/her household of one or more particular days.

The methods for the initial contact slightly differ. Some surveys start the process with face to face interviews or interviews by phone before providing the travel diary forms with detailed instructions. Others start by sending announcement letters partly combined with short interview forms, which allow to validate the list of participants, before sending the forms and/or contacting the selected persons personally or by phone.

In any case the most important goal of the initial contact is motivating the selected persons and their household member to keep a travel diary with details respect to travel mode and travel purpose for one or some defined days and to provide this data to the organisation performing the survey. This data submission can be carried out by sending the diary or by reporting it in (another) interview.

In most cases, the selected person is interviewed with **additional questions,** socio-economic questions based on the indicators that the study wants to calculate.

Some examples for national survey are:

- **National Travel Survey (NTS)**[26]
  - England, on behalf of Department of Transport
  - Since 2002 performed by **National Centre for Social Research (NatCen)**
  - Every year, since 1988
  - 6656 households fully participating in 2016
  - Face to face interviews and travel diary of all members of the household for 7 days
- **Transportvaneundersøgelsen (TU)**[27]
  - Denmark, on behalf of many partners (Ministry of Transport, national and regional governmental institutions related to transport, etc.)
  - Performed by Technical University of Denmark, Transport DTU28
  - Latest generation of survey continuously since 2006
  - About 3000 people responding each year
- **"Mobility in Germany" (MiD)**[29]
  - Germany, on behalf of the Federal Ministry of Transport and Digital Infrastructure
  - Performed by German Aerospace Center (DLR), Institute of Transport Research
  - Every 5 years, since 1976 (current 2017, previous: 2012, next: 2022)
    - 100.000 interviews over a period of one year

Some surveys include a longitudinal view by interviewing the same persons regularly. This allows drawing conclusions about the influence of changing life situations (birth of

[26] https://www.gov.uk/government/collections/national-travel-survey-statistics

[27] http://www.modelcenter.transport.dtu.dk/english/tvu

[28] http://www.transport.dtu.dk/english

[29] http://www.mobilitaet-in-deutschland.de/

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a child, loss of job, retirement, etc.) on mobility behaviour. An example for this specific type of survey is

- **German Mobility Panel (MOP)**[30]
  - Germany, on behalf of the Federal Ministry of Transport and Digital Infrastructure
  - Performed by Karlsruhe Institute of Technology (KIT)
  - Every year, since 1994
  - Between 1.500-2.500 interviews per year

More dedicated information about the local situation can be gained from locally oriented surveys, such as

- **"System of representative traffic surveys" (SrV)**[31]
  - Germany, on behalf of participating cities (incl. Dresden)
  - Performed by TU Dresden, Chair of Integrated Transport Planning and Traffic Engineering32
  - Every 5 years, since 1972 (current: 2018, previous: 2013, next: 2023)
  - Used by the city of Dresden33, 3.225 persons interviewed in 2013 in Dresden

5.3.1.2 Research on data based city planning

Planning processes within a city are more or less based on the collected data. But, the identification and collection of the data needed for the mobility characterization and integration of all planning components into a sustainable mobility plan (SUMP) is a complex task, which needs to be supported by scientific expertise and tools. There are some tools available, supporting this process as well as the higher level-processes leading to a new or improved SUMP, e.g.

- **WBCSD mobility**[34]
  - Created by the World Business Council for Sustainable Development (WBSCD)[35] in the framework of a scientific project
  - SUMP fact-based mobility planning tool:
    - Including stakeholders
    - Driven by data, based on mobility indicators
    - Providing relevant best practice examples

[30] https://mobilitaetspanel.ifv.kit.edu/english/index.php

[31] https://www.srv2018.de/Public/Info

[32] https://tu-dresden.de/bu/verkehr/ivs/ivst/die-professur/inhaber-in?set_language=en

[33] http://www.dresden.de/de/stadtraum/verkehr/verkehrsplanung/04/050_Verkehrserhebung_SrV.php

[34] http://www.wbcsdsmp.org/user/login

[35] https://www.wbcsd.org/

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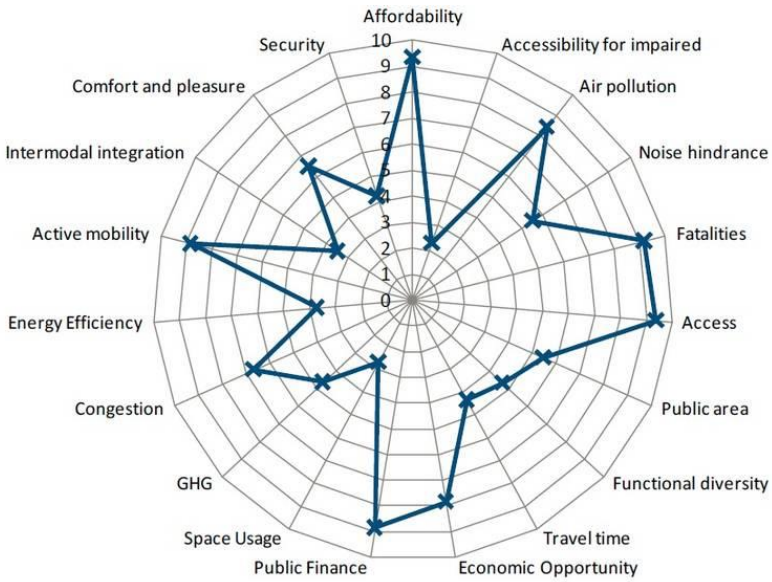

Figure 5.9: Spider chart for mobility indicators derived from WBCSD mobility[36]

- **CIVITAS inventory tools[37]**
  - Provided by CIVITAS Initiative38
  - Online database of tools and methods supporting the planning process, including guidelines, software tools, manuals, mobile apps, games, etc.
- **ADVANCE[39]**
  - Provided by Austrian Mobility Research, FGM-AMOR40, available as CIVITAS inventory tool
  - Support for the SUMP development process
  - Comparison of city SUMP development process with the ideal process

[36] Source: https://www.rupprecht-consult.eu/news/news-detail/news/new-project-on-sustainable-urban-mobility-indicators.html

[37] http://civitas.eu/tool-inventory

[38] http://civitas.eu/

[39] http://civitas.eu/tool-inventory/advance-audit-scheme

[40] http://fgm.at/

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Figure 5.10. Mission and Action Fields of ADVANCE Audit[41]

Besides tools for improving the planning process, there are research programs working on the scientific background or establishing networks to share the experience, for example

- **ECCENTRIC**[42]
  - demonstrates "the potential and replicability" of the SUMP process
  - dealing with mobility of persons and urban freight
  - including areas scarcely noticed in SUMP activities, before
- **ENDURANCE**[43]
  - Supports networking and exchange of best practice examples and experience

Furthermore, Guidelines are available that describe the methods and approaches related to the process of SUMP development in detail, some examples are:

- **Sustainable Urban Mobility Plan (SUMP) Guidelines**[44]

[41] http://eu-advance.eu/index.php?id=18

[42] http://civitas.eu/eccentric

[43] *http://www.epomm.eu/endurance/index.php*

[44] http://www.eltis.org/content/sump-process

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    - Guidelines describing in detail the process of developing or improving a sustainable mobility plan

Figure 5.11. SUMP planning cycle[45]

- **SIMPLA Project guidelines**[46]
    - Guidelines dealing with the harmonization of energy, transport and mobility planning

5.3.2 Methods and tools selected

It is most likely that the cities involved in the project **already have** established methodologies for mobility characterization in use, in order to supply the under 4.2.1 mentioned planning processes (city-, transport, public transport and mobility planning) with data.

Some of the aforementioned **examples** are methodologies that are used on a **regional or national scale** and it is a city's own decision, which methodology fits best for its planning processes. Most crucial is the aspect of **continuity in time series**: Since the interviews are performed every few years again, it is most important that the questions and derived indicators remain the same in order to create comparable data sets. Hence, it is **most unlikely** that a city will switch to another methodology which might interrupt the continuous time series.

[45] Source: http://www.eltis.org/content/sump-process

[46] http://www.simpla-project.eu/en/guidelines

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Rather, it should be focussed on which (relevant) indicators might not be covered by existing methodologies and how they can be derived by the existing methodology or how the existing methodology can be **carefully** extended[47] in order to support the new indicators and **sustain** the existing time series. Since national survey are often relatively inflexible, city or region-oriented surveys can help to gather data relevant for the specific situation or objectives.

If a new methodology has to be created from scratch, the SUMP guidelines (seeFigure 5.11) are a good starting point. Based on the planning cycle the characterization is related to the first phase. If no local or regional survey is available for collecting the relevant data, such a survey should be established on a local base. Even though data from one pass is less conclusive than data from a survey in a sequence, the data collected in the first turn is a valuable substitute to facts describing infrastructure and traffic volume, if it is gained according to the rules and procedures adopted for well-founded statistics. The process can be established according to the methods used for the German SrV [Ahr 2014].

This survey concentrates on traffic generated by residents. From a data base including all residents a defined number of persons is picked randomly. To avoid structural faults, this process is carefully supervised. For all members of the households each selected person all trips of a dedicated day[48] are inquired, including departure and arrival time, transport mode, purpose of the trip, location of the destination, and travel time. Necessary personal data and household characteristics are also recorded.

As a matter of course, participation is voluntary. This often leads to a substantial percentage of potential test persons denying their participation. Polling agencies as well as researchers note a growing share of rejectionists over the last decades [Nel 2005]. Besides, another considerable proportion of the basic set of selected test persons probably cannot provide information about all trips for all household members for the dedicated day. Partly such cancellations can be compensated by replacement with other probands, if the basic set of selected persons is much larger than the required number of respondents. The SrV therefore aims at selecting 5,000 persons randomly for a sampling size of 1,000. But it cannot be ruled out that responders and non-responders show different characteristics concerning their mobility behaviour. The SrV tries to identify and smooth out such potential differences applying weighting factors derived from a short post-enquiry[49] of non-responding persons combined with expert knowledge.

The potential participants are initially contacted by an announcement letter providing information about the survey as well as detailed, comprehensible information about data privacy, protection and security. As far as possible the diary information is collected in a telephone interview. Solely persons, who don't want to provide their phone number are invited to send the written information. As alternative or supplement, an online survey is available for all test persons. Reminders (up to 10) for non-

[47] For example: new questions in a questionnaire must not lead to a higher dropout rate

[48] Monday, Tuesday or Wednesday apart from holiday

[49] One page, concentrating on the most important characteristics, that allow to reduce selectivity

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responding households as well as get accompanying press and public relation activities are used to increase the response rate.

In a follow-up process the responses must be completed (e.g. addresses instead of point of interest), corrected (e.g. incorrect spelling) and confirmed (e.g. identification and labelling of wrong estimates of trip length). Afterwards the evaluation process including the calculation of indicators can be started.

5.3.3 Mobility city indicators

Within the project MAtchUP the consortium worked out a list of 49 indicators. The indicators relevant for mobility characterization are summarised in Table 5.5. More information is included in Annex I.

<table>
<tr><th>Domain</th><th colspan="5">Indicators</th></tr>
<tr><td rowspan="2">City mobile profile</td><td colspan="2">Modal Split: private motor vehicle, walk, bike, passenger transport</td><td>Number of fossil fuelled four wheels vehicles per capita</td><td>Number of fossil fuelled two wheels vehicles per capita</td><td></td></tr>
<tr><td>Average vehicle speed</td><td>Average occupancy in vehicles</td><td>Transportation Mode Share</td><td>Fuel mix</td><td>Total number of transport vehicles for passengers</td></tr>
<tr><td>City energy profile</td><td colspan="5">Final energy per sector: transport</td></tr>
<tr><td rowspan="2">Clean alternatives to private vehicles</td><td>Access to public transport</td><td>Public Transport Network</td><td>Access to vehicle sharing solutions (cars)</td><td>Access to bike sharing solutions</td><td>Length of bike route network</td></tr>
<tr><td colspan="2">Public transport use</td><td colspan="3">Public transport users</td></tr>
<tr><td>Air quality</td><td colspan="3">Exposure to noise pollution</td><td colspan="2">GHG emissions per sector: transport</td></tr>
<tr><td>Health</td><td colspan="3">Traffic accidents</td><td colspan="2">Congestion</td></tr>
<tr><td>Low emissions vehicles</td><td>Users of mass transit (MT)</td><td>Electric Vehicles in the city</td><td>Low-Carbon Emission Passenger Vehicles</td><td>Electric Vehicles per capita</td><td>Percentage of EV per sector (private, public and commercial)</td></tr>
<tr><td>e-charging infrastructure</td><td>Public charging points per eVehicle</td><td>Public charging e-car</td><td>Use of public EV charging stations (kWh recharged)</td><td>Use of public EV charging stations (number of recharges per year)</td><td>Public charging e-bike</td></tr>
</table>

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Domain	Indicators					
Smart management systems	Traffic managemen t system	Vehicle count at permanent measuring points	Parking space occupancy	Parking search traffic	Bicyccle count at permanent measuring points	Parking managemen t system
	Public transport managemen t system	Public bicycles managemen t system	Public transport stops	Public transport stops with real time info	e-ticketing	
Local government support	Existence of plans/programs to promote sustainable mobility			Existence of regulations for development of sustainable mobility		

Table 5.5. Mobility city indicators (See Annex A1)

5.3.4 Mobility characterization step by step

The process of mobility characterization may differ from city to city based on the available data and the efforts in time and money available for data collection. To get a full picture, all indicators should be calculated as far and as precise as possible. Therefore, the first step for each city is the definition of the most relevant questions to come to a priority list of indicators. Based on this list the budget can be used to collect data according to the importance. Since the characterization is improved by any additional indicator, data which is easily available should be included without regard to the list position.

Steps for each city:

1. Evaluate and review the mobility indicators referenced in 5.3.3
2. Evaluate the existing mobility characterization methodologies of the city and third-party sources such as transport operators' or statistical databases, to check which chosen indicators might be calculated
3. Use the priority list for indicators not covered by the existing methodologies by going over the following steps [Ahr 2014] (for details see the methodology report of SrV):
    a. Designing the survey (paper and online) that
        - asks the relevant questions (such as characteristics of person and household, disposability of vehicles, or availability of public transport),
        - captures the mobility behaviour of one or more days to its full extent, including for example all walks, the used modes of transport and the reason of travel.

    b. Gathering a representative sample database from a city's registry office or from a private agency that maintains contacts databases for interview-based studies. For middle sizes cities about 1,000 responses are necessary, for

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large cities like Berlin about 15,500 answers allow a purposeful evaluation. The base sample should be at least five times as large.

c. Validating the plausibility of the selected participants' data base (distribution of addresses, first letter of family name etc.)
d. Initiating a first contact and motivating the database's contact persons to allow interviewing, fill in a travel diary over a sufficient long period and to send paper surveys or provide the data in an online survey.
e. Remembering of non-respondents and padding the sample if necessary.
f. Validating the data, normalization, elimination of biases.
g. Scientifically calculating indicators.

4. **Providing a picture of the current situation probably with support of tools (see 5.3.1.2).**

   Later on, this data can be used for the additional steps, such as scenario development and identification of measures.

h. Integrating the data into a digital traffic model
i. identifying trends and developing forecasts of behaviour changes based on scenarios

The steps a, c, g, h, and i are mostly performed by traffic demand characterization experts during long-lasting studies to gather comparable time series. Such state-of-the-art studies can be distinguished into national surveys and surveys performed on behalf of dedicated cities or regions.

The steps h and i might be also performed by experts in the city (city and transport planning department) or by public transport planning experts in public transport operators and transportation authorities, probably supported by the demand characterization experts participating in the long-lasting studies.

The steps b, d, e, and f are mostly performed by survey and interview experts of market research institutes such as Infas[50], Infratest dimap[51] or Sinus-Institute[52].

5.4 Methodology/tools for ICT characterization

5.4.1 State of the art

ICT urban data platforms collect huge amount of data including transportation, energy, crowdsourced and more on while providing holistic view of the information in order to improve and develop smart city services in cities.

ICT urban platform solutions requires scalable, expandable, and flexible infrastructure for both real-time and non-real time aggregation, storage, processing, management as well as sharing various types of data obtained from and delivered to the broad spectrum of different devices and applications for cities. ICT platforms utilizing Internet

50 http://infas.eu/

51 https://www.infratest-dimap.de/en/

52 https://www.sinus-institut.de/en/

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of Things (IoT) enable many applications with high social, economic and environmental impact. Most important challenges in current research and development in the IoT domain are the definition of architectures, protocols and development of algorithms for efficient interconnection of smart objects, both between the objects themselves as well as with the future internet.

The methodology of an ICT urban platform typically consists of the following aspects:

1- IoT backend device management
2- IoT enabled context management
3- Applications

There are several commercial and open source ICT platforms. FIWARE[53] is one of the most widely used ICT urban platform, which combines components that enables the connection to IoT with context information and big data services in the cloud.

The generic components and enablers of FIWARE architecture is given in Figure 5.12. The main component of FIWARE platform is Context Broker generic enabler which brings a fundamental function of data and context management in any smart city solution. In case of use and management, context information enables to perform updates and bring access to smart city components.

FIWARE Context Broker deals with:

- Interfacing with the IoT, Robots and third-party systems
- Context Data/API management, publication and monetization
- Processing, analysis and visualization of context information

[53] https://www.fiware.org

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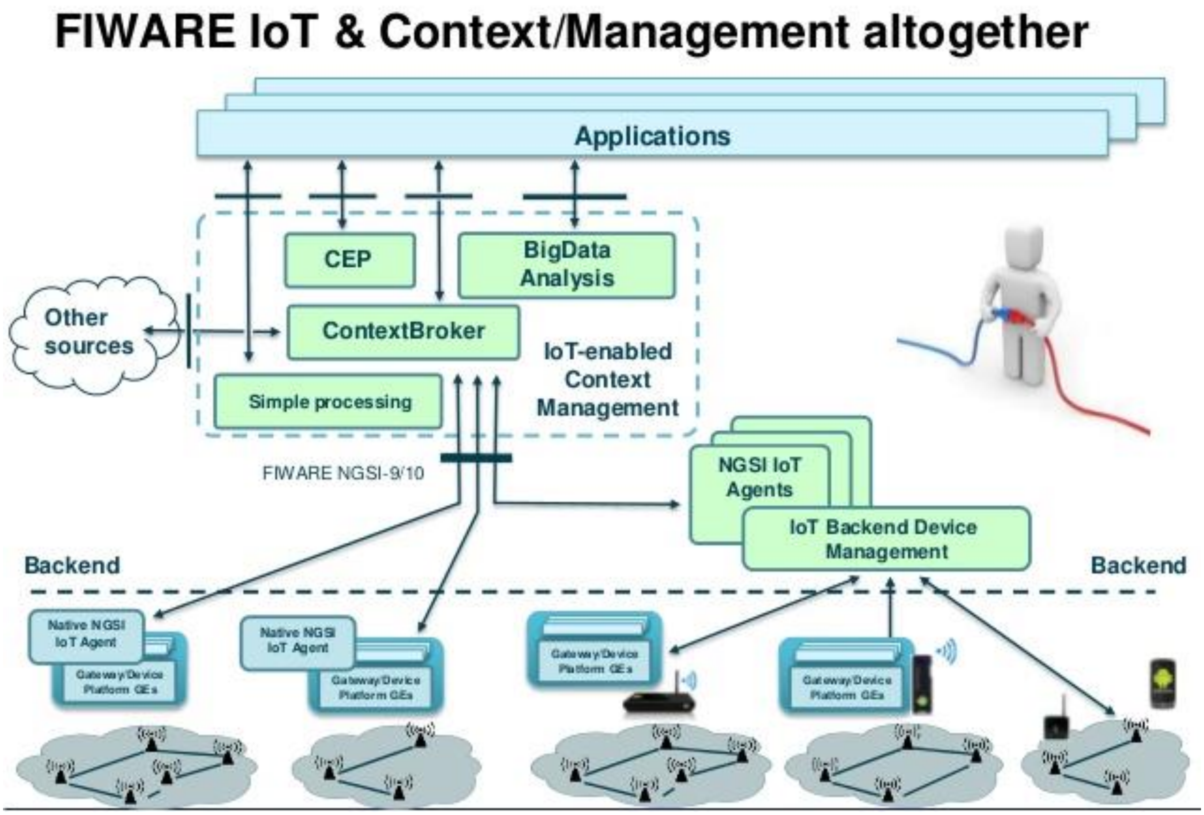

Figure 5.12: Architecture of FIWARE ICT Platform [54]

Another ICT platform that the cities use SOFIA2[55] is a middleware that allows the interoperability of multiple systems and devices, offering a semantic platform to make real world information available to smart applications (IoT).

It is multi-language and multi-protocol enabling the interconnection of heterogeneous devices. It provides publishing and subscription mechanisms, facilitating the orchestration of sensors and actuators in order to monitor and act on the environment.

- Data is collected, processed, filtered and transmitted from a connected terminal or device
- Data pass through the network which can be wi-fi,3G/4G ,radio satellite
- Information through IoT is collected and stored
- Through manual or automatic processing knowledge is extracted
- Results of the knowledge is sent to people, IT systems or IoT devices to perform.

ThingWorx[56] is also an ICT platform for smart cities. This platform enables the rapid development of IoT applications. The architecture of ThingWorx is shown at Figure 5.13Connect to any device, with any protocol, over any network, in any cloud or on premise

[54] https://www.fiware.org

[55] http://sofia2.com

[56] https://www.ptc.com

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- Visually model the "Things" in your world to increase development velocity, ease of maintenance and reusability of solutions
- Build interactive applications, dashboards, collaborative workspaces, and mobile interfaces with "Drag & Drop" user interface creation
- Deliver innovations such as augmented reality for rich visualization and real time predictive analytics to help find actionable insight from IoT data
- Multilevel security from device to application, with support for identity and access management

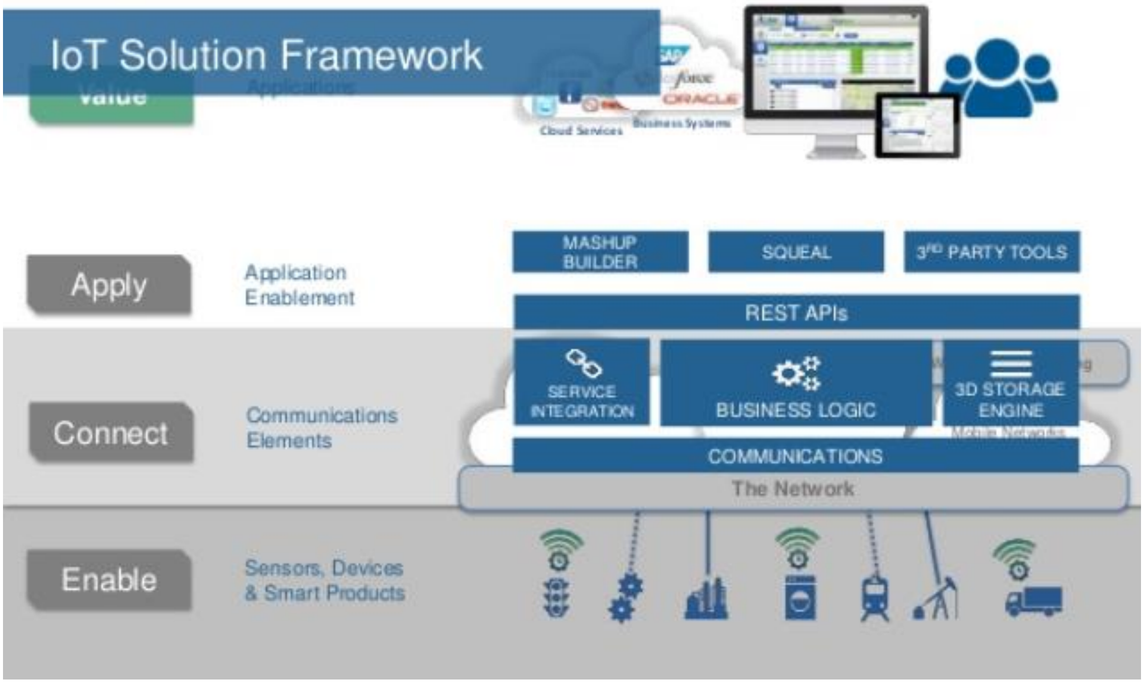

Figure 5.13. ThingWorx architecture

There are many ICT urban platforms that have been developing, such as REMOURBAN[57], Triangulum andGrowSmarter Projects.

In the scope of REMOURBAN, information management tools are implemented for the realization of smart cities. Gathering and analyzing different data coming from the city, specifically regarding energy and mobility, this platform delivers the relevant information in order to:

- improve the use of energy (direct surplus to the district/building needing it, reduce waste),
- improve the mobility within the city,
- inform the citizens of dangers (health risks, quality of air….),
- inform the citizens about worthwhile alternatives (free parking slots or electric charging station, car sharing or public transport instead of private car, for example, in case of congestion…etc.).

The world of ICT urban platform has been developing and there are more than 400 platforms has been in progress. Improvement of big data technologies will therefore affect the ICT platform applications in a positive manner.

[57] http://www.remourban.eu/

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5.4.2 Methods and tools selected

In our century, cities surely have their initiatives and existing solutions regarding ICT perspective. MAtchUP aims to enhance these solutions and introduce novel "*innovative palette of solutions*" for cities. In particular, the MAtchUP urban platform for lighthouse cities will act as the Open Data Gateway for all interventions and integrations between other ICT services of the cities, 3rd parties and other e-government services.

To create such a platform, cities' existing ICT indicators and ICT plans (local, regional and national) will be examined. The current status of the ICT infrastructures and the ICT plans will be analyzed considering their objectives, actuation areas and status of implementation. National e-Government Strategy and Action Plans, National ICT & Cloud Strategies and National Interoperability Standards will be also reviewed.

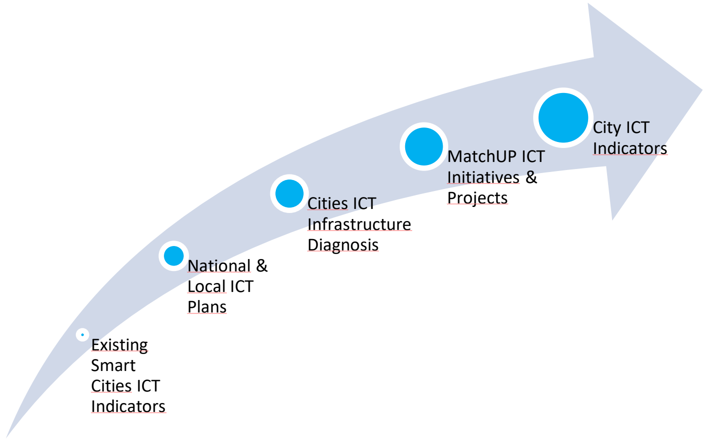

Figure 5.14. MAtchUP ICT Diagnosis Approach

In general, we enhance the existing ICT capabilities of the cities such as:

- Hardware, software, IT resources & capacities,
- City connectivity,
- The Urban Platform of the City,
- Applications and services of the Urban Platform,
- Interoperability Requirements

In MAtchUP there are common ICT actions as New open data gateway, New Open API developments, Big data Functionalities and IoT adaptors. These will include real-time and batch context data integration, open data portal and open data management, evolution of city management dashboard, integration of data market & economy of data mechanisms, IoT devices and data acquisition systems integration for smart controls, domotics for smart home and buildings, public lighting sensors, charging stations, electric storage unit measurements etc.

In particular, our methodology for ICT characterization can be listed in four items as:

1. Research in existing methods or tools for ICT characterization
2. Validate the viability with the ICT partners and each city
3. Determination of the common ICT indicators
4. Start the ICT City Diagnosis by collecting the data regarding these ICT indicators

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An extensive research has been performed with partners and current methods from earlier projects and other initiatives (REMOURBAN, , mySMARTLife, SmartEnCity, REPLICATE, CITYkeys, SEAP, EUROSTAT, SCIS) which are widely acknowledged, are examined. A list of ICT indicators is determined and 37 of them are commonly found to be applicable to the pilot cities, In addition, new methods offered by technical partners have been discussed within the consortium. As a result, the viable methods were decided to be utilized in MAtchUP. To check the applicability of methods to the pilot cities, advanced city diagnosis process of a period of 10-month, including three workshops that are to be held in the pilot cities, has been launched. In the first workshop, ICT working group will be created and initial ICT diagnosis program will be decided, initial agenda (investigating existing plans and studies, identify missing points/aspects to be analysed, gathering different perspectives) that is to be applied until the second workshop. Until the second workshop ICT city characterization, analyzing the city ICT infrastructure, identifying the city needs will be carried out. By the third workshop, these processes will be continued along with the consideration of citizen views and optimization of the existing works. Furthermore, the data regarding the common indicators will be collected in cooperation with the municipalities and the technical partners.

5.4.3 ICT City indicators

As a result of the work described in the methodology section, we have found 37 ICT indicators. The annex contains the list of indicators and a detailed definition.

Domain	Indicators					
ICT extent	Number of high edu degrees related with ICT per 100,000 population	Employment ICT sector	e-governance & citizens	e-governance existence	e-payment	Number of cameras available
	Expenditure in education for promoting ICT	ICT resources in the educational centres	Digital literacy	Digital service usage per citizen	e-commerce	Municipal ICT Budget
	Public employments in ICT	Tax Collection Rate through Digital Channels		Number of computers/similar devices per 100 employees		e-goverment
Communication infrastructure	Access to public free WiFi	Access to high speed internet	Number of smart phone connections per 100,000	Number of Internet connections per 100,000		

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Domain	Indicators					
			inh	inh		
Smart management systems	Lighting smart management system			Waste smart management system		
Urban platform	Number of sensors/devices connected	Number of services deployed	Number of available Open APIs	Number of available Open Data sources	Number of accesses to the urban platform APIs	Data Center Capacity
	Data privacy	Business intelligence	Application of big data	Public service Processes	Automated Public Service Processes using ICT	
	Cloud Solutions/Services	Cybersecurity	Number of data publishers		Application of Geographic Information System (GIS)	

Table 5.6. ICT city indicators (See Annex A1)

5.4.4 ICT diagnosis and its impact in the Energy dimension

ICT solutions are required to implement monitoring of energy efficiency, real time monitoring and infrastructure efficiency. One of the most important aim of ICT urban platform is reducing the energy usage. In order to achieve this aim ICT provides integration of renewables in the energy supply, implementation of advanced energy management systems combined with high quality energy storage systems and maximizing the potential of energy grids and mobility infrastructures. An advanced ICT urban energy infrastructure will be set up with smart meters, smart controls, electrical storage, urban renewables, smart grids, public lighting, district heating, thermal storage. There are many researches and statistical analyses which demonstrate usage of ICT platforms decreases energy consumption, air pollution and greenhouse emissions.[58] In terms of managing different actors and technologies in the electricity network, ICT is the key enabler and usage of ICT platforms decreases almost 20 % of energy usage.

[58] Decomposition analysis for policymaking in energy: which is the preferred method (Energy policy)

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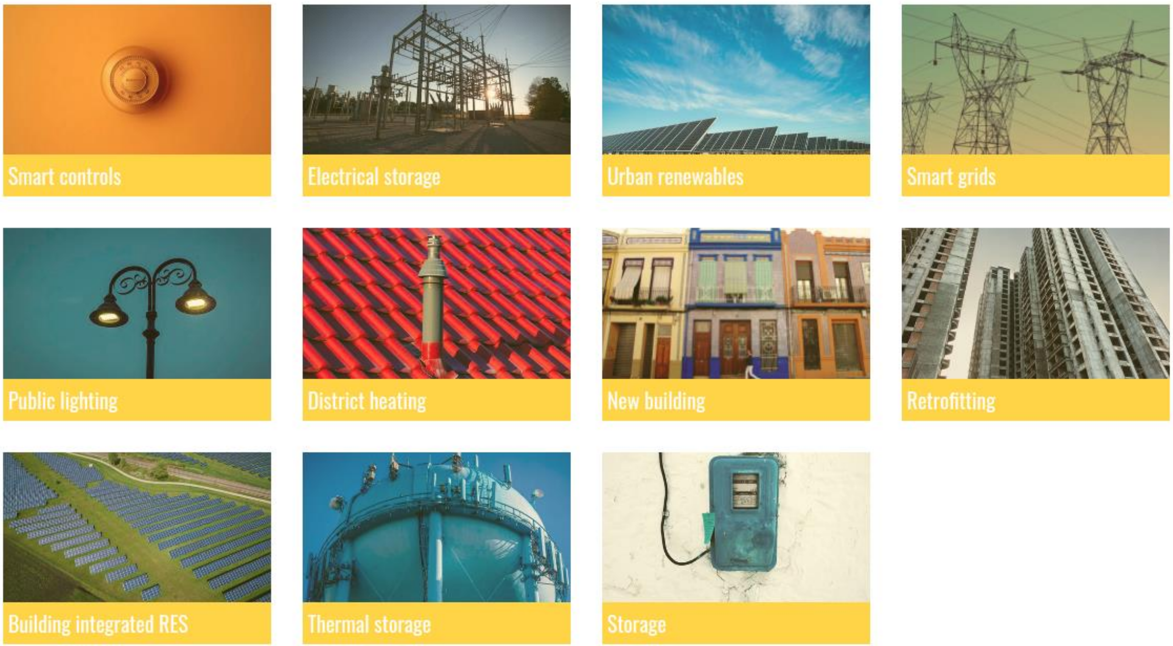

Figure 5.15. ICT Energy Infrastructure

5.4.5 ICT diagnosis and its impact in the Mobility dimension

Mobility is one of the most vital component of ICT urban platforms. Smart mobility solutions provide better mobility and sharing of resources. Electro-mobility solutions for people and goods will be implemented by electric vehicles and charging infrastructure. In order to set up this infrastructure ICT urban platform will define a common approach for all functional requirements, software architecture, data structure and best algorithms to achieve mobility.

ICT will impact mobility systems to create sustainable transportation. Sustainable transportation is not only focused on electric vehicles but also machine to machine applications that range from location-aware vehicles, devices, bikes, buses, trains for locally sourced transactions.

ICT urban platform helps majors and transportation managers to deliver the most dynamic, flexible and cost effective transportation options and it also provides a perfect monitoring systems to evaluate the benefits of these mobility investments.

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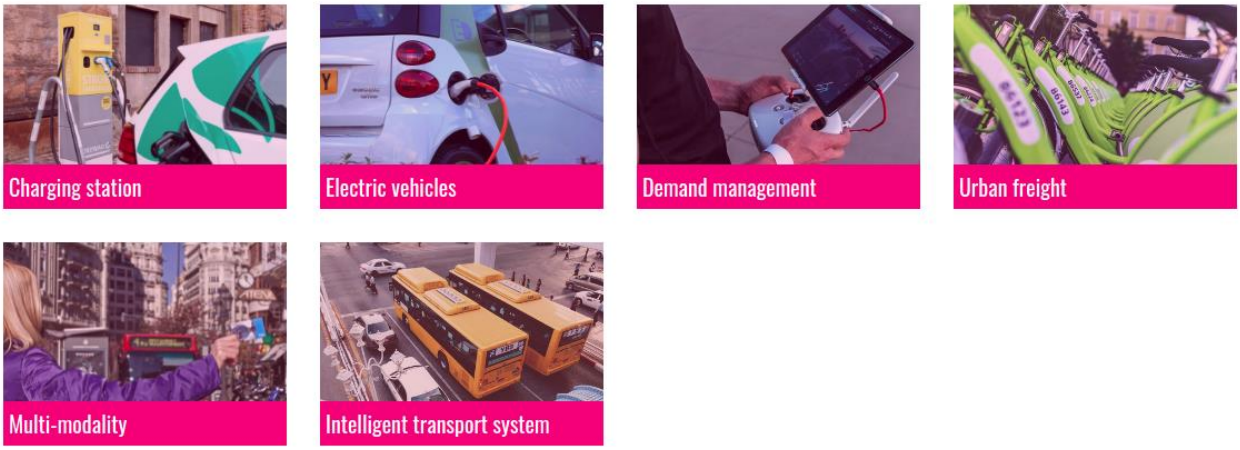

Figure 5.16. ICT Mobility Infrastructure

5.5 Methodology/tools for Social characterization

5.5.1 State of the art

Cities are comprised of components that belong either to physical or to social spheres: physical components concern physical resources and processes within a city's boundaries or that the city interacts with. Social components, or soft facilities, represent the human elements that reside within a city permanently or those that flow into, and/or interact with a city (Anthopoulos, 2017) and they concern intangible resources (people, organizations, activities, knowledge, wealth, etc.). Social infrastructure (intellectual capital and social capital) is indispensable endowment to smart cities. That infrastructure is about people and their relationship. Smart city is about a mix of education/training, culture/arts, and business/commerce. The social infrastructure concept comprises various factors like social inclusion of various urban residents in public services, social and ethnic plurality, urban diversity and cultural mix, social/human/relational capital, and knowledge base such as educational institutions and R&D capacities (Monfaredzadeh and Krueger, 2015).

The current strategies for smart cities aim to connect the physical space of cities with the economic and social sphere and work towards the advancement of the human and social capital (Angelidou, 2015). Nonetheless, the topic of people and communities as part of smart cities traditionally has been neglected on the expense of understanding more technological and policy aspects of smart cities and the social dimension (or 'social sustainability') has gained increased recognition as a fundamental component of sustainable development (Colantonio, 2009; Bibri and Krogstie, 2017) only in recent years, when the interest in sustainability took an urban focus (Vojinovic, 2014).

The human and social capital have been differently defined along the continuum of the research efforts around the conceptualization of smart cities, depending on the theoretical approach, disciplines, referring models, while the domain remains ambiguous (Anthopoulos, 2017) and the lack of consensus is acknowledged by literature (Ben Letaifa, 2015). Accordingly, there are few references on specific tools for the social characterization of smart cities, while significant efforts were done towards

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standardization and performance measurement (ISO 37120; UN-Habitat; U4SSC; EU-funded projects CITYKeys, ESPRESSO).

5.5.1.1 Social factors in the smart cities conceptualization

In the smart cities arena there is not one single definition, but many alternatives and a multitude of definitions and solutions (Angelidou, 2014; Anthopoulos, 2017; Bibri and Krogstie, 2017). According to Giffinger et al. (2007) **human and social capital** refers to **education** (qualification and lifelong learning), social and ethnic **plurality**, flexibility, creativity, cosmopolitanism, participation in public life (*Smart people*). The definition of smart people includes soft infrastructure of the city such as knowledge, inclusion, participation, social innovation and social equity (Angelidou, 2014), while *Smart governance* includes all parties in transparent decision-making process (Ben Letaifa, 2015). Smart cities aim to foster more informed, educated, and participatory citizens and smart cities initiatives allow members of the city to participate in the governance and management of the city and become active users. Empowering people to participate in influencing choices for development and in decision-making is one of the criteria of a society being sustainable (Baines, 2004).

A city is then smart when investments in human and social capital, traditional and modern communication infrastructure fuel sustainable economic development and a high quality of life, with a wise management of natural resources, through participatory governance (Bencardino and Greco, 2014). The social component is included also in the *Smart living* domain, another of the six most-common indicators of the Vienna University of Technology. This notion involves improving life quality in terms of **services**, social cohesion and safety. Social services are the major carriers of universal social rights and citizenship (Martinelli, 2012), while a better quality of life and well-being of citizens is the main outcome of smart sustainable cities (Bibri and Krogstie, 2017). Well-being is a multidimensional concept encompassing environmental, economic and social life (Stiglitz et al 2009), while quality of life covers material living conditions, health, work, education, social connections, civic engagement and governance, environment and subjective well-being (OECD; EC). The multidimensional **prosperity** concept, also frequent in the literature on smart cities, group similarly quality of life, equity and social inclusion, and governance (UN-Habitat, 2015).

Other definitions stress the role of **education** in the urban development. Berry and Glaser (2005) show that the most rapid urban growth rated have been achieved in cities where a high share of educated labour force is available. In particular, the authors model the relation between human capital and urban development by assuming that innovation is driven by entrepreneurs who innovate in industries and products which require an increasingly more skilled labour force (Bencardino and Greco, 2014).

Besides, in the smart city the dimension of **equity** must be held into consideration. The equity must take account of the distribution and redistribution of the benefits of prosperity of a city, in order to obtain a reduction of poverty, a supply of adequate housing, a protection of the rights of minorities and vulnerable groups, a gender equality and a public participation of citizens in political and cultural life (State of the World's Cities 2012/2013, prosperity of cities). **Social equity (access to services,**

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facilities and opportunities) is one of the qualities of social sustainability (Monfaredzadeh and Krueger, 2015) and can be operationalized through four core urban objectives (Vojinovic, 2014): essential economic, social and health resources for residents, regardless of gender, ethnicity or income; political structures enabling political representation, democratic participation and political, personal and religious freedoms; construction of urban built environments that meet the needs of residents, regardless of income, gender or ethnicity, and encourage the social cohesion; maintaining urban environments that avoid health risks.

Moreover, Floridi points to the **digital divide** in particular as the source of many of the ethical problems emerging from the evolution of the information society. The digital divide disempowers, discriminates and generates dependency (Floridi, 2001). From one hand there is no infrastructure that covers all regions and social areas, on the other hand, there is the issue of knowledge to use new technologies that is not equal among different demographic aspects such as age, sex, income or education.

Furthermore, according to Sassen (2011), technologies should be useful to new urban needs, where a smart city is '*an overall process of sensing and actuating for the transformation of the city, where there are particular needs of citizens, active and passive actors in the process'* (Bencardino and Greco, 2014, p. 42). Indeed, the Employment, Social Policy, Health and Consumer Affairs (EPSCO) Council affirmed in 2013, in its conclusions on a social investment approach that a '*social policy instruments should be responsive to the needs of society and its citizens, adequate to respond to crises, and incentivise active participation in the labour market and society*'59.

In conclusion, merging and combining the social component concepts and definitions described above, we identified the **most relevant domains that the social characterization** of the cities should cover:

- Income and material living conditions
- Work
- Health
- Education
- Housing
- Access to public services
- Plurality
- Civic engagement and governance

Moreover, the social characterization of a city should be based on the **social needs of citizens**, and **citizen-centric** and **participatory approaches** should be applied (Monfaredzadeh and Krueger, 2015).

59 Council conclusions: 'Towards social investment for growth and cohesion', Employment, Social Policy, Health and Consumer Affairs Council, 20-21 June 2013:

http://www.consilium.europa.eu/uedocs/cms_data/docs/pressdata/en/lsa/137545.pdf

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5.5.1.2 Alignment with the European strategy for social inclusion

Within the European research and policies[60] in the field of social inclusion, the **quality of life, well-being and prosperity** dimensions are referred to as *social inclusion indicators*, which cover all key dimensions of the commonly agreed EU objectives and/or highlighting the social situation of key sub-populations. In this domain an extended set of indicators exists since 2001 in the framework of the **Social Open Method of Coordination (OMC)**, allowing the accessibility of statistical data sets harmonized along the EU member States.

The availability of the Social OMC indicators is a facilitator for the social characterization of the cities. The Community Statistics on Income and Living Conditions (EU-SILC) and the EU Labor Force Surveys (LFS) are the main referring statistical sources in this domain.

The social OMC, established by the Lisbon European Council in 2000, has been a major element of the EU framework for coordinating and supporting member state policies on social inclusion and comprises common objectives, common indicators, reporting, analytical capacity building and mutual learning instruments. In order to tackle the complexity of the concepts involved, a **multidimensional set of indicators** was considered more appropriate than considering only income-based measures. Indeed, the European Commission highlighted the '*multi-dimensional nature of the mechanisms whereby individuals and groups are excluded from taking part in the social exchanges, from the component practices and rights of social integration*' (European Commission, 1992, page 8).

The Social OMC includes a set of sixteen core indicators (including at risk-of-poverty rate, but also indicators on access to health, school dropout, in-work poverty….) as well as six contextual indicators (such as unemployment rate, life expectancy, social protection expenditure…). In the social inclusion area, they encompass Income poverty risk (Indicators P1-P3), Unemployment and Joblessness (P4 and P5), Low educational qualifications (P6), Employment situation of migrants (P7), Material deprivation (P8) and Access to healthcare (P10). They also include indicators that are currently being developed, relating to Housing and Child well-being (P910 and P11 respectively).

5.5.2 Methods and tools selected

Cities will collect data within the social domain, according to the specific indicators selected under the social and human capital dimensions referred above (Income and material living conditions, Work, Health, Education, Housing, Access to public services, Plurality, Civic engagement and governance). The data sources will be administrative and statistical data from population and sample surveys, such as the Community Statistics on Income and Living Conditions (EU-SILC) and the EU Labor Force Surveys (LFS) and other international, national and local statistical sources.

60 Social Protection Committee (2015), Portfolio of EU Social Indicators for the monitoring of progress towards the EU objectives for social protection and social inclusion 2015 Update, European Commission, Brussels.

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The indicators were proposed to cities, and validated according to the relevance and availability of data (see Annex I). A gender breakdown of each of the Indicators for social inclusion and a breakdown of most by broad age groups should be provided. The full list of social indicators is shown in Paragraph 5.5.3.

The social characterization of cities will have a participatory approach and will combine the perspective of experts and the perspective of users, using quantitative and qualitative data.

	Perspective	Method	Sources and tools	Data
EXPERTS	Diagnosis + Thematic Working Group	Desk research	Administrative data; existing surveys; workshop (validation of results, refinments)	Quantitative Qualitative
	Key informants	Consultation	Semi-structured interview (validation of results)	Qualitative
USERS	Stakeholders	Participatory worskhop	Workshop (validation of results; prioritization)	Quantitative & qualitative
	Citizens	Participatory worskhop	Workshop (validation of results; prioritization)	Quantitative & qualitative

Table 5.7. Methods and data source for the social characterization

5.5.2.1 Perspective of experts

The desk research will be performed by experts of the City Diagnosis Working Group with the support of the Thematic Working Group (TWG) dedicated to the Social component.

The consultation of municipality's experts through semi-structured interviews is recommended, in order to strengthen indicators and validate preliminary and consolidated results.

The data collection, sources and schedule will be launched during the **WS1.** Diagnosis Launch Workshop **(M9).** This first meeting will be aimed to get acquainted with the overall city perspective, identify potential missing studies or information to characterise the MAtchUP social dimension and its interrelations with the others, and identify information and data ownership.

5.5.2.2 Perspective of users

It is recommended to validate the completeness and relevance of the data with stakeholders (municipality technicians; professionals; representatives of local universities and RTDs; NGOs). The **WS2.** City Characterization Workshop **(M13)** may be used to this end. It will be aimed to present the overall city diagnosis and gather first views on needs and priorities from the city perspective.

The following profiles will be identified and involved.

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Experts	Technicians from the departments of welfare and social services, health, education and citizens' participation of the municipality
Researchers	Public and private universities; RTDs
Decision makers	Policy makers in the area of social services, education, health and citizens' participation
Civil society organizations	NGO and associations active in the field of social inclusion, education, health, housing, participation

Table 5.8. WS2 Key participants for social characterization

The results of the desk research and stakeholders' consultation will constitute the *Preliminary social characterization* of the city, and will be worked on with citizens in the WS3. City needs and priorities Workshop **(M15)**.

During the WS3 participatory workshop the preliminary social characterization will be disseminated and the main social needs assessed[61] through a collaborative process.

As a preparatory task previous to the workshop, a didactic toolkit should be prepared, including reports and summaries based on the preliminary results of the social characterization; the social toolkit will be easily understandable by general public and will be used as working material for the prioritization by participating citizens. The participants will then be involved in the participatory session, aimed to reach consensus on the social characterization through an Advanced SWOT followed by the results prioritization through a Matrix ranking or Scenario techniques (EASW[62], among others). Other tools for participatory diagnosis can be explored, where relevant and applicable. In order to strengthen the participation and ensure representativeness, an **online consultation** may also be performed.

5.5.3 **Social City Indicators**

The final set of 48 social indicators will constitute the Key Performance Indicators of the cities under the Citizens field and will allow cities to measure their performance in the social domain. The list of indicators can be found in the Annex 1 of this document.

<table>
<tr><th>Domain</th><th colspan="3">Indicators</th></tr>
<tr><td>Demographic profile</td><td>Annual population chang</td><td>Average population age</td><td>Population Dependency Ratio</td></tr>
<tr><td>Education</td><td colspan="2">Number of high edu degrees per 100,000 population</td><td>Early school leaving</td></tr>
</table>

[61] A needs assessment is understood as a systematic set of procedures undertaken for the purpose of setting priorities (Witkin and Altschuld, 1995).

[62] European Awareness Scenario Workshops.

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<table>
<tr><th>Domain</th><th colspan="6">Indicators</th></tr>
<tr><td>Plurality</td><td colspan="3">Net migration</td><td colspan="3">Foreigners as a proportion of population</td></tr>
<tr><td rowspan="2">Income and material living conditions</td><td>GDP</td><td>Fuel poverty</td><td>GINI index</td><td colspan="3">Population receiving social assistance</td></tr>
<tr><td colspan="2">People > 75 years</td><td colspan="2">Median disposable income</td><td colspan="2">People at risk of poverty or social exclusion (AROPE)</td></tr>
<tr><td>Work</td><td>Unemployment rate</td><td colspan="2">Youth unemployment rate</td><td>Job creation</td><td colspan="2">Employment rate in vulnerable groups (age)</td></tr>
<tr><td>Housing</td><td>Dwelling price</td><td colspan="2">Under age 5 mortality per 1000 live births</td><td>Housing cost overburden rate</td><td colspan="2">Housing overcrowding rate</td></tr>
<tr><td>Health</td><td>In-Patient Hospital Beds</td><td>Average life expectancy</td><td colspan="2">Ratio of city inhabitants with electronic clinical records per 1000 patients</td><td colspan="2">Number of physicians per 100 000 population</td></tr>
<tr><td rowspan="2">Access to public services</td><td>Access to basic health care services</td><td colspan="2">Access to sport facilities</td><td colspan="2">Access to schools</td><td>Access to libraries</td></tr>
<tr><td colspan="2">Access to educational resources</td><td colspan="2">Access to high schools</td><td colspan="2">Access to kinder gardens</td></tr>
<tr><td rowspan="3">Civic engagement and governance</td><td>Availability of government data</td><td>Open government dataset</td><td>Number of interactive social media initiatives</td><td>Citizens Registered in City Web/Services</td><td>Digital access to urban planning documents</td><td>Number of municipal websites for citizens</td></tr>
<tr><td>Open public participation</td><td>Web Apps/Services Use</td><td>Number of local associations per capita</td><td>Voter participation</td><td>Women elected to city-level office</td><td>E-mail suggestion, complains and comments</td></tr>
<tr><td colspan="2">% of citizens' participation in online decision-making processes</td><td colspan="2">Written suggestions, complains and comments</td><td colspan="2">Number of information contact points for citizens</td></tr>
</table>

Table 5.9. Social city indicators

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6 Step 3. Methods for city needs and priorities identification

The previous Step 1 and Step 2 of the methodology intended to give to the Municipality and city experts a good diagnosis and perspective of the city performance and objectives on the different dimensions.

After these two steps, a characterization of the city through the city level indicators should be available, and analyzed in comparison with the city objectives, and benchmarking indicators with other cities whenever possible. However, according to Huovila et al. (2017), cities seem to be more interested in using the indicators to set own targets and monitor progress, rather than comparing to each other and benchmarking.

Cities can also add their own target values for KPIs and set weights to indicate the mutual importance of different KPIs and/or domains.

With this as a starting point, a city will have to prioritize and target particular areas of action, as it is very unlikely that a city has the capacity to target many areas at the same time in a short term. The decision on what areas or topics to target first, it is a complex exercise which should include some initial perspective of economic, environmental, technical, or social benefits, combined with citizen opinions and acceptance, which entail the corresponding subjective and qualitative evaluations by citizens and other city stakeholders resulting from the Participatory Process.

For example, it could be that a topic which through the city level indicators seems to be a major issue due to the bad performance against objectives, or in relation to other cities. A first expert evaluation of potential economic, technical and social benefits can also be good.

6.1 Indices

The design of indices from the aggregation of indicators is a complex task whose phases involve several alternatives and possibilities that affect the quality and reliability of the results. The techniques to apply in the building of indices are:

- Normalizing the individual indicators to make the indicators comparable when the indicators have not the same unit.
- Weighting and aggregating the normalized indicators. The aim of the aggregation through weights is to add a relevance meaning to each of the elements aggregated and therefore impact in the calculation of the indexes.

6.1.1 Normalization techniques

There are various methods of normalization, such as standardization (or z-scores), rescaling (or min-max transformation), indicization (index number transformation or ‘distance’ to a reference) and categorical scale.

Standardisation (or z-scores) converts indicators to a common scale with a mean of zero and standard deviation of one. Indicators with extreme values thus have a greater

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effect on the composite indicator. This might not be desirable if the intention is to reward exceptional behaviour, *i.e.*, if an extremely good result on a few indicators is thought to be better than a lot of average scores. This effect can be corrected in the aggregation methodology, *e.g*. by excluding the best and worst individual indicator scores from inclusion in the index or by assigning differential weights based on the "desirability" of the individual indicator scores.

Min-Max normalises indicators to have an identical range [0, 1] by subtracting the mínimum value and dividing by the range of the indicator values. However, extreme values/or outliers could distort the transformed indicator. On the other hand, Min-Max normalisation could widen the range of indicators lying within a small interval, increasing the effect on the composite indicator more than the z-score transformation.

Distance to a reference measures the relative position of a given indicator vis-à-vis a reference point. This could be a target to be reached in a given time frame. This approach, however, is based on extreme values which could be unreliable outliers.

Categorical scale assigns a score for each indicator. Categories can be numerical, such as one, two or three stars, or qualitative, such as 'fully achieved', 'partly achieved' or 'not achieved'.

The selected method should be relevant for the issue of interest in each case, taking into account the theoretical framework and the data available. Two factors should be ensured when selecting the normalisation approach among all existing techniques: the robustness (insensitivity against the existence of extreme values) and efficiency (estimated value close to the expected optimum when the real data distribution is unknown) of the selected technique.

6.1.2 **Weighting techniques**

There are several techniques to accomplish weighting process. In case of MAtchUP Project, since it is thought that there is a lack of reliable and amount of data available to perform statistical models, the method considered defining the weights of the indicators is the multi-attribute decision making technique: Analytic Hierarchy Process (AHP). This it is not a pure statistical technique so it can be used when data are not available, but at the same time, it takes into account both qualitative and quantitative aspects of a problem although with certain degree of subjectivity. Although this method seems the most suitable at the moment, other techniques will be analyzed in a further step of the Project for identify that which better suits to the results obtained.

This methodology tries to analyze the importance of indicators assigning preferences to them, by doing pairs of comparison, asking which of the two is the more important and by how much. The relative results are represented in a comparison matrix to obtain the weights. It is thought to be applied during the Participatory Process to be developed by the cities requiring to the participants the allocation of weights in each of the indicators considered according to the relevance of each indicator for measure the city performance in terms of sustainability.

6.1.2.1 Analytical Hierarchical Process

The Analytic Hierarchical Process (AHP) is a structured technique for organizing and analyzing complex decisions developed by Thomas L. Saaty in the 1970s. The

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methodology allows stakeholders the evaluation of different topics through pair-wise comparison, after stablishing a structure of the topics and sub-topics to evaluate. It is particularly relevant when qualitative criteria, such as political impacts, are considered.

Intensity of importance	Definition	Explanation
1	Equal importance	Two elements contribute equally to the objective
3	Moderate importance	Experience and judgment slightly favor one element over another
5	Strong Importance	Experience and judgment strongly favor one element over another
7	Very strong importance	One element is favored very strongly over another, it dominance is demonstrated in practice
9	Extreme importance	The evidence favoring one element over another is of the highest possible order of affirmation
2,4,6,8 can be used to express intermediate values, 1.1, 1.2, etc. for elements that are very close in importance		

Table 6.1. Intensity of importance during AHP

In this process of prioritization at diagnosis level, it is expected that carrying the AHP for the indicators for each core category does now provide additional insights leading to understand citizen and stakeholder needs.

6.1.2.2 Example of application

The AHP process consist on a pair-wise comparison between each element as it can be seen in the table below, using as reference the intensity of importance defined in Table 6.1.

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	Element			More Important	Intensity (1-9)
	A		B		
1	Air quality	compared with	City energy profile	A	6
2			City mobility profile	B	5
3			Health	B	3
4			Clean alternatives to own vehicles	A	3
5			Low emissions vehicles	A	5
6			e-charging infrastructure	A	3
7			Smart management systems	A	3
1	City energy profile	compared with	City mobility profile	B	1
2			Health	B	5
3			Clean alternatives to own vehicles	B	3
4			Low emissions vehicles	A	3
5			e-charging infrastructure	A	3
6			Smart management systems	A	3
1	City mobility profile	comp. with	Health	A	1
2			Clean alternatives to own vehicles	A	7
3			Low emissions vehicles	A	7
4			e-charging infrastructure	A	5
5			Smart management systems	A	5
1	Health	comp. with	Clean alternatives to own vehicles	A	3
2			Low emissions vehicles	A	5
3			e-charging infrastructure	A	5
4			Smart management systems	A	5
1	Clean alternatives to own vehicles	vs	Low emissions vehicles	A	1
2			e-charging infrastructure	A	1
3			Smart management systems	A	1
1	Low emissions vehicles	vs	e-charging infrastructure	A	1
2			Smart management systems	A	1
1	e-charging infrastructure	vs	Smart management systems	A	1

Table 6.2. AHP application to the mobility dimensions

This process could be applied through the participatory process, either by survey or directly through workshops.

The results of the pair-wise comparison are represented in the comparison matrix to obtain the weights of each element.

Matrix	Air quality	City energy profile	City mobility profile	Health	Clean alternatives to own vehicles	Low emissions vehicles	e-charging infrastructure	Smart management systems		
Air quality	1	6	1/5	1/3	3	5	3	3	∑(F75:M75)/n=	19%
City energy profile	1/6	1	1	1/5	1/3	3	3	3		10%
City mobility profile	5	1	1	1	7	7	5	5		28%
Health	3	5	1	1	3	5	5	5		24%
Clean alternatives to own vehicles	1/3	3	1/7	1/3	1	1	1	1		7%
Low emissions vehicles	1/5	1/3	1/7	1/5	1	1	1	1		4%
e-charging infrastructure	1/3	1/3	1/5	1/5	1	1	1	1		4%
Smart management systems	1/3	1/3	1/5	1/5	1	1	1	1	n:	4%
SUM:	10,37	17,00	3,89	3,47	17,33	24,00	20,00	20,00	116,05	

Figure 6.1. Comparison matrix & weights resulting for the mobility dimensions

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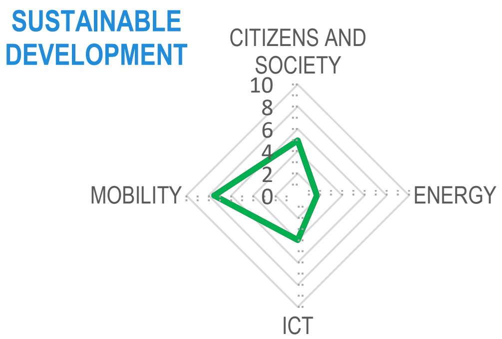
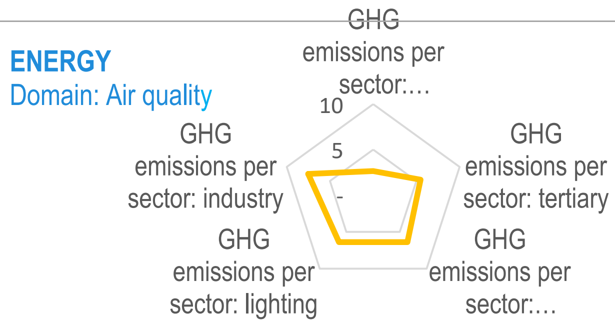
6.2 Graphical representation as result of city needs and priorities

The result of the AHP can be represented in radar graphs for a better interpretation of the city needs and priorities.

The different expected outcomes can be seen in the figures below presenting domains, fields and dimensions.

Outcome	Graphic
Sustainable city profile in each one of the fields of the project	
City profile in all domains defined in each field of the project	
City profile of all indicators considered in a domain and field	

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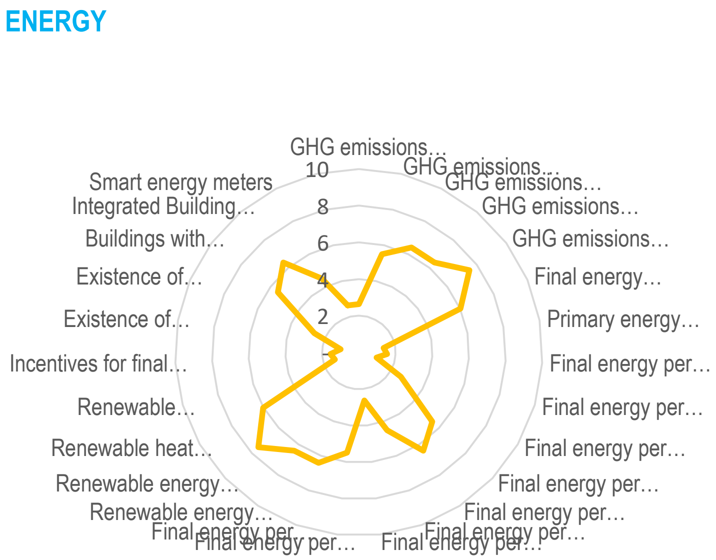
Outcome	Graphic
City profile of whole indicators belong to a domain and field	

Figure 6.2. Outcome of city needs and priorities

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7 Conclusions

The work presented in this document furnishes a description of the Advanced City Diagnosis modelling and diagnosis. The work described in this document is part of task "T1.1: Advanced city diagnosis: identification and review of city challenges and priorities" and it is complemented with the Advanced Diagnosis of each Lighthouse and Follower city that will be accomplished in month 15.

"D1.1. Report on indicators, tools and methods for advanced city modelling and diagnosis" will be the guidelines for cities to carry out the Advanced Diagnosis. During this process, cities will be supported by technical partners: TEC, CAR, KVEL, INN, SAM, TUD and DEM. Methods and tools described in this document will be adapted to the casuistic of each city.

The Advanced City Diagnosis will be the base for the definition of demand and supply scenarios and will be part of the Smart City strategic and Replication plan of each city. Furthermore, it will constitute the base to update SEAPs/SECAPs.

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Annex A1. City level evaluation framework

City level evaluation framework in MAtchUP aims to provide a consistent method to make an advanced city diagnosis to measure the progress of the cities on the road to sustainability and smartness. In this annex is described the tool designed to be used with this purpose and the process that has leaded to build a tailored evaluation framework to be applied in the advanced city diagnosis of cities involved in MAtchUP Project. In addition, it has to mention that this methodology can be applied to any city since it is based in indicators already used by cities.

A1.1. Background and context

There is a wide number of documents that analyze and provide evaluation frameworks for identify the needs and challenges of cities that are smart cites or are in the process to become. In order to short the long list of existing frameworks, partners working in the design of MAtchUP evaluation framework considered to focus in those that are based in the term of sustainability. This conclusion was taken when the concept “Smart City” was analyzed and was found that this term is understood under different scopes, being the term *“Sustainable development”* the most frequently mentioned topic in the existing definitions. Hence, the MAtchUP evaluation framework that supports the method for advanced city diagnosis is based in the concept of sustainable development.

This term of sustainable development was defined by first time in the Brudtland report (WCED, 1987) as *“that development that meets the needs of the present without compromising the ability of future generations to meet their own needs”.* In addition, this concept is used by an initiative that guides the United Nations Programme (UNDP) policy from 2016 until 2030 and that intends to stimulate actions in areas of critical importance for humanity and the planet *(to end poverty, protect the planet and ensure that all people enjoy peace and prosperity)* through the definition of 17 Sustainable Development Goals (SDGs). This initiative is named as United for Smart Sustainable Cities (UA4SSC) and it is the result of collaboration among United Nations Economic Commission for Europe (UNECE) and the International Telecommunication Union (ITU). In fact the Goal 11: “Make cities and human settlements inclusive, save, resilient and sustainable” is the basis of the Evaluation Framework for characterizate the seven cities that participate in MatchUP.

Sustainable development goals promoved in UA4SSC are represented in figure below.

Figure A1.1: Sustainable Development Goals from United Nations

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Finally, the concept of triple bottom line (TBL) has been also considered for the design of MAtchUP Evaluation Framework. This is a well-known scientific model that was first coined in 1994 and that can be applied in a wide spectrum of contexts. For example, in its origins aimed to measure the financial, social and environmental performance of a corporation over a period of time, considering that only a company that follows this TBL scheme is taking account the full cost involved in doing business. Therefore, a company not only had to measure the economy profit but also how social and environmentally responsible has been in its operations.

Figure A1.2: Triple bottom line

(http://realbuildingconsultants.com)

A1.2. Objectives of the city evaluation framework

A1.2.1. Global objectives

The MAtchUP evaluation framework has as main objective to support Smart Cities in strengthening their strategic planning through the definition of a methodology to assists city managers and stakeholders to measure the progress of cities on the road to sustainability and smartness. This methodology will allow to assess specific characteristics of the city, to diagnose challenges or discover patterns through reliable metrics but also to compare the different aspects of the cities thanks to the standardization of the indicators and indexes defined.

Specifically, the city level evaluation framework through the calculation of indicators aims to achieve the following objectives:

- Know a first identification of city needs and challenges that help city managers in the decision-making process of the city and when prioritizing a city strategy.
- Measure different aspects of cities to be aware how close a city is to become a sustainable and smart city.
- Monitor the progress of the city to show to what extent sustainability and smart goals have been reached.
- Provide information in a more comprehensive way to facilitate the communication of information to stakeholders and city planners. The well-integrated index defined can simplify elaborated data and to reach wider audiences.

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- Set a reference methodology for benchmarking and comparison of different aspects of cities and to compare cities with other, although such a comparison should be done with care.
- Evaluate the context where MAtchUP Project actions and interventions will be executed to identify in advance the city's strengths and weakness in order to guide the implementation process.

A1.2.2. Measurable objectives

MAtchUP evaluation framework is also based in the benefits that expect the cities when they decided to be smart and implement smart solutions. Since there are differences in the scope that cities have with the term of Smart City, the methodology that is originated from this evaluation framework has been defined to be aligned with the next definitions:

- European Commission (2012): *"The Smart Cities and Communities is a partnership across the areas of energy, transport and information and communication with the objective to catalyse progress in areas where energy production, distribution and use; mobility and transport; and information and communication technologies (ICT) are intimately linked and offer new interdisciplinary opportunities to improve services while reducing energy and resource consumption and greenhouse gas (GHG) and other polluting emissions".*
- European Innovation Partnership on Smart Cities and Communities (2013): "*Smart cities should be regarded as systems of people interacting with and using flows of energy, materials, services and financing to catalyse sustainable economic development, resilience, and high quality of life; these flows and interactions become smart through making strategic use of information and communication infrastructure and services in a process of transparent urban planning and management that is responsive to the social and economic needs of society".*

Where it can conclude by merging both definitions that a smart city uses innovative technology and implement efficient solutions in the areas of energy, mobility and ICT for encourage a sustainable urban development and improve the quality of life at the same time that citizens are considered as a key pillar in the process of transformation of a city.

Thus, taking into account the scope of MAtchUP *(reduce pollutants and CO_2 through energy efficient solutions in buildings and city infrastructures, improve the city mobility and reduce the CO_2 derived from city transport and develop an open urban platform, all involved in a citizen-centric approach),* a set of measurable objectives have been identified. They are represented in the table below as areas of study that will be deployed in domains and indicators to evaluate each of the fields of the project (energy, mobility, ICT, citizens). Global objectives of a city, that are named as sustainable dimensions in MAtchUP evaluation framework, are also included in the table below.

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Global city objectives	Measurable city objectives	Areas of study
Economic and Social objectives	Impulse the economic development of the city	Economic performance of the city
		Employment rate in the city
	Increase city competitiveness	Business in innovation
		Urban infrastructure managed by ICT
	Face poverty and inequality	Social inclusion
		Affordable housing
Environmental objectives	Reduce the air pollution	Air quality
		Noise
	Diminish climate change impacts due to human activities in the city	City energy profile
		RES in the city
		GHG emissions
		Climate change effects
	Application of sustainable and smart measures in buildings and districts	Green buildings
		Smart buildings
	Increase the clean transport in the city	Mobility city profile
		Clean alternatives to private vehicles
		Low emissions vehicles
		Existing charging infrastructure for EV
		Use of charging infrastructure for EV
Social objectives	Socioeconomic characteristics of population	Age structure of citizens
		Education level of citizens
		Economic level of citizens
		Citizens diversity
	Better quality of life for citizens	Citizens health
		Good health and well-being in the road
	Promote the involvement of citizens in the decision making process of the city	Existing channels for the communication with the local government
		Use of the existing communication channels with the local government
	Encourage the use of ICT in society	ICT in education
		ICT in citizens
		ICT in public sector
	Institutions more transparent for the citizens	Digital infrastructure
Economic, social and environmental objectives	Advance in the transformation of the city towards the sustainability	Local government support for sustainable initiatives
		Expenses and public administration for low carbon initiatives
		Governance collaboration

Table A1.1. Areas of study in MAtchUP city evaluation framework

A1.3. Evaluation approach

An important feature of this evaluation framework is its holistic approach that allows to cover all the goals of a smart city and the mission of MAtchUP project which aims at transforming cities through innovative solutions at the service of local communities and

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that will be applied in three fields: energy, mobility and ICT. In this section, it will describe how the city level evaluation framework is structured and their components as well as a brief description of the project level evaluation that will be also developed in the project to evaluate the success of the actions and interventions implemented in the LH cities.

A1.3.1. City and project MAtchUP evaluation frameworks

Two levels of evaluation have been identified in the project: city level and project level in order to measure two axes of the project: urban planning based on efficient measures *(under city level framework)* and execution of efficient measures in the cities *(project level framework).* Indicators will be the main tool used in both cases.

The evaluation framework defined in this deliverable corresponds with City Level and intends to guide the cities in the design of strategic plans through city diagnosis. City level indicators will be defined with the purpose to identify the current status of the cities in certain fields as well as the needs and capacities to become even more smart and sustainable. Also the indicators defined under this framework can help cities to track the progress towards city objectives. Project level framework will be defined in Deliverables 5.1, 5.2 and 5.3 and will evaluate the success of the demonstration activities and other non-technical actions implemented in the cities. Specifically, project indicators will be defined to quantify the improvements from technical, economic and social point of view.

Figure below detailed the two levels of evaluation applied in the project.

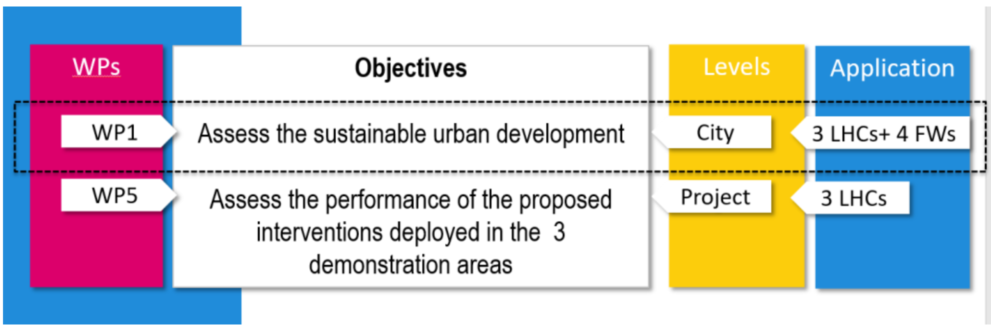

Figure A1.3: MAtchUP Evaluation framework levels

A1.3.2. Sustainability approach

City level evaluation framework in MAtchUP is based in the concept of sustainable development that comprises these three aspects: economic, social and environmental. In this section it will describe the sustainable approach of the framework through a detailed analysis of the three sustainable dimensions of the term and their interactions.

The development of a given territory is considered sustainable when this fulfil all the qualities associated to the interaction among these dimensions. However, the development of this territory can be addressed to fulfil only some of these qualities. All the possible interactions are detailed in the text and figure below for a better understanding of the method:

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- The development of the territory is guided only for achieve an economic progress. In this case, the territory is only focused in the economic dimension.
- The development of the territory is addressed towards the improvement of the quality of citizens without intends an economic progress of the territory or to protect the environment. In this case, the territory is only focused in the social dimension.
- The development of the territory aims to prevent environmental pollution and tacke specific environmental problems. In this case, the territory is only focused in the environmental dimension.
- The development of the territory prioritizes the economic progress of the city but also intends facing poverty. As result of the interaction of economic and social objectives, the territory intends to be equitable since this impulses economic development and social wellbeing.
- The development of the territory is addressed towards an increase of the economic performance but considering that this must be limited to the capacity of the environment. As a result of the interaction of environmental and economic dimensions, the policies impulsed for the economic development of the territory have an environmental responsibility.
- The development of the territory is concentrated in social and environmental objectives to obtain a better quality of the citizens but also to achieve habitable place. As result of the interaction of these dimensions, the territory pretend to be bearable since pursued environmental responsibility and social wellbeing.
- The development of the territory is addressed to economic, social and environmental objectives. City managers promotes to increase the quality of life of citizens through the impulse of social measures that help inhabitants to have better access of services and to impulse an economic development that take into account the capacity of the ecosystems and avoid the depletion of nonrenewable resources. In this case, the territory intends to be sustainable since this is positioned in the three dimensions of this concept.

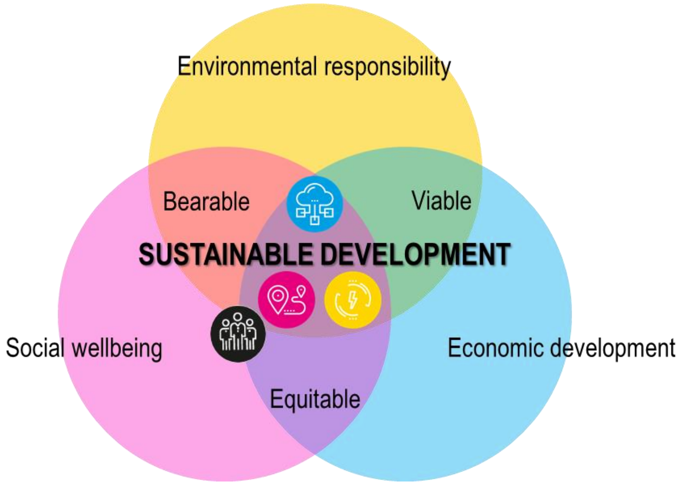

Figure A1.4: MAtchUP Evaluation framework sustainable approach

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A1.4. Evaluation framework structure

The general scheme designed in MAtchUP for the evaluation of the performance of a city is based in the definition of city indicators in each one of the fields considered in the Project that are later grouped in core categories (domains) to evaluate main aspects of the city. In a further step, the aggregation of indicators will built Indices to measure how sustainable has been the development of the city.

Figure below represent the evaluation structure of MAtchUP.

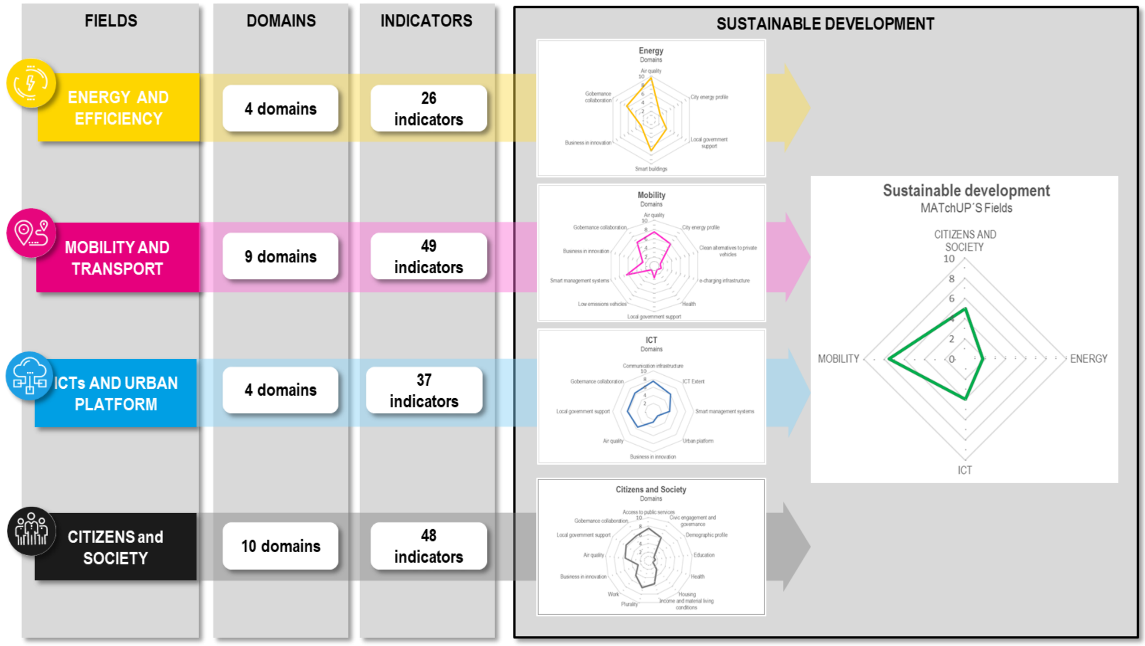

Figure A1.5. MAtchUP City level evaluation framework structure

This scheme is the result to apply two approaches in the definition of indicators since they were proposed to evaluate each one of the fields through diverse topics (domains) but also to measure how the city managers are conducting the city towards a global objective (sustainable dimension) through the implementation of actions in the fields of energy, mobility, ICT and citizens.

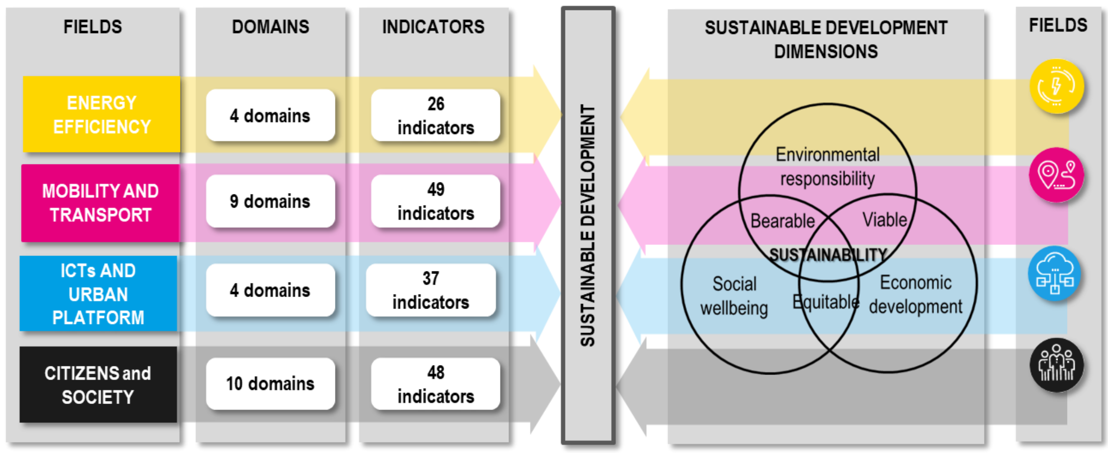

Figure A1.6. MAtchUP City level evaluation framework approach

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A1.4.1. Components

Under this section is described the general structure for representing the components of the City Evaluation Framework which are: field, dimensions, domains, indicators and indices and whose combination will allow to know different profiles of cities. Table below introduces the whole structure of the evaluation framework and how the components are connected as a result of a classification of indicators in each one of the sustainable dimensions.

Sustainable development dimensions	Domains	Fields				
Bearable	Air quality					
	Clean alternatives to private vehicles					
	Health					
	City mobility profile					
	Low emissions vehicles					
Equitable	Demographic profile					
	Income and material living conditions					
	Work					
	Business in innovation					
	ICT Extent					
	Urban platform					
	Housing					
	Demographic profile					
	Education					
	Plurality					
	Access to public services					
	Civic engagement and governance					
	Communication infrastructure					
Viable	Urban platform					
	City mobility profile					
	City energy profile					
	Low emissions vehicles					
	Smart buildings					
	e-charging infrastructure					
	Smart management systems					
Sustainable	Local government support					
	Gobernance collaboration					
Social	Health					

Table A1.2. MAtchUP Evaluation framework components

- Fields: Four fields have been considered in the evaluation framework that corresponds with the sectors where project actions are implemented and that are:
    - *“Energy efficiency in urban infrastructure”;* which correspond with energy field.
    - *“Mobility and transport”;* which represent the mobility field.

  - *"Integrated Infrastructures. ICT infrastructures and services" as a backbone of Smart Cities;* which is linked with ICT field.
  - *Citizens and society*; which correspond with citizens field.

  On the other hand, some indicators cannot classify in any of these fields. For example, some indicators are useful to characterize the city as a whole and not a specific field. They are represented in a field named ALL. In addition, there are other indicators that do not identify any city needs but static features of the city such as climate, population or city surface.

- Dimensions involve the sustainable aspects of a city transformation and the interaction among them and are named as social, environment and economy and the interaction among them: bearable, viable, equitable and sustainable.

  Figure below represents the fields and sustainable dimensions.

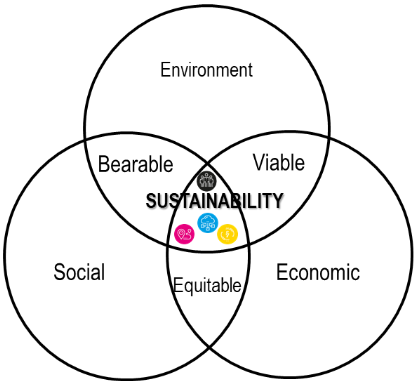

Figure A1.7: MAtchUP dimensions and fields scheme

- Domains reflect the categories that group indicators and are associated to the areas of study that represent. Domains identified in this evaluation framework can be seen in table above.
- Indicators and indexes: Each indicator consists of variables to be measured from real or calculated data and allows evaluating different aspects of cities under the scope defined in the evaluation framework. They are the core of the holistic methodology developed under MAtchUP city level evaluation framework and when they are reported and represented together in graps can provide the potential areas (domains) where the city needs to improve to be smarter and more sustainable.

  In order to know better the scale of sustainable development achieved in each on the fields of the Project (mobility, energy, ICT and citizens and society), indexes (also named as composite indicators) will be built. An “index” is a quantitative aggregation of many indicators and aims to provide a simplified, coherent, multidimensional view of a system. Indices usually give a static overview of a system, but when calculated periodically, they can indicate whether the system is becoming more or less smart, and can highlight which factors are most responsible for driving the system. In the case of our methodology, these indices will be a single metric to measure the accomplish of specific purpose that is which sustainable

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dimension is being promoted by the city managers (social, economic, environment or their interactions).

A1.4.2. Indicators

The evaluation framework defined considers the indicators as the core of the methodology to make an advanced city diagnosis. Through the extend work developed with technical experts and cities from the project and making use of documents with consolidated list of indicators already tested by other technical partners and cities, the list of indicators defined in MAtchUP can help city stakeholders to better understand the specific challenges of the cities, provides insights into effective policies and best practices and supports their decision making.

The list of indicators defined under the city level evaluation framework of the Project MAtchUP has the following features:

- The set of indicators defined has a sound basis after the dedication of technical experts in the identification and selection of the most suitable indicators. In addition, they have been validated by the cities involved in MAtchUP in order to detect those indicators that despite being good for measure specific aspects of the city, will not be quantified due to the non-availability of data or reliable data in the cities.
- The set of indicators allows the identification of the most appropriate "strategy" according with the city demand identified during the city diagnosis.
- The set of indicators gives the state of the sustainability in the city as well as the current status of the energy, mobility, ICT and citizens fields under the sustainable development target.
- The set of indicators allows the monitoring of the progress of the city to show to what extent sustainability and smart goals have been reached.

City level framework consists of 188 indicators that have been classified in core indicators (165) and additional indicators (23 indicators). All the indicators were considered from the beginning as core to be analysed by all cities to provide a basic outline of smartness and sustainability and the level of performance in the topics analysed. However, it was found some difficulty to evaluate some of them due to the lack of data at city level. As a result, they were named as complementary indicators to be used optionally by cities for complete the city characterization. The list of indicators and if they are considered as core or complementary (named as CI) can be seen in the Annex. In addition, it has to mention that part of the city indicators correspond with the fields analysed (energy, mobility, ICT and citizens), whereas some indicators are focused in the whole city under categories All and City characterization.

The description of each indicator has been accurate in order to ensure that reported indicators value are consistent and includes this information: name of indicator, unit, description of indicator, formula to calculate the indicator, source where the indicator was extracted, specific domain, sustainable development dimension and MatchUP field. Below it is reported some issues considered in the process of definition of indicators.

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- The selection of the indicator unit is considered as essential since a good indicator is achieved when is possible to understand the context of the city when this is reported. Hence, for the selection of indicators, it has considered that these are measured in terms per capita (e.g. city size, city population) or link variables (e.g. fuel costs in terms of incomes). This requirement has also be applied in those cases in which the indicator has been defined by the MatchUP partners.
- Description of indicator must be precise in order to avoid interpretations and obtain incorrect results reported. During the collaborative work for the definition of indicators, those cases in which was detected that the description of the indicator was incomplete, unfamiliar or could have different interpretations, have solved with an improvement in the definition of the indicator.
- The formula to calculate the indicator is indispensable in order to identify all the variables that need to be quantified and the equation to apply.
- In order to support the selection of indicators, each indicator is accompanied by the sources identified that previously defined or included such indicator. In this way, it can assure that the set of indicators provided is the result of a rigorous work done previously by other entities or under initiatives promoted by relevant organisms and that has improved by experts working in MatchUP for a better application in the cities involved in the project.

Finally, it has to mention that as part of MAtchUP evaluation framework, it has considered the design of indices from the aggregation of indicators.

A1.5. Process applied for defining city indicators

This section describes the procedure applied for the selection of indicators to be used for the city diagnosis of MAtchUP cities.

1) Definition of the approach of the evaluation framework

The selection of the approach is very important in order to search the indicators under this criteria as well as to align the structure for group them. The proper structure of MAtchUP Project as well as the analysis of document were the responsible of the scope considered of the evaluation framework.

2) Identification of sources to be consulted for the identification of suitable indicators for our city diagnosis

The selection of indicators was the result of the analysis of existing indicators systems. Currently, there are diverse documents developed under diverse initiatives that have been working in deploying list of indicators. For the selection of sources to be consulted, it was considered that should follow the evaluation approach and fall in one of the following categories: International and European Standards, European frameworks, Relevant FP7 and H2020 projects, selected cities frameworks and existing statistical sources.

A brief description of initiatives considered in the identification of indicators is provided below:

- Standards which defines indicators at city level:

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ISO 37120: 2014: Sustainable development of communities - Indicators for city services and quality of life. This is the unique international standard on city data which defines a set of indicators to steer and measure the performance of city services and quality of life. It is applicable to any city, municipality or local government that undertakes to measure its performance in a comparable and verifiable manner, irrespective of size and location; developed for a holistic and integrated approach to sustainable development and resilience under this standard.

- Initiatives funded by the Commission to develop specifically indicators for Smart Cities and that are expected to be used for all the Horizon2020 “lighthouse projects”.

  CITYKeys: Project focused in the development of a harmonized and comparable holistic performance measurement framework for being considered in future European cities activities during the implementation of Smart City solutions. The main aim of this Project is the definition and validation with the aid of cities of a list of indicators that can be used for tracking the progress towards city objectives. http://www.citykeys-project.eu

  ESPRESSO: Project aims to defining a systemic standardisation approach to empower Smart Cities and Communities and where a set of indicators has been defined to measure performance in different sectors of Smart Cities and Communities. http://espresso.espresso-project.eu/

  EU Smart Cities Information System (SCIS) is a knowledge platform to exchange data, experience and know-how and to collaborate on the creation of smart cities. It is focuses on the development of indicators to measure technical and economic aspects of energy related measures. These should be applicable to European funded demonstration projects for Smart Cities and Communities (SCC), Energy Efficient buildings (EeB) and designated projects funded under the calls for Energy Efficiency (EE). https://smartcities-infosystem.eu/

- Global initiatives focused in the promotion of Smart Sustainable Cities

  United for Smart Sustainable Cities (UA4SSC): UNECE and the International Telecommunication Union (ITU) elaborated the Smart Sustainable Cities Indicators together with a consortium of partners. They have developed a tool to evaluate how smart and sustainable a city is and serve as a starting point to implement concrete actions and measures and improve a city’s sustainability level. In addition, Smart Sustainable Cities Indicators will help cities to evaluate their performance against the SDGs.

- From previous Smart Cities and Communities Lighthouse projects

  Indicators from *REMOURBAN, mySMARTLife, REPLICATE, SmartEnCity and CITyFiED.* The main reason for consider these projects and not other is the participation of MatchUP partners in them.

- Statistics on cities

  EUROSTAT and City Audit: The Urban Audit is a joint effort by the Directorate-General for Regional Policy (DG REGIO) and Eurostat to provide reliable and comparative information on selected urban areas in Member States of the

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European Union and the Candidate Countries. http://ec.europa.eu/eurostat/web/main/home

- From initiatives promoted by experts

  Fundación Telefónica and ITU as experts in ICT have worked in the definition of evaluation framework for evaluating ICT services and ICT urban platforms. As a result, each entity has deployed a list of indicators to be applied in the ICT sector.

  https://en.fundaciontelefonica.com/

  https://www.itu.int/en/ITU-D/Statistics/Documents/publications/wtid/WTID2017_ListOfIndicators_Dec.pdf

  On the other hand, World Bank works for promoting the development and sustainability as way to face poverty in the world. An exhaustive list of indicators is found inhttps://data.worldbank.org/indicator?tab=all

- From cities involved in the Project

  Indicators already used by cities to make city audits such as the municipality of Valencia. The source used correspond with: *"Guidelines for improving the urban quality of neighborhoods".* http://www.valencia.es/revisionplan/sites/default/files/docs/directrices_mejora_calidad_urbana_v06_web_1.pdf

3) Establish the criteria for indicators selection

Given the long list of existing indicators, it is needed to take into account a set of criteria for reduce the number of indicators to be considered in the Project. Such criteria have already identified by projects such as CITYKEYS and ESPRESSO and correspond with:

- RELEVANCE: Each indicator should have a significant importance for the evaluation process. That means that the indicators should have a strong link to the subthemes of the framework.
- COMPLETENESS: The set of indicators should consider all aspects of the implementation of smart city projects and be connected with policy goals.
- AVAILABILITY: Data for the indicators should be easily available to be quantified with few efforts.
- MEASURABILITY: The identified indicators should be capable of being measured, preferably as objectively as posible. Nevertheless, some indicators can be quantified in a qualitative way on a symmetric agree-disagree scale for a series of statements.
- RELIABILITY: The definitions of the indicators should be clear and not open for different interpretations. This holds for the definition itself and for the calculation methods behind the indicator.
- FAMILIARITY: The indicators should be easy to understand by the users.
- NON-REDUNDANCY: Indicators within a system/framework should not measure the same aspect of a subtheme.
- INDEPENDENCE: Small changes in the measurements of an indicator should not impact preferences assigned to other indicators in the evaluation.

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4) Selection of indicators

The indicators have been selected in a collaborative way through the partner cities and experts from the consortium. Firstly, a screening of sources and indicators have been done by the partner responsible for defining the evaluation approach (CAR), taking into account that indicators must fulfill the expectatives considered in the evaluation framework and the knowledge gained in previous city diagnosis in other LH cities. Then, experts from each field (TECNALIA: energy, FRAUNHOFER: mobility, SAMPAS and ITU: ICT and KVELOCE: citizens) have reviewed the list in order to propose changes in the indicators by adding new indicators or rejecting those that were not suitable. In a further step, cities were invited to check the list with the intention to detect the availability of data for calculate each indicator. Final list was the result of a discussion in the meeting of Antalya. It has to mention that some indicators have been proposed by MatchUP partners for those cases in which it was detected a gap in the documents analyzed. Furthermore, some of the 'new' indicators are reformulations or combinations of existing indicators.

5) Definition of categories for indicators

The areas of study decided at a first moment was the scheme of MAtchUP project supported by the review of different documents that define city evaluation framework but in particular CITYkeys, EXPRESSO and ISO 37120 and the sustainable approach defined. As the result, different areas of interest to group indicators were proposed that transformed when the list was ended in domains from the evaluation framework. Several interchange of impressions among experts were held to elaborate the final structure.

Figure below corresponds with the workshop held in Antalya for the validation of the indicators and categories.

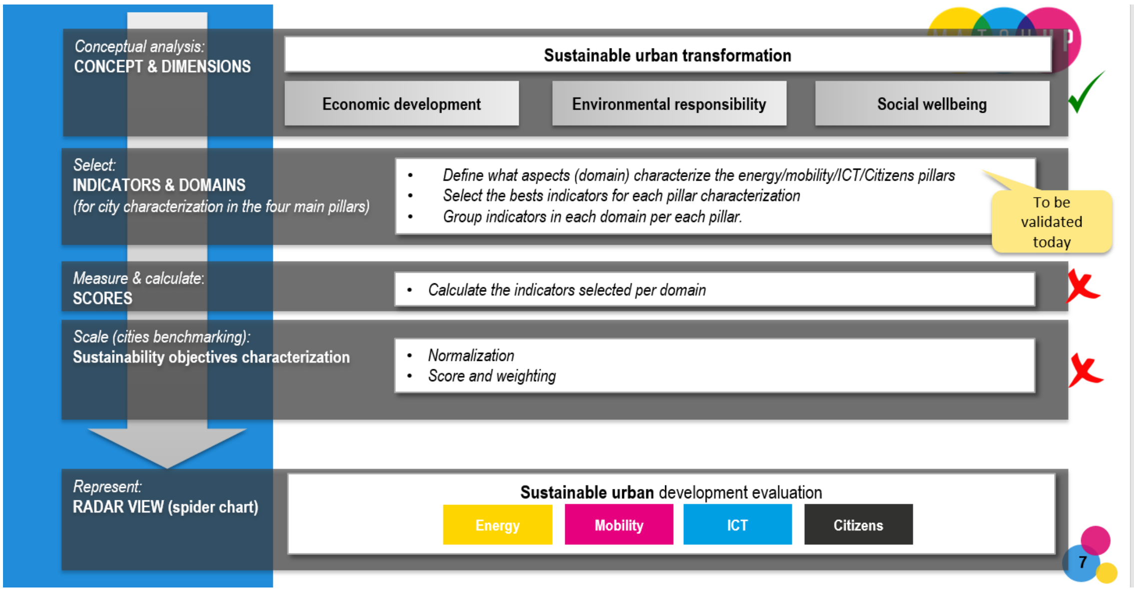

Figure A1.8. Process for validation of indicators and dimensions

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6) Classification of indicators in sustainable dimensions

The last step in the process applied for the definition of indicators consists of link each indicator with a sustainable dimension. This process of assignation has been carried out by a group of experts from a subjective point of view.

7) Data collection, analysis and building index

Once the process of data collection and calculation of indicators have ended, the results can provide the performance of the city. However, as part of MAtchUP evaluation framework, it has considered the design of indices from the aggregation of indicators.

Constructing a composite index is a complex task whose phases involve several alternatives and possibilities that affect the quality and reliability of the results. The steps for building an index are described in Step 3.

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A1.6. List of indicators.

A1.6.1. Energy efficiency in urban infrastructure field

ID	Indicators	Formula	Units	Description of the indicator	Source	Domain	Sustainable development dimension
1098	Final energy consumption per capita	Final energy consumption/inhabitants	TWh/inhab	Annual final energy consumption for all uses and forms of energy. End users include residential, tertiary sector, public lighting, industry and transport	CITYkeys, SEAP, SCIS	City energy profile	Viable
1099	Primary energy consumption in the city	Primary energy consumption/inhabitants	MWh/inhab	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	MAtchUP	City energy profile	Viable
1100	Final energy per sector: residential	Final energy consumption (residential)/inhabitants	MWh/inhab	Annual final energy consumption of residential sector of the city	SEAP,SCIS	City energy profile	Viable

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ID	Indicators	Formula	Units	Description of the indicator	Source	Domain	Sustainable development dimension
1101	Final energy per sector: tertiary	Final energy consumption (tertiary)/inhabitants	MWh/inhab	Annual final energy consumption of tertiary sector of the city	SEAP,SCIS	City energy profile	Viable
1102	Final energy per sector: municipal	Final energy consumption (municipal)/inhabitants	MWh/inhab	Annual final energy consumption of buildings and municipality facilities	SEAP,SCIS	City energy profile	Viable
1104	Final energy per sector: public lighting	Final energy consumption (public lighting)/inhabitants	MWh/inhab	Annual final energy consumption of public lighting of the city	SEAP,SCIS	City energy profile	Viable
1105	Final energy per sector: industry	Final energy consumption (industry)/inhabitants	MWh/inhab	Annual final energy consumption of existing industries in the city	SEAP,SCIS	City energy profile	Viable
1106	Final energy per energy carrier: electricity	Final energy consumption (electricity)/inhabitants	MWh/inhab	Annual final energy electricity consumption of the city	SEAP,SCIS	City energy profile	Viable
1107	Final energy per energy carrier: heat/cold	Final energy consumption (heat/cold)/inhabitants	MWh/inhab	Annual final energy consumption to heat and cold uses of the city	SEAP,SCIS	City energy profile	Viable
1108	Final energy per energy carrier:	Final energy consumption (fossil fuel	MWh/inhab	Annual final energy consumption from fossil	SEAP,SCIS	City energy	Viable

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ID	Indicators	Formula	Units	Description of the indicator	Source	Domain	Sustainable development dimension
	fossil fuels	carrier)/inhabitants		fuels in the city		profile	
1109	Final energy per energy carrier: RES	Final energy consumption (RES)/inhabitants	MWh/inhab	Annual final energy consumption in the city from renewable sources	SEAP,SCIS	City energy profile	Viable
1110	Renewable energy generated within the city	(Energy generated in the city with RES/city energy consumption) x 100	%	The percentage of total energy derived from renewable sources, as a share of the city's total energy consumption	CITYkeys	City energy profile	Viable
1111	Renewable energy per carrier		GWh/RES_supplier	Energy that each renewable systems provides to the city	MAtchUP	City energy profile	Viable
1112	Renewable heat generated within the city	(Total consumption of heat generated from RES/total heat consumption) x 100	%	The percentage of heat energy derived from renewable sources, as a share of the city's total heat consumption	REPLICATE	City energy profile	Viable
1113	Renewable electricity generated within the city	(Total consumption of electricity generated from RES/total electricity consumption) x 100	%	The percentage of electric energy derived from renewable sources, as a share of the city's total	REPLICATE	City energy profile	Viable

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ID	Indicators	Formula	Units	Description of the indicator	Source	Domain	Sustainable development dimension
				energy consumption			
1115	GHG emissions per sector: residential	GHG emissions (residential)/inhabitants	Tonnes of CO2/ inhabitant	CO2 emissions of residential sector of the city	SEAP	Air quality	Bearable
1116	GHG emissions per sector: tertiary	GHG emissions (tertiary)/inhabitants	Tonnes of CO2/ inhabitant	CO_2 emissions of tertiary sector of the city	SEAP	Air quality	Bearable
1117	GHG emissions per sector: municipal	GHG emissions (municipal) /inhabitants	Tonnes of CO2/ inhabitant	CO_2 emissions of municipal sector of the city. It refers to public buildings	SEAP	Air quality	Bearable
1119	GHG emissions per sector: lighting	GHG emissions (lighting)/inhabitants	Tonnes of CO2/ inhabitant	CO_2 emissions of the city lighting	SEAP	Air quality	Bearable
1120	GHG emissions per sector: industry	GHG emissions (industry)/inhabitants	Tonnes of CO2/ inhabitant	CO_2 emissions of industry sector of the city	SEAP	Air quality	Bearable
1141	Existence of plans/programs to promote energy efficient buildings	Is there any specific plan/program for promoting energy efficient buildings in the city? How many?	First question: YES/NO Second question: #	o	SmartEnCity	Local government support	Sustainable

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ID	Indicators	Formula	Units	Description of the indicator	Source	Domain	Sustainable development dimension
1143	Existence of regulations for development of energy efficient districts	Is there any specific regulation for developing energy efficient districts in the city? How many?	First question: YES/NO Second question: #	Existence of laws in the city as specific instruments to foster the implementation of energy solutions in buildings or the energy refurbishment of buildings.	SmartEnCity	Local government support	Sustainable
1164	Buildings with green/sustainable certificate	(Number of buildings with green/sustainable certificates/Total number of buildings in the city) x 100	%	Percentage of total buildings with green/sustainable certificate (LEED, BREEAM, etc)	CITYFiED	Smart buildings	Viable
1165	Integrated Building Management Systems in Public Buildings	(Number of public buildings using ICT-based systems for integrated management in the city/ Total number of public buildings in the cities) x 100	%	Percentage of public buildings using integrated ICT systems to automate building management and create flexible, effective, comfortable and secure environment	Based in U4SSC	Smart buildings	Viable
1166	Smart energy meters	(Number of dwellings with smart energy meters/Total number of dwellings in the city x 100	%	Percentage of homes (multifamily & single-family) with smart meters	SCIS, REPLICATE	Smart buildings	Viable

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ID	Indicators	Formula	Units	Description of the indicator	Source	Domain	Sustainable development dimension
1167	Number of connections to a district heating network	(Total number of buildings connected to a DH/ total number of buildings in the city) x 100	% of buildings	Percentage of buildings connected to a district heating network of the city	SmartENcity?, REPLICATE	Smart buildings	Viable

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A1.6.2. Mobility field

ID	Indicators	Formula	Units	Description of the indicator	Source	Domain	Sustainable development dimension
1087	Average occupancy in vehicles		number of passengers per vehicle	Average of number of passengers per vehicle per trip	SmartEnCity	City mobility profile	Viable
1088	Access to public transport	(Number of inhabitants with a transportation stop <500m/total population) x 100	% of people	Share of population with access to a public transport stop within 500m	CITYkeys, REPLICATE	Clean alternatives to private vehicles	Bearable
1089	Public Transport Network	(Length of public transport lines within city boundaries (one way length)/city population) x 100,000	Km / 100,000 inhabitants	Length of public transport network per 100,000 inhabitants	U4SSC	Clean alternatives to private vehicles	Bearable
1090	Access to vehicle sharing solutions (cars)	(# vehicle for sharing / total population) x 100 000	#/100 000 people	Number of vehicles available for sharing per 100.000 inhabitants	CITYkeys	Clean alternatives to private vehicles	Bearable
1091	Access to bike sharing solutions	(# bikes for sharing / total population) x 100 000	#/100 000 people	Number of shared bikes in the city per capita	MatchUP	Clean alternatives to private vehicles	Bearable
1097	Exposure to noise pollution	(population affected by noise > 55dB at night	% of people	Share of the population affected by noise >55 dB(a)	CITYkeys, REPLICATE	Air quality	Bearable

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ID	Indicators	Formula	Units	Description of the indicator	Source	Domain	Sustainable development dimension
		time/total population) x 100		at night time			
1103	Final energy per sector: transport	Final energy consumption (transport)/inhabitants	MWh/inhab	Annual final energy consumption of transport of all types	SEAP,SCIS	City energy profile	Viable
1118	GHG emissions per sector: transport	GHG emissions (transport)/inhabitants	Tonnes of CO2/ inhabitant	CO_2 emissions of transport sector of the city. The information should be provided by the total transport sector but also for the public, private and commercial. Public and private refers to transport persons whereas commercial is for delivery parcel, post, waste, maintenance	SEAP	Air quality	Bearable
1122	Modal Split: Private motor vehicle		%	Percentage of trips using a private motor vehicle as type of transportation. The indicator searches the total number but also to distinguish in inner-city traffic and commuter-traffic (from outside)	REMOURBAN, REPLICATE	City mobility profile	Bearable

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ID	Indicators	Formula	Units	Description of the indicator	Source	Domain	Sustainable development dimension
1123	Modal Split. Walk		%	Percentage of trips walking as type of transportation	REMOURBAN, REPLICATE	City mobility profile	Bearable
1124	Modal Split. Bike		%	Percentage of trips using a bike as type of transportation	REMOURBAN, REPLICATE	City mobility profile	Bearable
1125	Modal Split. Passenger transport		%	Percentage share of each mode of transport in total inland transport, expressed in passenger-kilometers (pkm). The indicator searches the total number but also to distinguish in inner-city traffic and commuter-traffic (from outside)	REMOURBAN, REPLICATE	City mobility profile	Bearable
1126	Number of fossil fuelled four wheels vehicles per capita	Number of fossil fuelled vehicles (four wheels) of the city distinguishing by type (public, private and commercial) and divided by the population	#/cap	Number of fossil fuelled vehicles (four wheels) of the city per capita. Public and private refers to transport persons whereas commercial is for delivery parcel, post, waste, maintenance	SCIS, REPLICATE	City mobility profile	Viable

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ID	Indicators	Formula	Units	Description of the indicator	Source	Domain	Sustainable development dimension
1127	Number of fossil fuelled two wheels vehicles per capita	Number of fossil fuelled vehicles (two wheels) of the city distinguishing by type (public, private and commercial) and divided by the population	#/cap	Number of fossil fuelled vehicles (two wheels) of the city per capita. Public and private refers to transport persons whereas commercial is for delivery parcel, post, waste, maintenance	REPLICATE	City mobility profile	Viable
1128	Total number of transport vehicles for passengers	(Vehicles destinated to transport passangers/inhabitants) x 100,000	#/100,000 people	Number of available vehicles in the city that are destinated to transport passangers (bus, taxis…) per capita	Based on SmartEnCity	City mobility profile	Bearable
1129	Public transport users	# of public transport users / total population	#/cap/year	Annual number of public transport users per capita	MatchUP	Clean alternatives to private vehicles	Bearable
1130	Public transport use	# of trips made annually in the city with public transport / total population	#/cap/year	Annual number of public transport trips per capita	CITYkeys, REPLICATE	Clean alternatives to private vehicles	Bearable
1131	Public transport use (2)	# of annual tickets of public transport/# of annual passes of public transport	#	Relation of the annual tickets and passes in order to know the number of frequent and sporadic users		Clean alternatives to private vehicles	Bearable

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ID	Indicators	Formula	Units	Description of the indicator	Source	Domain	Sustainable development dimension
1132	Length of bike route network	The indicator shall be calculated as the total kilometres of bicycle paths and lanes (numerator) divided by one 100 000th of the city's total population (denominator). The result shall be expressed as the kilometres of bicycle paths and lanes per 100 000 population.	% in km	% of bicycle paths and lanes in relation to the length o streets (excluding motorways)	REPLICATE	Clean alternatives to private vehicles	Bearable
1133	Length of bike route network	(Lenght of lanes/inhabitants) x 100,000	km/100000 people	Lenght of lanes in the city for bikes per 100,000 inhabitants	SCIS	Clean alternatives to private vehicles	Bearable
1142	Existence of plans/programs to promote sustainable mobility	Is there any specific plan for promoting sustainable mobility in the city? How many?	First question: YES/NO Second question: #	Inclusion of sustainable mobility actions in the urban plans developed by the own local government to design the future vision of the city	SmartEnCity	Local government support	Sustainable
1144	Existence of regulations for development of sustainable mobility	Is there any specific regulation for developing sustainable mobility in the city? How many?	First question: YES/NO Second question: #	Existence of laws in the city as specific instruments to foster the implementation of sustainable mobility actions	SmartEnCity	Local government support	Sustainable

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ID	Indicators	Formula	Units	Description of the indicator	Source	Domain	Sustainable development dimension
1153	Traffic accidents	(Number of Fatalities Related To Transportation Of Any Kind/city population) x 100,000	#/100 000 people	Number of transportation fatalities per 100 000 population in a year. Fatalities includes dead but also hospitalization	CITYkeys, REPLICATE	Health	Social
1154	Congestion	((travel times in peak hours - travel times during non-congested periods (free flow*))/travel times during non-congested periods)x100	% in hours	Increase in overall travel times when compared to free flow situation (uncongested situation)	CITYkeys	Health	Bearable
1156	Fuel mix		%	Percentage of the market share of transport fuel for each type of fuel used (petrol, diesel, petrol/LPG, electric, electric and hybrid vehicles	SmartEnCity	City mobility profile	Viable
1157	Average vehicle speed		km/h	Average network speed by vehicle (peak/off-peak)	SmartEnCity	City mobility profile	Bearable
1158	Transportation Mode Share	(Number of travellers using various transportation mode/Total number of travellers) x 100	%	The percentage of people using various forms of transportation to travel to work	U4SSC	City mobility profile	Bearable

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ID	Indicators	Formula	Units	Description of the indicator	Source	Domain	Sustainable development dimension
1159	Users of mass transit (MT)	Users of mass transit (buses, subways, and elevated trains)/users of private vehicles (cars, motorbikes, bikes, taxis)	%	Percentage of users of MT vs other means of transport. Report on modes: public transportation, personal vehicles, bicycles, walking, paratransit	Sustainable indicator paper	Low emissions vehicles	Bearable
1160	Number of Electric Vehicles in the city		#	Number of electric vehicles in the city (including private, public and commeercial vehicles as well as motorbikes) . Public and private refers to transport persons whereas commercial is for delivery parcel, post, waste, maintenance. Total number and by each type should be calculated	REMOURBAN	Low emissions vehicles	Viable
1161	Number of Electric Vehicles per capita	(# EVs / total population) x 100,000	#/100 000 people	Number of total electric vehicles in the city (including private, public and commeercial vehicles as well as motorbikes) in relation to the number of inhabitants. Public and	REPLICATE	Low emissions vehicles	Viable

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ID	Indicators	Formula	Units	Description of the indicator	Source	Domain	Sustainable development dimension
				private refers to transport persons whereas commercial is for delivery parcel, post, waste, maintenance.			
1162	Percentage of EV per sector (private, public and commercial)	Total number of all type EV (per sector)/ Total number vehicles	%	Number of electric vehicles related to total number of vehicles. Total number and by sector should be reported	REMOURBAN	Low emissions vehicles	Viable
1163	Low-Carbon Emission Passenger Vehicles	(Number of low emission passengers vehicles registered (PHEV & EV)/Number of total vehicles) x 100	%	Percentage of low-carbon emission passenger vehicles (PHEV & EV)	U4SSC	Low emissions vehicles	Bearable
1168	Public charging points per eVehicle	Total charging points/# eVehicles	#	This indicator measures the number of public charging points related to the total amount of electric vehicles in the city.	SmartEnCity	e-charging infrastructure	Viable
1169	Public charging e-car		#	Total number of public charging points in the city for e-cars	REPLICATE	e-charging infrastructure	Viable

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ID	Indicators	Formula	Units	Description of the indicator	Source	Domain	Sustainable development dimension
1170	Public charging e-bike		#	Total number of public charging points in the city for e-bikes	REPLICATE	e-charging infrastructure	Viable
1171	Use of public EV charging stations (kWh recharged)		kWh/year	Number of kWh recharged by all types of electric vehicles during a year in the public charging stations	SmartEnCity	e-charging infrastructure	Viable
1172	Use of public EV charging stations (number of recharges per year)		#/year	Number of recharges in public electric car recharge infrastructures in the city during a year	SmartEnCity	e-charging infrastructure	Viable
1173	Traffic management system	Is there an automated system for the management of the traffic in the city?	YES/NO	Existence of an automated traffic management system in the city	SmartEnCity	Smart management systems	Viable
1174	Vehicle count at permanent measuring points	Are roadside sensors for counting vehicles in the city?	YES/NO	Existence of roadside sensors for counting vehicles	MatchUP	Smart management systems	Viable
1175	Bicyccle count at permanent measuring points	Are roadside sensors for counting bicyles in the city?	YES/NO	Existence of roadside sensors for counting bicycles	MatchUP	Smart management systems	Viable

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ID	Indicators	Formula	Units	Description of the indicator	Source	Domain	Sustainable development dimension
1176	Parking management system	Is there an automated system for the management of free parking spaces at city level?	YES/NO	Existence of an automated system for the management of free parking spaces at city level	SmartEnCity	Smart management systems	Viable
1178	Parking space occupancy	Is there an automated system for the prediction of the occupancy for the parking spaces in a given date and time in the future?	YES/NO	Existence of an automated system for the prediction of the occupancy for the parking spaces in the city for a given date and time in the future.	MatchUP	Smart management systems	Viable
1179	Parking search traffic	Is there an automated system for the identification of location of free parking spaces at city level?	YES/NO	Existence of an automated system for the identification of available parking spaces at city level	MatchUP	Smart management systems	Viable
1180	Public transport management system	Is there an automated system for the management of the public transport in the city?	YES/NO	Existence of an automated system for public transport in the city	SmartEnCity	Smart management systems	Viable
1181	Public bicycles management system	Is there an automated system in the city for hiring public bicyles?	YES/NO	Existence of an automated system for hiring public bicycles	SmartEnCity	Smart management systems	Viable

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ID	Indicators	Formula	Units	Description of the indicator	Source	Domain	Sustainable development dimension
1182	Public transport stops	(total number of all public transport stops/inhabitants)*100000	#/100,000 people	Total number of public transport stops in the city per capita	MatchUP	Smart management systems	Viable
1183	Public transport stops with real time info	(total number of all public transport stops/inhabitants)*100000	#/100,000 people	Total number of public transport stops with real time info in the city per capita	MatchUP	Smart management systems	Viable
1184	Public transport stops with real time info	(Number of public transport stop with real time information/total number of public transport stop) x 100	%	Number of public transport stops with real time information regarding the total number of public transport stops	SmartEnCity, REPLICATE	Smart management systems	Viable
1185	e-ticketing		Y/N or %	The presence of the e-ticketing service in the public transport of the city The mandatory field is the esence (yes or no) of the service, while an optional evaluation could be, if it's in place, the number of e-tickets versus the total number of tickets sold	REPLICATE	Smart management systems	Viable

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A1.6.3. Integrated Infrastructures. ICT infrastructures and services

ID	Indicators	Formula	Units	Description of the indicator	Source	Domain	Sustainable development dimension
1014	Employment ICT sector	(Number of employees in ICT sector/total number of employees in the city) x 100	%	This indicator measures the proportion of employees in ICT sector, usually linked with software and computer services industries, among all employees in the city.	REMOURBAN	ICT Extent	Equitable
1015	Number of data publishers *(C. I)*	-	#	Number of data publishers that publish data into the existing urban platform (e.g. website)	Fundación Teléfonica	Urban platform	Viable
1016	Number of sensors/devices connected**	-	#	Number of IoT sensors/devices from any field that are connected in the current urban platform (e.g. website)	Fundación Teléfonica	Urban platform	Viable

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ID	Indicators	Formula	Units	Description of the indicator	Source	Domain	Sustainable development dimension
1017	Number of services deployed	-	#	Number of available services in the current urban platform (e.g. website)	Fundación Teléfonica	Urban platform	Equitable
1018	Number of available Open APIs	-	#	Number of available APIs in the current urban platform (e.g. website)	Fundación Teléfonica	Urban platform	Equitable
1019	Number of cameras available *(C. I)*		#	Number of cameras available in the city for surveillance purposes.	MatchUP	ICT Extent	Equitable
1020	Number of available Open Data sources	(Total number of open data sets published/total number of data sets) x 100	#	Number of available Open Data sources in the current urban platform (e.g. website). Open means anyone can freely access, use, modify, and share for any purpose (subject, at most, to requirements that preserve	Fundación Teléfonica. U4SSC	Urban platform	Equitable

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ID	Indicators	Formula	Units	Description of the indicator	Source	Domain	Sustainable development dimension
				provenance and openness)."			
1021	Number of accesses to the urban platform APIs	-	#	Number of accesses that have been made into the APIs of the urban platforms (e.g. website)	Fundación Teléfonica	Urban platform	Equitable
1022	Business Intelligence	Does the city business intelligence applications?	YES/NO	Existence of Business Intelligence applications (Visualized Real-time or Historical Information on city assets)	MatchUP	Urban platform	Equitable
1023	Application of big data	Does the city big data applications?	YES/NO	Big Data Applications existence	MatchUP	Urban platform	Equitable

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ID	Indicators	Formula	Units	Description of the indicator	Source	Domain	Sustainable development dimension
1024	Public Service Processes	(number of public service processes documented /inhabitants) x 100,000	#	Number of public service processes documented in different departments of the public authority	MatchUP	Urban platform	Equitable
1025	Automated Public Service Processes using ICT	(number of public service processes automated /inhabitants) x 100	#	Number of public service processes automated using ICT and e-Government Services	MatchUP	Urban platform	Equitable
1026	Application of Geographic Information System (GIS)	Does the city GIS applications and ICT software infrastructure?	YES/NO	GIS applications and ICT software infrastructure (entire collection of software used to develop, test, operate, monitor, manage and/or support information technology services) existence	MatchUP	Urban platform	Equitable
1027	Cloud Solutions/Services	Number of cloud based SaaS solutions/services that the city provides	#	Number of cloud based SaaS solutions in relation to the services that the city provides	MatchUP	Urban platform	Equitable

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ID	Indicators	Formula	Units	Description of the indicator	Source	Domain	Sustainable development dimension
1028	Data Center Capacity		#	Number of servers & capacity & processing power available in city data center	MatchUP	Urban platform	Equitable
1029	Cybersecurity *(C. I)*	Likert scale Low level of cybersecurity — 1 — 2 — 3 — 4 — 5 — High level of cybersecurity	Likert scale	The level of cybersecurity of the cities' systems	CITYkeys	Urban platform	Equitable
1030	Data privacy	Does the city follow EU General Data Protection Regulation 679/2017 (GDPR).	YES/NO	The level of data protection by the city	MAtchUP	Urban platform	Equitable
1069	Number of high edu degrees related with ICT per 100,000 population	(# people with tertiary education in ICT field/total population) x 100,000	#/100 000 people	High education degrees corresponds with tertiary education and refers to all post-secondary education, including but not limited to universities	Fundación Teléfonica	ICT Extent	Equitable

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ID	Indicators	Formula	Units	Description of the indicator	Source	Domain	Sustainable development dimension
1070	Expenditure in education for promoting ICT *(C. I)*	(Educational budget dedicated to ICTs/Total educational budget) x 100	%	Percentage of educational budget dedicated to ICTs in a city	Fundación Teléfonica	ICT Extent	Equitable
1071	ICT resources in the educational centres *(C. I)*		#/100	Number of computers per 100 inhabitants in the educational centers	Fundación Teléfonica	ICT Extent	Equitable
1072	Digital literacy *(C. I)*	(Number of people reached/number of people in target group)*100%	%	Percentage of target group reached (elderly, less educated, immigrants) by activities (e.g. courses) to increase digital literacy, taking into account the 5 main competence areas: information, communication, content creation, safety and problem-solving	CITYkeys	ICT Extent	Equitable

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ID	Indicators	Formula	Units	Description of the indicator	Source	Domain	Sustainable development dimension
1073	Access to public free WiFi *(C. I)*	(sum of wifi node coverage)/total city urban surface)x100	%	This indicator measures the percentage of a city's public space which is covered by a public Wi-Fi network	CITYkeys, REPLICATE	Communication infrastructure	Equitable
1074	Access to high speed internet *(C. I)*		#/100	Fixed (wired)-broadband subscriptions per 100 inhabitants	CITYkeys	Communication infrastructure	Equitable
1075	Number of smart phone connections per 100,000 inh *(C. I)*	(Number of smart phone connections /inhabitants) x 100,000	#/100,000	Total number of smart phone connections in the city in relation to the population of the city	SmartEnCity	Communication infrastructure	Equitable
1076	Number of Internet connections per 100,000 inh *(C. I)*	(Number of internet connections /inhabitants) x 100,000	#/100,000	Total number of internet connections in the city in relation to the population of the city	SmartEnCity, REPLICATE	Communication infrastructure	Equitable

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ID	Indicators	Formula	Units	Description of the indicator	Source	Domain	Sustainable development dimension
1077	Digital service usage per citizen *(C. I)*	(Number of digital service request /inhabitants) x 100,000	#/100.000	Number of Digital Service Requests per Citizen per Year being the application of ICT for delivering e-government services, exchange of information, communication transactions, integration of various stand-alone systems and services between government-to-citizen	MatchUP	ICT Extent	Equitable
1078	e-commerce *(C. I)*	Number of e-commerce transations/100 inhabitants	Number of transaction per 100 inhabitants	E-commerce represents the number of e-commerce transactions per 100 inhabitants through electronic and mobile payment	REMOURBAN	ICT Extent	Equitable
1079	e-governance & citizens		%	% of use of digital signature by citizens in the transations	Fundación Teléfonica	ICT Extent	Equitable
1080	Number of computers/similar devices per 100 employees *(C. I)*	(# of computers - similar devices/# of employees in the public authority)*100	%	% of digitized employees in the public sector	MatchUP	ICT Extent	Equitable

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ID	Indicators	Formula	Units	Description of the indicator	Source	Domain	Sustainable development dimension
1081	e-governance existence		YES/NO	Existence of a digital procedure to municipal services (change of residence, payment of local taxes, etc)	Fundación Teléfonica	ICT Extent	Equitable
1082	e-payment	Is there any electronic and mobile payment platforms in the city?	YES/NO	Availability of electronic and mobile payment platforms	MatchUP	ICT Extent	Equitable
1083	Municipal ICT Budget	% of Municipal Budget Allocated to ICT	%	Percentage of municipal budget allocated to the ICT facilities	MatchUP	ICT Extent	Equitable
1084	Public employments in ICT	(Number of employees in ICT/total number of employees in the municipality) x 100	%	This indicator measures the proportion of employees in ICT dept, usually linked with software and computer services industries, among all employees in the municipality.	MatchUP	ICT Extent	Equitable

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ID	Indicators	Formula	Units	Description of the indicator	Source	Domain	Sustainable development dimension
1085	Tax Collection Rate throught Digital Channels *(C. I)*	Tax Collection Rate through Digital Channels	%	Percentage of tax collected through digital channels compared to conventional methods of payment	MAtchUP	ICT Extent	Equitable
1086	e-goverment		%	Percentage of public services delivered through electronic means	U4SSC	ICT Extent	Equitable
1186	Lighting smart management system	Is there an automated lighting management system in the city?	YES/NO	Existence of an automated system for public lighting in the city	SmartEnCity	Smart management systems	Viable
1187	Waste smart management system	Is there an automated waste management system in the city?	YES/NO	Existence of an automated system for the collection of waste in the city	SmartEnCity	Smart management systems	Viable

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A1.6.4. Citizens and society field

ID	Indicators	Formula	Units	Description of the indicator	Source	Domain	Sustainable development dimension
1006	Annual population change		%	Change in the number of inhabitants in the last year	REMOURBAN, SmartEnCity, REPLICATE	Demographic profile	Equitable
1007	GDP	GDP/city population	€/cap	City's gross domestic product per capita	CITYkeys, REPLICATE	Income and material living conditions	Equitable
1008	Unemploy ment rate	(# working-age city residents without work/ total labour force) x 100	%	Percentage of the labour force unemployed	CITYkeys, REPLICATE	Work	Equitable
1009	Youth unemploym ent rate	(# unemployed youth inhabitants/ total labour force) x 100	%	Percentage of youth labour (<24years) force unemployed	CITYkeys	Work	Equitable

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ID	Indicators	Formula	Units	Description of the indicator	Source	Domain	Sustainable development dimension
1010	Job creation *(C. I)*	(# new jobs created/ total labour force) x 100	%	Annual rate of contratation in all the sectors per year	Sustainable indicator paper	Work	Equitable
1031	Fuel poverty *(C. I)*	Fuel costs/income	% of households	The percentage of households unable to afford the most basic levels of energy	CITYkeys, REPLICATE	Income and material living conditions	Equitable
1032	People at risk of poverty or social exclusion (AROPE) *(C. I)*	(People living below the AROPE thresholds/total city population)x 100	% of total population	The indicator sums up the number of persons who are at risk of poverty, severely materially deprived or living in households with very low work intensity. Threshold: http://ec.europa.eu/eurostat/cache/metadata/EN/t2020_50_esmsip.htm	EU statistics on income and living conditions (EU-SILC)	Income and material living conditions	Equitable
1033	People > 75 years	(Population elder than 75 years old living in the city/Population of the city) x 100	%	Population elder than 75 years old living in the city	SmartEnCity	Income and material living conditions	Equitable

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ID	Indicators	Formula	Units	Description of the indicator	Source	Domain	Sustainable development dimension
1034	Employment rate in vulnerable groups (age)	(# unemployed elder inhabitants/ total labour force) x 100	%	Employment rate of workers aged 55-64 expressed as a percentage	MatchUP	Work	Equitable
1035	Population receiving social assistance	(Population which receive social assistance/total people with needs of social assistance) x 100	%	Percentage of workforce receiving social assistance	Sustainable indicator paper	Income and material living conditions	Equitable
1036	Dwelling price		€/m2	Average price for buying an apartment per m2 in a city	EUROSTAT	Housing	Equitable
1037	Housing cost overburden rate	(Population living with housing cost overburden/total population) x 100	%	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).	EU statistics on income and living conditions (EU-SILC)	Housing	Equitable

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ID	Indicators	Formula	Units	Description of the indicator	Source	Domain	Sustainable development dimension
1038	Housing overcrowding rate	(Population living in an overcrowded household/total population) x 100	%	Te percentage of the population living in an overcrowded household. A person is considered as living in an overcrowded household if the household does not have at its disposal a minimum number of rooms. Threshold: http://ec.europa.eu/eurostat/statistics-explained/index.php/Glossary:Overcrowding_rate	EU statistics on income and living conditions (EU-SILC)	Housing	Equitable
1041	Average population age	-	years	Average of the age of the population	SmartEnCity	Demographic profile	Equitable
1042	Population Dependency Ratio	100 x ((Population (0-14) + Population (65+)) / Population (15-64)	#/100	Number of economically dependent persons (net consumers) per 100 economically active persons (net producers)	CITYkeys, REPLICATE	Demographic profile	Equitable
1043	Number of high edu degrees per 100,000 population	(# people with tertiary education/total population) x 100,000	#/100 000 people	High education degrees corresponds with tertiary education and refers to all post-secondary education, including but not limited to universities	REPLICATE	Education	Equitable

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ID	Indicators	Formula	Units	Description of the indicator	Source	Domain	Sustainable development dimension
1044	Early school leaving	(# people who do not obtain any academic certificate/total population) x 100,000	#/100 000 people	Number of people who do not obtain any academic certificate	MatchUP	Education	Equitable
1045	Median disposable income		€/household	Median disposable annual household income	CITYkeys, REPLICATE	Income and material living conditions	Equitable
1046	Net migration	((Move-ins – move-outs)/total population) x 1000	#/1000	Rate of population change due to migration per 1000 inhabitants	CITYkeys	Plurality	Equitable
1047	Foreigners as a proportion of population	(Number of foreigners living city / total city population) x 100	#/100	Population of foreigners in relation to the city population	REMOURBAN	Plurality	Equitable
1048	Access to basic health care services	(Number of inhabitants with a health centre <500m/total	% people		CITYkeys, Municipality of Valencia	Access to public services	Equitable

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ID	Indicators	Formula	Units	Description of the indicator	Source	Domain	Sustainable development dimension
		population) x100					
1049	Access to sport facilities	(Number of inhabitants with a sport facilities <500m/total population) x100	% people		Municipality of Valencia	Access to public services	Equitable
1050	Access to libraries	(Number of inhabitants with a library <500m/total population) x100	% people		Municipality of Valencia	Access to public services	Equitable
1051	Access to educational resources	Likert scale: Not at all – 1 – 2 – 3 – 4 – 5 – very much	Likert scale	The extent to which the city provides easy access (either physically or digitally) to a wide coverage of educational resources	CITYkeys	Access to public services	Equitable
1052	Access to schools	(Number of inhabitants with a school <500m/total population) x100	% people		Municipality of Valencia	Access to public services	Equitable

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ID	Indicators	Formula	Units	Description of the indicator	Source	Domain	Sustainable development dimension
1053	Access to high schools	(Number of inhabitants with a high school <500m/total population) x100	% people		Municipality of Valencia	Access to public services	Equitable
1054	Access to kinder gardens	(Number of inhabitants with a kinder garden <500m/total population) x100	% people		MatchUP	Access to public services	Equitable
1055	Digital access to urban planning documents *(C. I)*				EXPRESSO	Civic engagement and governance	Equitable
1056	Availability of government data	Likert scale: Not at all – 1 – 2 – 3 – 4 – 5 – Excellent	Likert scale	The extent to which goverment information is published	CITYkeys	Civic engagement and governance	Equitable

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ID	Indicators	Formula	Units	Description of the indicator	Source	Domain	Sustainable development dimension
1057	Open goverment dataset	(number of open government datasets/total population) x 100.000	#/100.000	# of open government datasets per 100.000 inhabitants	CITYkeys	Civic engagement and governance	Equitable
1058	Number of municipal websites for citizens	(Number of municipal websites/population of city) x100,000	#/cap	Total number of municipal websites which belong to the municipality for sharing information of the city to the citizens (citizen participation portal, open data, transparency, etc.)	SmartEnCity	Civic engagement and governance	Equitable
1059	Number of local associations per capita	Number of community associations / Total city population x100,000	#/cap	Total number of community associations registered with the local authority related to total city population	SmartEnCity	Civic engagement and governance	Equitable
1060	Number of interactive social media initiatives	(Number of accounts in social media/population of city) x100,000	#/cap	Number of accounts in social media created by the municipality for sharing information about the city (e.g. news, cultural agenda, etc).	SmartEnCity	Civic engagement and governance	Equitable

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ID	Indicators	Formula	Units	Description of the indicator	Source	Domain	Sustainable development dimension
1061	Voter participation	(number of people who voted in last municipal elections/total population eligible to vote) x 100	%	The percentage of people that voted in the last municipal election as share of total population eligible to vote. The indicator should be reported also by sex and range of ages (<30 years, 30-50 years, >50 years)	CITYkeys	Civic engagement and governance	Equitable
1062	Women elected to city-level office	(number of women elected to city-level office/total elected) x 100	%	Women as a percentage of total elected to city-level office.	ESPRESSO, ISO 37120	Civic engagement and governance	Equitable
1063	E-mail suggestion, complains and comments	(Emails petitions/inhabitants) x 100,000	#/cap	Emails received from the main municipality contact about a political or social issue per 100000 population.	CIRCLE	Civic engagement and governance	Equitable
1064	% of citizens' participation in online decision-making		%	% of citizens' participation in online decision-making processes	ESPRESSO	Civic engagement and governance	Equitable

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ID	Indicators	Formula	Units	Description of the indicator	Source	Domain	Sustainable development dimension
	processes						
1065	Written suggestions, complains and comments	(Written petitions/inhabitants) x 100,000	#/cap	Written petitions received from the main municipality contact about a political or social issue per 100000 population.	CIRCLE	Civic engagement and governance	Equitable
1066	Open public participation	(Total amount of open public participation processes/City population) x1000	#/100.000	Open public participation: number of public participation processes per 100.000 per year	CITYKEYS	Civic engagement and governance	Equitable
1067	Citizens Registered in City Web/Services	(number of citizens registered in goverment applications/total city population) x 100	%	Percentage of citizens registered in government applications over total population in the city.	REMOURBAN	Civic engagement and governance	Equitable

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ID	Indicators	Formula	Units	Description of the indicator	Source	Domain	Sustainable development dimension
1068	Web Apps/Services Use	(Number of visits of city apps/inhabitants) x 100,000	#/cap	Number of visits of city apps for city services in a year per 100000 population.	REMOURBAN	Civic engagement and governance	Equitable
1148	In-Patient Hospital Beds	(Total number of in-patient hospital beds (public and private)/city population) x 100,000	#/100 000 people	Number of in-patient public hospital beds per 100,000 inhabitants	ISO 37120:2014, U4SSC, REMOURBAN	Health	Social
1149	Average life expectancy	Average number of years that a newborn is expected to live if current mortality rates continue to apply.	years	The mean number of years a newborn child can expect to live if subjected throughout his or her life to the current mortality conditions, the probabilities of dying at each age.	ESPRESSO, SSC, WHO	Health	Social
1150	Under age 5 mortality per 1000 live births		Deaths/ 1000 live births	The probability per 1,000 that a newborn baby will die before reaching age five, if subject to age-specific mortality rates of the specified year.	ESPRESSO, WHO, World Bank	Health	Social

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ID	Indicators	Formula	Units	Description of the indicator	Source	Domain	Sustainable development dimension
1151	Ratio of city inhabitants with electronic clinical records per 1000 patients *(C. I)*	(Number of city inhabitants with electronic health records/ Total number of city inhabitants)x100 %	%	Electronic health records (also known as e-health records) refers to a system of collecting patient health records, which are stored digitally so that they can be accessed and shared amongst all relevant health providers.	ESPRESSO, SSC	Health	Social
1152	Number of physicians per 100 000 population *(C. I)*	Number of general or specialized physicians working in the city/ One 100,000th of the city's population	Number / 100,000 inhabitants.	Number of physicians per 100 000 population. Physicians Includes generalist medical practitioners and specialist medical practitioners. The city shall report on the number of licensed physicians and report as full-time equivalence (FTE).	ESPRESSO, SSC,WHO	Health	Social
1155	Number of information contact points for citizens	(Number of contacts points/ population of city) x100,000	#/cap	Total number of contact points (physical meeting places and online systems) established in the city by the municipality to share information from the city to the citizens (tourism, events, mobility, etc)	SmartEnCity	Civic engagement and governance	Equitable

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ID	Indicators	Formula	Units	Description of the indicator	Source	Domain	Sustainable development dimension
1188	GINI index	A value of 0 represents absolute equality, a value of 100 absolute inequality.	0/100	Measure of the deviation of the distribution of income among individuals or households from a perfectly equal distribution	World Bank	Income and material living conditions	Equitable

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A1.6.5. All

ID	Indicators	Formula	Units	Description of the indicator	Source	Domain	Sustainable development dimension
1011	New startups (C.I)	(Number of new starups registered/Total Population) x 100,000 inhabitants	#/100 000 people	Number of new start-up in the last year per 100,000 population. An average of the last 5 years with available data	CITYkeys	Business in innovation	Equitable
1012	Research intensity (C.I)	(R&D expenditure/city's GDP)x 100	% in euros	R&D expenditure as percentage of city's GDP	CITYkeys	Business in innovation	Equitable
1013	Patents (C.I)	(Number of patents registered/Total Population) x 100,000 inhabitants	#/100 000 people	Total number of new patents issued to residents and organizations of the city per 100,000 inhabitants per year	REMOURBAN	Business in innovation	Equitable
1039	Expenditures by the municipality for the transition towards smart city	(Total annual expenditures by the municipality for a transition towards a Smart city/total population)	€/persons	Annual expenditures by the municipality for a transition towards a smart city	CITYkeys, REPLICATE	Local government support	Sustainable

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ID	Indicators	Formula	Units	Description of the indicator	Source	Domain	Sustainable development dimension
1092	NOx emissions		µg/m3	Annual PM10 particulate concentration and days above threshold *Threshold: Year average is 40 and max number of dayly averages above 200 is 18 days*	REMOURBAN, REPLICATE	Air quality	Bearable
1093	PM2.5 emissions		µg/m3	This indicator measures the average exposure to PM2.5 (particles that are less or equal to 2.5 µ in diameter) in the city. *Threshold*: Year average: 25 µg/m3	REMOURBAN	Air quality	Bearable
1094	PM10 emissions		µg/m3	Annual PM10 particulate concentration (particles that are less or equal to 10 µ in diameter) and days above threshold. *Threshold:* *Average annual value is 40 µg/m3 and max number of dayly averages above 50 µg/m3 is 35 days*	REMOUBAN, REPLICATE	Air quality	Bearable
1095	O_3		µg/m3	Days above alert threshold. *Alert threshold is 240 µg/m3 for more than one hour*	MatchUP	Air quality	Bearable

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ID	Indicators	Formula	Units	Description of the indicator	Source	Domain	Sustainable development dimension
1096	Air quality index	Pollution Index Value (airqualitynow.eu) Very Low: 0 / 25 Low: 25 / 50 Medium: 50 / 75 High: 75 / 100 Very High: > 100		Air quality is expressed as the concentration of major air pollutants. At this moment from a human health perspective most important are particulates (PM10, PM2,5), NO2 (as indicator of traffic related air pollution) and ozone (important for summer smog). Each country has specific indexes. European initiative to make possible the comparison among cities (http://www.airqualitynow.eu/index.php): roadside index, background index and city index.	MAtchUP	Air quality	Bearable
1114	GHG emissions per capita	GHG emissions (city)/inhabitants	Tonnes of CO2/ inhabitant	The CO2 emissions generated over a calendar year by all activities including indirect emissions outside city boundaries	CITYkeys, SEAP, SCIS, REMOURBAN, REPLICATE	Air quality	Bearable
1121	Urban Heat Island		°C UHImax	Maximum difference in air temperature within the city compared to the countryside during the summer months	CITYkeys	Air quality	Bearable
1134	Overall CO2 emission reduction target	-	%	The objective of reduction of CO2 in the cities according to its SEAP makinng reference the baseline year and the quantity of CO2 emissions this year	SEAP	Local government support	Sustainable

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ID	Indicators	Formula	Units	Description of the indicator	Source	Domain	Sustainable development dimension
1135	Existence of an Agenda 21	Has the city elaborated an Agenda 21?	YES/NO	Existence of an Agenda 21 in the city which guides the city towards the sustainability	REPLICATE	Local government support	Sustainable
1136	Existence of local sustainability plans	Is there any specific sustainability plan in the city?	YES/NO	Existence of an urban strategic planning in the city focused to achieve a sustainable city	SmartEnCity, REPLICATE	Local government support	Sustainable
1137	Signature and compliance of the Covenant of Mayors	Has the city signed the Covenant of Mayors. And Is the city complying with it? (both questions need to be aswered)	YES/NO	Commitment of the municipality with the European Comission to reduce CO2 emissions through the signature of the Covenant of Mayors as well as the posterior fulfillment of the target agreed	REPLICATE	Local government support	Sustainable
1138	Existence of Smart Cities strategies	Is there any specific Smart City strategy in the city?	YES/NO	Inclusion of smart cities strategies in the urban strategic plans of the city	REPLICATE	Local government support	Sustainable
1139	Smart city policy	Likert scale: Not at all – 1 — 2 — 3 — 4 — 5 — Very supportive	Likert scale	The extent to which the city has a supportive smart city policy	CITYkeys	Local government support	Sustainable

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ID	Indicators	Formula	Units	Description of the indicator	Source	Domain	Sustainable development dimension
1140	Level of correspondence with national regulation	Is there any discrepancy between the energy performance requirements to be met by buildings of the city analyzed with respect to the national regulation?	YES/NO	Existence of discrepancy in energy-related requirements in building codes of the city analysed with respect to the requirements to be met at national level	SmartEnCity	Local government support	Sustainable
1145	Cross-departmental integration	Likert scale: Only one department involved – 1 – 2 – 3 – 4 – 5 – All departments are actively involved	Likert scale	The extent to which administrative departments contribute to “smart city” initiatives and management	CITYkeys	Gobernance collaboration	Sustainable
1146	Multilevel government	Likert scale: Not at all – 1 – 2 – 3 – 4 – 5 - Very much	Likert scale	The extent to which the city cooperates with other authorities from different levels	CITYkeys	Gobernance collaboration	Sustainable
1147	Climate resilience strategy	Likert scale: No action taken – 1 — 2 — 3 — 4 — 5 — 6 – 7 – implementation, monitoring and	Likert scale	The extent to which the city has developed and implemented a climate resilient strategy	CITYkeys, REPLICATE	Local government support	Sustainable

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ID	Indicators	Formula	Units	Description of the indicator	Source	Domain	Sustainable development dimension
		evaluation on the way					
1040	Incentives for final users for low carbon measures	Total amount of euros financed annually to private sector for energy efficiency within the municipal boundaries/population number	€/persons	Total amount of euros promoted by the municipality to finance private low carbon actions (RES, energy efficiency, mobility)	REPLICATE	Local government support	Sustainable

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A1.6.6. City Characterization

ID	Indicators	Formula	Units	Description of the indicator	Source	Domain
1001	Climate koppen geiger classification	-	-	The Köppen climate classification scheme divides climates into five main groups (A, B, C, D, E) and subtypes. Each particular climate type is represented by a two- to four-letter symbol. http://koeppen-geiger.vu-wien.ac.at/pdf/kottek_et_al_2006_A4.pdf	REPLICATE	Climate
1002	Size	-	km2	Land area of the city	REMOURBAN, SmartEnCity	Size
1003	Type of city	-	-	Typology of the city under study: metropolitan, urban, suburban - Metropolitan areas are urban areas with more than 500,000 inhabitants - Urban area is a functional economic unit characterised by densely inhabited 'cities' with more than 50,000 inhabitants and 'commuting zones' whose labour market is highly integrated with nearby cities - Suburban areas correspond with a residential district located on the outskirts of a city and with a population less than 50,000 inhabitants	SmartEnCity	Type of city
1004	Population	-	Inh	Total number of persons inhabiting a city at a given time	REPLICATE, REMOURBAN, SmartEnCity	Population

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ID	Indicators	Formula	Units	Description of the indicator	Source	Domain
1005	Population density	Population of the city/ Land area of the city	Inh./km2	Population per unit area in the city	CITYkeys, SmartEnCity, REPLICATE	Population

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