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SMART CITY PERFORMANCE MEASUREMENT SYSTEMS:
A NOVEL FRAMEWORK FOR ENERGY-RELATED PERFORMANCE

Master Dissertation of:

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Declaration

This dissertation is the result of the authors' own work and includes nothing which is the outcome of work done by others except as specified in the text.

The authors further state that no substantial part of their dissertation has already been submitted, or, is being concurrently submitted for any such degree, diploma or other qualification at Politecnico di Milano or any other University or similar institution.

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Sono giunto alla fine di un lungo percorso universitario iniziato 5 anni fa, durante il quale si sono susseguite innumerevoli sfide e ho potuto crescere come studente e come persona. Non sono mancati attimi di difficoltà o alcune piccole delusioni, ma i ricordi sono pieni soprattutto di momenti felici e di soddisfazioni personali e di gruppo, assieme alle tantissime persone che ho potuto conoscere e con le quali ho condiviso questi anni.

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Let today be a new beginning.

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Acronym	**Full name**
ACM	Association for Computing Machinery
AHP	Analytic Hierarchy Process
BCA	Building and Construction Authority
BEMS	Building energy management systems
BEV	Battery Electric vehicle
BOMA	Building Owners and Managers Association
BREEAM	Building Research Establishment Environmental Assessment Method
CASBEE	Comprehensive Assessment System for Built Environment Efficiency
CESBA MED	Common European Sustainable Built Environment Assessment Mediterranean Area
CEUR	Central Europe
CH_4	Methane
CO	Carbon Oxide
CO_2	Carbon Dioxide
DE	Domestic Extraction
DGNB	German Sustainable Building Council
DMC	Domestic Material Consumption
DMI	Direct Material Input
DMP	Data Management Platforms
DSO	Distributor System Operators
EDEN	Energy Data Engagement
ESS	Energy Storage System
ESCI	Emerging and Sustainable Cities Initiatives
ESCo	Energy Service Company
EU	European Union
EV	Electric vehicle
FCEV	Fuel-Cell electric vehicle
GDP	Gross Domestic Product
GHG	Greenhouse gas
GIEC	Gross inland energy consumption

GIS	Geographical Information Systems
GSE	Gestore dei Servizi Energetici
HEV	Hybrid electric vehicle
HFCs	Hydrofluorocarbons
ICT	Information & Communication Technologies
IDB	Inter-American Development Bank
IFIP	International Federation for Information Processing
IOP	Institute of Physics
IoT	Internet of Things
ISO	International Organization for Standardization
ISTAT	Istituto Nazionale di Statistica
KPIs	Key Performance Indicators
LEED	Leadership in Energy and Environmental Design
LED	Light Emitting Diode
NO_2	Nitrogen dioxide
N_2O	Nitrous oxide
PCA	Principal Component Analysis
PFCs	Perfluorocarbons
PEC	Certified Electronic Mail
PHEV	Plug-in hybrid electric vehicle
PM	Particulate Matter
POCACITO	Pot-Carbon Cities of Tomorrow
POD	Point of Delivery
PPP	Power purchasing parity
REPLICATE	Renaissance of Places with Innovative Citizenship and Technology
RES	Renewable Energy Source
SETIS	Strategic Energy Technologies Information System
SF_6	Sulfur hexafluoride
SO_2	Sulfur dioxide
STEEP	System Thinking for Comprehensive City Efficient Energy Planning
SRS	Stockholm Royal Seaport
ST DEV	Standard Deviation
TSO	Transmission System Operators
UHI	Urban heat island

UN	United Nations
UK	United Kingdom
US$	United States Dollars
U4SSC	United for Smart Sustainable Cities
VEP	Voting Eligible Population
W2E	Waste to Energy
WHO	World Health Organization
ZEN	Zero Emission Neighborhood

ABSTRACT

Nowadays researchers agree that the first urban civilization labeled a “city” was Sumer in c. 4500 BC. However, the meaning of the word has evolved over the years with the advancement of technology, and to reflect this evolution, adjectives such as digital, intelligent and smart have been prefixed to “city”. Today, population growth, rapid urbanization and climate change are triggering the need of smart city solutions and services. In 2050 global population is projected to reach approximately 9.8 billion people, and the 68% of us is expected to live in cities, compared to the today 56%. This will boost the number of people living in urban areas by 2.5 billion, meaning that we will have to build a new ‘Milan’ per week for the next thirty years. The incredible concentration of people, communities, activities, flows and impacts lead to sever challenges for cities. That is why the quite novel “smart city” topic is gaining more and more attention, becoming high on the agenda of many cities worldwide. In both planning and implementing smart city solutions, performance measurement is one key component. Nevertheless, and although they would like to do so, cities have not widely adopted or implemented such performance measurement systems yet. The aim of this work is to become a “facilitator” in this direction, providing City Authorities with an effective framework of key performance indicators (KPIs) focused on monitoring the evolution of a city towards an even smarter city. In doing this, the authors focus on energy-related performances of the city, addressing the so-called “energy pillars”. First, an initial theoretical framework is proposed, which is built according to the results obtained from literature. Successively, it is tested in order to validate its peculiarities and identify potentials for further development. Thus, a final performance measurement framework is presented, ready to be applied to real case scenarios.

1 INTRODUCTION

The first chapter introduces the work, and it has two main objectives. First the concept of Smart City is introduced and described. It is important to properly define what is a Smart City, its pillars and the different typologies of Smart Cities in order to portray this incredibly vast concept and provide a broad understanding of the phenomenon. The second goal is to assess the necessity of proposing a consistent Monitoring Framework for measuring the performance levels of a Smart City. This can be done defining appropriate Key Performance Indicators (KPIs). Today there is not a worldwide adopted framework of KPIs for Smart Cities and this existing issue constitutes the object of research. Therefore chapter 1 is essential as (i) it introduces the work, providing the key concepts at the basis of the analysis and (ii) it lays the foundations for the research questions and objects that are developed in the following chapters.

The chapter begins with a description of the main trends that in recent years are transforming the society and the city. In this context the term Smart City emerges, and different definitions are provided and discussed. It is also reported the definition of Smart City according to the authors of the thesis, with a description of the main characterized elements.

Then the Six Pillars that compose a Smart City are defined and explained. For each of them, the constituting elements are described, and the main challenges of today are discussed. Even though the scope of research is initially the Smart City in a comprehensive way, the research will be mainly focused just on pillars Smart Environment, Smart Living and Smart Mobility.

Furthermore, the different Smart City typologies are described, according to the way it is built, with related strengths and weaknesses. In particular there can be greenfield Smart Cities, built from scratch, or brownfield Smart Cities, which are existing cities implementing smart projects.

After that, the chapter introduces the need of defining a robust performance measurement system for Smart Cities, through accurate Key Performance Indicators, and the main current challenges for smart cities.

Finally, the two last sections present the research questions and objectives of this work and the research methodology and thesis outline.

1.1 Smart city definitions and concepts

The worldwide population increase has led to a continuous transformation in the society and the lifestyle of habitants, mainly in **cities and urban areas**. Nowadays it is assessed that the resources of the planet are too limited to stand the actual demand and habits of final consumers. It is time for cities to shift towards more eco-efficient and sustainable models, in order to preserve actual natural and human ecosystems. (UN-Habitat 2016).

A relevant trend that is undoubtedly transforming the society is **digitalization**. Nowadays the outstanding development of digital technologies permits a higher data and information availability, which brings to a more efficient consumption and utilization of resources. Thanks to data analysis, IoT technologies and ICT tools, cities have the possibility to measure and control every service they provide to its dwellers and find new solutions and targets (Ibrahim et al. 2015).

Digitalization can be seen as an enabler of many sustainable and smart configurations that are emerging today: with digital technologies it is possible to adopt the prosumer-consumer configuration, in which different final energy users are connected one with the other in smart grids, micro grids or energy communities. This trend, also called **distributed energy generation**, is based on a bidirectional flow of energy between the final user and the grid, enabling cities to become more independent from the grid (Arup 2016).

Digital technologies facilitate also **electrification**, because high-tech devices and smart meters permit efficient electricity utilization even with several loads connected simultaneously (lighting systems, air conditioning and refrigeration, E-vehicles charging station, etc.), increasing the level of performance and comfort inside a city (World Economic Forum 2017).

All these new trends which combine the exploitation of Information and Communication Technologies with the idea of creating a sustainable eco-system and increase urban quality of life, are included in the concept of **Smart City**. More precisely, a City is Smart when it uses digital technologies to implement systems and solutions that are efficient and sustainable in the long run, helping to face existing economic, environmental and social priorities and increasing citizens' quality of life (Hameed 2019).

The term Smart related to a city first appeared in the early 1990s, in relation to the concept of Digital City, when Internet adoption raised in everyday life (Dameri et al. 2013). The literature regarding this topic starts to increase in the firsts 2000, together with the growing attention to sustainability projects and actions made at national or international scale, for example by the European Union. The number of publications has exponentially grown since 2010, when all the issues related resource scarcity and the population growth started to be clear and it was time to cope with them (Dameri et al. 2013). During the years different **definitions** of Smart Cities has been adopted. Of course, Smart City is not a mathematical concept and therefore there is not a definition that can be considered as the most appropriate in absolute terms. Moreover, it also depends according to the perspective considered: cities are a complex system, in which several actors interact in different places and with different needs. Then, the definition of Smart City has to be the most comprehensive one, covering as many different aspects as possible. Some of the most meaningful ones are reported below.

Caragliu et al. 2011	"A city to be smart when investments in human and social capital and traditional (transport) and modern (ICT) communication infrastructure fuel sustainable economic growth and a high quality of life, with a wise management of natural resources, through participatory governance"
SETIS 2009	"Smart City is a city in which it can combine technologies as diverse as water recycling, advanced energy grids and mobile communications in order to reduce environmental impact and to offer its citizens better lives"
Bakıcı et al. 2013	"Smart city as a high-tech intensive and advanced city that connects people, information and city elements using new technologies in order to create a sustainable, greener city, competitive and innovative commerce, and an increased life quality."
Chen 2010	"Smart cities will take advantage of communications and sensor capabilities sewn into the cities' infrastructures to optimize electrical, transportation, and other logistical operations supporting daily life, thereby improving the quality of life for everyone."
Zygiaris 2013	"A smart city is understood as a certain intellectual ability that addresses several innovative socio-technical and socio-economic aspects of growth. These aspects lead to smart city conceptions as green, intelligent, interconnected, innovative and knowledge cities."

Table 1 – Smart City definitions

To mention few explanations of the smart city definition, according to the first definition provided by Caragliu et al. (2011), it is clear that, in order to be smart, cities need the effort of the governance in charge, that has to drive a sustainable and efficient solutions and increase of quality of life, through the right actions and investments. Of course, in order to guarantee better social conditions and the economic growth, also private citizens play a key role. This is why education and awareness of the actual smart plans and strategies have to be properly diffused, together with the right attitude and active involvement of each individual (Griggs et al. 2013).

In the definition provided by the European Commission (SETIS 2009), there is more reference to the environmental aspects related to a city. Concepts such as circular economy, energy efficiency and resource optimization are cardinal in the Smart City idea. The attention for environment is clear since the problem of resources depletion and scarcity has risen in the recent years, and digital technologies can provide a wiser exploitation of each source. This will inevitably improve the life quality of citizens, certifying the link between environmental and social spheres (Lehni 2000).

In the majority of the definitions reported, there is an indirect link with the six pillars of the Smart City: Smart Environment, Smart Mobility, Smart Living, Smart Economy, Smart People and Smart Governance (Zubizarreta et al. 2016). Their meaning, goals and challenges are explained more in detail in chapter 1.3.

Among the several existing definitions it is reported the following, that tries to summarize the key elements constituting the smart city paradigm and is provided by the authors of the work.

"The Smart City consists in a city which aims to face public and territorial problematics, through the utilization of solutions based on the adoption of ICT and digital technologies, involving a multiplicity of different stakeholders, through partnerships with the municipal bodies".

Public themes can be summarized and represented by the **6 pillars.**

Technologies as **qualifying factors** to answer the smartness needs of the city

The multiplicity of stakeholders requires a **centralized coordination**

Smart City projects require the interaction and **participation of different stakeholders**

According to this definition, there are 4 main elements that constitute Smart Cities and that are highlighted with colours: Smart City Pillars, digital technologies, centralized coordination and participation among stakeholders. First of all, the Smart City approach is multidisciplinary and based on its 6 pillars: Smart Environment, Smart Mobility, Smart Living, Smart Economy, Smart People and Smart Governance. As previously said, they are explained in detail in section 1.3.

In order to enable the evolution of a City, the second relevant factor is the exploitation of digital technologies as a key success factor, since they are powerful tools that provide innovative and efficient solutions to overcome cities priorities and challenges.

The third element is centralized coordination: Smart City projects are complex as there is a large multiplicity and variety of actors involved, that are public authorities, local governments, private companies and single citizens. Therefore, centralized coordination is necessary: it is crucial to develop a robust and long-term plan that is comprehensive of all the Smart City pillars (Caragliu et al. 2011).

The cooperation and participation of the different stakeholders is the 4th element of Smart Cities and has to be guaranteed, since projects can have different sources and commitments but cannot be in trade off one with the other. For this reason, central coordination has to drive each project in a way that contributes to increase the City Smartness in its comprehensive view, without being in contrast with another project. In addition, Smart City development has to be punctually measured and evaluated with properly designed **Key Performance Indicators (KPIs)** (Caird et al. 2019).

1.2 Smart City Pillars

Smart City concept includes several different spheres, of which some are directly related to energy sources optimization and the environmental aspects, while others are more related to social and economic issues. According to the European Smart City Classification Standard (Giffinger et al. 2007), the smart City concept is made by **6 main Pillars**, which cover all the aspects related to a city. These dimensions are Smart Environment, Smart Mobility, Smart Living, Smart People, Smart Economy and Smart Governance, and they are explained in detail below (Zubizarreta 2016).

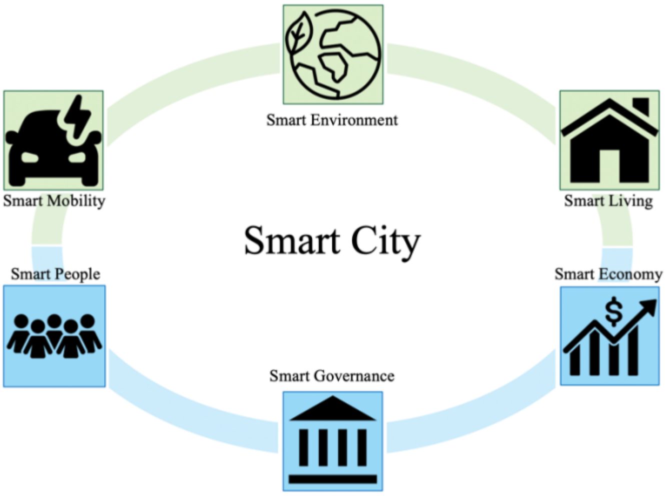

Figure 1 – Smart City Pillars

Smart Environment: it is the growing attention to environmental sustainability of the city, through an efficient resource utilization and management system and acting against climate change, pollution, resource depletion. Practises such as clean energy consumption and material reuse and recycling are key factors in Smart Environment, together with the use of sensors, devices and smart applications that drive a wise and more optimal consumption of energy, water, soil and all other natural resources. Challenges related to Smart Environment are a more optimal exploitation of the city areas, in order to facilitate the rapid city growth, together with a more efficient use of resources, in line with their availability and scarcity in the long run (Hameed et al. 2019).

Smart Mobility: this pillar is focused on the promotion of sustainable transportation business models, that mainly concern electric or low emission vehicles, both private and public, autonomous driving, shared mobility, pedestrian and cycling routes. All of these solutions contribute to decrease pollution and emissions and raise local and international accessibility of the city in a sustainable and safe manner. A city is Smart in Mobility when it offers an efficient public transportation system, in line with actual citizens demand during peak hours, and smart ways for dwellers to have access to public and private transportation services, arising citizens quality of life and city attractiveness. Challenges connected to Smart Mobility are the diffusion of the propter infrastructure, such as charging stations for electric vehicles, the abundancy of sharing vehicles to cover the daily demand, the availability of pedestrian and cycling paths, the implementation of a road network that minimizes congestion, traffic and incidents and that facilitates the City growth (Zyryanov 2019; Pinna et al. 2017).

Smart Living: it is the adoption of smart and efficient solutions for public lighting around the city, the so-called Smart Lighting, and efficient heating and refrigeration systems for public and private buildings, namely Smart Building. The Smart Living concept is strictly linked with digital technologies since ICT solutions are enabler of the newest housing and industrial applications to limit and optimize energy consumption, thanks to smart meters and devices. Challenges connected to Smart Living for cities are the ability of improving the energetic class of a district without compromising its historical and/or artistical heritage, the equal distribution of wealthy among the different city areas, the fight against criminality (Baralas et al. 2019; Ambrogi et al. 2016).

Smart People: the key aspects of this dimension are the level of education and qualification of the citizens, the social, cultural and ethnic plurality, the open-mindedness and participation in public life and events. It is clear that the Population is the subject of the city and its effort and contribution is necessary in the development of a smarter city. Pro-active and qualified citizens facilitate the creation and success of new businesses, enhancing urban development, city attractiveness and equal distribution of wealthy among the different city areas. Aspects such as citizens health and security have to guaranteed and this is a big challenge for Smart Cities, together with society development, the creation of cultural identity, the availability and access to the newest technologies and the employment rate, often critical especially for young people (Allam et al. 2018).

Smart Economy: this pillar includes innovative spirit, entrepreneurship, productivity, labour market, economic wellness and growth. The development of a city that facilitates business progress and economic prosperity is at the basis of the application of the other pillars of a smart city. Budgets and investments of a City have to be addressed to innovative and sustainable business, finding profitable solutions in the long term. Digital technologies enable the implementation of new activities, indeed there is a wide space for start-ups and innovative businesses that can be a relevant source of progress and have to be sustained with the right funds and financial structure. Another challenge of Smart

Economy is the access of dwellers to infrastructures, services and technologies, that contribute to grow quality of life and attractiveness of the area (Zubizarreta 2016).

Smart Governance: local government strategies and actions affect the smartness of a city. In order to positively contribute to its development, social services and public participation have to be guaranteed and facilitated. Smart Governance is when there is a relevant presence of institutions and therefore various stakeholders are involved in decision making cycles and in the application of public services, facilitating connection between governments and citizens. Since there is a huge variety and amount of stakeholders involved in Smart City projects, a central coordination is essential in order to properly drive the different actions and efforts towards a unique effective solution. Institutions should also guarantee stability and longevity in their governance strategies, enabling profitable plans in the long run. The concept of e-governance, dealing with the use of ICT, is necessary to lead smart city plans to citizens, and to keep transparency in the decision and implementation process (Albino et al. 2015).

Among these six Pillars, Smart Environment, Smart Mobility and Smart Living are identified as "**energy pillars"**, since they are directly related with the process of "energy digitalization" in Smart Cities (Energy & Strategy Group 2019). "Digital energy" means the possibility of using digital technologies to control energy flows. In these pillars it is possible to implement digital and sustainable solutions such as Blockchain, IoT or Big Data and Analytics with the aim to optimize energy and resources, and to enable the current energy trends of distributed energy generation and electrification previously described (World Economic Forum 2017).

Instead, Smart People, Smart Economy and Smart Governance are considered as "non-energy pillars", since they are mainly connected with social and economic spheres. In the work the term "energy pillars" always refers to Smart Environment, Smart Mobility and Smart living while "non-energy pillars" refer to the other pillars.

Among all them, the work is more focused on the energy pillars, for which a deep analysis is developed. However, in order to have a comprehensive view of the Smart City concept, all its constituting elements are taken into consideration.

Of Course, there are often interconnections among these pillars, since there are aspects and concepts such as circular economy, or emissions coming from transportation, that are consequence of two or three pillars at the same time. This is because it is not a mathematical theory, but more an empirical vision that is quite common among experts and that the authors of the study adopt. However, there also have been found and analysed works and projects with different views, dividing the smart city concept in different categories, of which the most common are Energy, Society, Infrastructure and ICT. The authors decide to use the Six Pillars categorization because it is the most used and comprehensive view.

Interconnections between the 6 pillars can also make some actions unfeasible, because some interventions that would improve one dimension can negatively affect one other. As an example, a solution with large economic profit but also large environmental problems could not be considered a smart application (Zubizarreta et al. 2016). For this reason, it is always very important to adopt a comprehensive view in order to reach the highest level of smartness for a city.

1.3 Smart Cities typologies

Smart cities can be classified into two different typologies according to the way they are built:

- **Greenfield**: it is a completely new city created from scratch and characterized by a high level of smartness, i.e., a high utilization degree of digital solutions.
  Examples are the cities of Masdar (United Arab Emirates) and Songdo (South Korea). The former was built with a mix of public transportation and pedestrian/cycle areas that overcome the need of private cars, which will be deposited in park-and-ride outside the city. The latter, started in 2013 and expected to be finished in 2020, made great investments in electric vehicles, low carbon growth with export-oriented manufacturing and implemented an efficient waste management system that minimizes the need of human intervention (Han et al. 2018).

- **Brownfield**: it is built by the modification and transformation of existing cities through smart interventions with the aim of improving the life quality of citizens.
  Examples are the Boston Innovation District (Boston, United States of America), Lyon Smart Community (France) and Stockholm Royal Seaport (Sweden). The first succeeded in transforming the urban waterfront with opportunities for investments in collaborative technologies, sustainable growth and a shared economy. The second represents an example of efficient energy management by using solar power generation and introduction of smart

energy devices for energy visualizations. Finally, in Stockholm were implemented several projects to reduce carbon dioxide emissions and mitigate with future climate change strategies (Adapa 2018).

Different challenges are related to the two different typologies of Smart City. For sure, the greenfield alternative requires a higher organizational structure, as it is based on the idea of developing the city from zero. The focus on innovative planning through smart solution and digitalization requires large investments in information and communication technologies (ICT) for the development of new constructions (Hayat, P. 2016). Moreover, time required to design and implement the greenfield solution is often higher. Investments needed for this type of solution are so high that often make this alternative unfeasible, especially at large scale levels (Ibrahim et al 2015). This is why nowadays there are just few dislocated projects. However, ideally, greenfield cities represent a great opportunity to meticulously plan the city incorporating all desired attributes in an efficient manner.

On the other hand, brownfield alternatives often present issues in the coordination among projects, as they require meticulous retrofitting and reinforcement of the existing areas (Adapa 2018). Actually, the implementation of a brownfield solution has to harmonically fit with the city history and development. In addition, some brownfield projects are commissioned by private entities and citizens, that may do not consider the other interventions made in the same city. Therefore, a central coordination is fundamental, in order to guarantee synergies among interventions and reach a higher level of smartness at the whole city level. As positive attribute, brownfield projects usually imply lower investments compared to the greenfield ones.

1.4 Smart City Performance Measurement System

In order to speed up the wide scale deployment of smart city solutions, it is fundamental to facilitate and enable stakeholders in creating trust in solutions, learning from each other and monitoring progresses. In both planning and implementing smart city solutions, performance measurement is one key component. Thus, a set of standardized indicators is necessary to provide a uniform approach to what is measured and how that measurement needs to be undertaken.

The purpose of building a **Key Performance Indicators (KPIs) framework** is to keep continuous track of interventions to answer questions on city progress, to understand whether the intended results has been achieved or something could have been done differently and to undertake countermeasures if necessary. This enables the overall results assessment and a successful communication of results. In particular, smart city indicators should have two primary target groups. The first group refers to decision makers in city council, who need to assess the impact of their smart city strategy over time, to understand if and how the city has become smarter and what has been the target outcome. The second group refers to national governments and other bodies (e.g., European ones), that verify whether their smart city policies reached specific goals and tend to use indicators to compare cities (Bosch et al. 2017).

Nevertheless, and although they would like to do so, cities have not widely adopted or implemented such performance measurement systems yet. In this introductive chapter there is a general explanation of the main challenges that smart cities have to face.

1.4.1 Challenges in monitoring Smart Cities

The great challenge for smart cities in monitoring their performances is represented by data and ICT platforms to be managed. Today there is a big opportunity to collect and report precise data thanks to the huge amount of information available from different networks around cities. However, the huge amount of data to be handled in order to implement the indicators implies the need of relevant digital strategies to be implemented in measurement and monitoring systems.

In particular, the collection and utilization of data coming from cities' sources is not a linear and easy activity. Indeed, it presents many criticalities:

- **Information management**: the first problem regards the actors responsible for the different gathering and analysis phases. In fact, they must be organized as a unique entity, or, if more than one, they must be coordinated.
- **Interoperability**: several issues are related to the data interoperability, namely the possibility to realize simplified and standardized processes and an efficient data fruition.
- **Heterogeneity of data**: collected data are often heterogenous. This causes a reduction in the speed of analysis and a lower usability at community level, subsequently requiring additional steps for data cleaning. Thus, it's fundamental to standardize the processes of data provision and guarantee continuity in their collection and recording.

- **Speed**: the capability to analyze and extract values from data rapidly represents a problem, especially in case of real time services.
- **Privacy**: one of the most discussed themes at city level. The ability to guarantee privacy and security of data concerning the applications dedicated to the city is certainly a priority.
- **Accessibility**: in order to extract values from data, it is not sufficient to just collect them, but they must be made available to providers who are responsible to offer services and information to the final user. If cities don’t share gathered data, the only entity with the possibility to develop services, provided that there are resources and capabilities to do that, remains the municipality.
- **Open data**: in order to provide services to citizens and firms, it is favorable that information and collected data are accessible and available to all data users. For instance, data on energy consumption of final users (at the POD) might be made available to firms, in particular to ESCo, which offer energy efficiency services to citizens, firms and public administration (Energy & Strategy Group 2019).

The fact that the urban ecosystem can be monitored in all its aspects opens the city to a broad range of opportunities, but also to new criticalities in terms of information access and utilization, for both aggregated and singular procedures. Thus, the platform management within a city introduce some issues to be considered:

- **Integration among data sources**: before starting to manage data, it is necessary to set up the interconnection among sources. The final objective is to maintain a constant transmission of data from different sources. To do that, it is mandatory that all sources satisfied system requirements and were compatible with each other.
- **Data governance**: administration of data and planning of smart cities’ development activities. Collecting systems of data return information, but cities are still unable to deal with governance and analysis since the shocking amount of data generated by IoT devices.
- **Platform scalability**: the higher the possibility of scaling and resizing, the better the platforms for data analysis in terms of operative functioning. One of the most effective solutions for DMP scalability is to use a cloud storage.
- **Data storage**: data must be stored in a secure way. The most feasible solution is the preservation of data in the cloud storage.
- **Cybersecurity of data**: it fundamental to guarantee the security of data and analysis carried out inside the platforms to avoid the possibility to compromise the reliability of data, quantifiable in losses of several millions.

- **Platforms interoperability**: in case the city had adapted more platforms to manage different problems, it usually faces issues related to the interoperability, namely the capacity of two or more networks, systems, devices, applications or components to exchange information, according to arranged request-response sequences, sharing their meaning, and to use them in a simple, safe and effective way, minimizing the inconveniences for the user (Energy & Strategy Group 2019).

Clearly, in addition to the common issues regarding data management, the smart city challenges are related to the different specific aspects of the city. There are areas in which cities mostly need indicators to measure their performances. For example, those generally include: energy, greenhouse gas emissions, transportation, digital infrastructure and e-services, resource management, citizens' participation, competitiveness, economy, environment, quality of life and research and knowledge creation (Bosch et al. 2017). Let's finally and briefly discuss few of them and provide the reader a first introduction into the issues related to the smart city areas. One very discussed specific aspect of the city and is the transportation systems and logistics. It usually concerns the transition to meet the targets set by the European Union strategy of reducing greenhouse gas emissions (European Commission 2011). The construction of propter mobility KPIs is fundamental to enable the shift towards a sustainable transport system, especially for the implementation of effective policies for low-emission vehicles, shared mobility and cycling and pedestrian paths. Then, a recurrent challenge in developing countries is the development of a sustainable road management system that can be measured and monitored (Giret et al. 2018, Zyrianov 2019, Kamil et al. 2014). Moreover, city waste is often a critical topic to address. In many countries, municipal waste management systems and urban waste heat recovery systems are still very poor. Thus, adequate selected indicators are powerful tools for the efficacy of investments in alternative solutions to meeting sustainable development goals and highlight the emergency and the need of intervention for a more sustainable environment and society (Da Silva et al. 2019, Andrés et al. 2018).

1.5 Research Question and Objectives

As mentioned before, despite the significant efforts, and although they would like to do so, cities have not widely adopted or implemented such effective performance measurement systems yet. The whole work represents the attempt to construct a performance measurement system that supports the speeding up of wide-scale deployment of smart city solutions and services in order to create impact on major societal challenges around the climate strategies and targets and the continuous growth and densification of cities. Therefore, this work aims to create a continuous improvement process through which cities are facilitated in learn from each other, create trust in solutions, and monitor progress, by means of a common integrated performance measurement framework. In doing this, the authors will focus on the major challenge of energy digitalization, and subsequently on the so-called energy pillars, which are usually identified in literature as Smart Environment, Smart Living and Smart Mobility. Thus, the research question has been defined as follow:

How should a performance measurement framework be built to monitor the evolution of a city towards an even smarter city and address existing challenges?

Thus, the aim of this work is to become a “facilitator” in this direction, providing City Authorities with an effective framework of key performance indicators (KPIs) focused on monitoring the evolution of a city towards an even smarter city. In the next and final section of this chapter, the authors describe the research methodology and the thesis outline in order to provide an initial overview of the whole work.

1.6 Research Methodology & Thesis Outline

After this section, which describes Smart City concepts and research objectives, the second chapter introduces the literature review. It displays the frameworks analyzed, delineating the reasons for their investigations, the different methodologies for key performance indicators classification and the main gaps of literature that hamper the diffusion and applicability of the existing frameworks at global scale.

The third chapter shows the research questions of the work, which derive from the literature gaps identified in the previous chapter, and the theoretical framework proposed by the authors. The research question has the objective of investigating on one or more gaps found from the literature. Subsequently, the authors present their conceptual framework for measuring and monitoring the energy pillars of Smart Cities, based on the literature review, with the definition of the subcategories that compose each energy pillar.

Once defined, the proposed theoretical framework is tested in chapter 4 across a broad group of empirical contributions that analyze specific energy aspects of a smart city. In this way it is possible to assess the validity of the proposed theoretical framework, identifying possible changes and integrations in case additional Smart City aspects emerge from the empirical contributions.

After this integration with the empirical contributions, in chapter 5 a new comprehensive framework for measuring and monitoring energy pillars of Smart City is then built, with a reclassification of the subcategories included in each energy pillar and the punctual definition of the Key Performance Indicators, which are described in detail.

In chapter 6 the work furtherly includes the reporting of a survey developed by the authors of the work and addressed to the Italian cities, with the aim of assessing the relevance of the gaps identified from the literature: the survey investigates on the current main issues that emerge in the Italian context during the application of Smart City monitoring frameworks.

Finally, chapter 7 presents the findings and the overall results of the work, its theoretical and practical implications, its limits and the avenues of future research and analysis.

2 LITERATURE REVIEW

The second chapter is fully dedicated to the review of the extant literature. The aim of such an in-depth literature review is twofold. First it aims at identifying and analyzing the different frameworks and sets of key performance indicators found in literature in order to provide the reader with a thorough understanding of the theme, critically exploring its lights and shadows, without slipping into the trap of a misguided enthusiasm or an unfair criticism towards the existing frameworks. Second, by such a meticulous and broad review, the authors are able to properly locate the research problems, particularly highlighting the main problematics of the existing smart cities performance measurement systems that the authors aim to bridge.

Therefore, chapter 2 is a key component for the overall work as it (i) substantiates the existence and the importance of the limits raised by the authors and (ii) it serves as a fundamental examination of the theme to better specify the research focus and boundaries.

This chapter begins showing the sources of this step of the project and the procedure for searching them. After a deepened and targeted research, a large and diverse set of documents has been selected in order to have a perspective which was as broad as possible. This set, which forms the basis for the authors' first examination, is composed by some sources addressing more and different aspects of a smart city and some others focusing on specific ones.

Next, the chapter presents a deep analysis of the contributions, aimed at gathering all the information related to the frameworks and indicators examined. Particular attention was paid to the topics and themes observed going through smart city concepts and the features and specifics characterizing the indicators. The whole analysis was based on 37 contributions, presenting approximately 1292 KPIs.

Finally, the limits of these projects are explored in order to capture the main problematics of the existing smart cities performance measurement systems. This step was essential in order to understand what are the gaps that need to be bridged in order to improve the existing models. This lays the foundation for defining the objectives of the overall work.

2.1 Literature Contributions

The literature contributions have many different origins (e.g., articles, conference proceedings, books and book chapters). In particular, 17 of them examine different smart city aspects, while 20 are focused on one or two specific aspects of the city. It should be specified that the sectors in table below are indicated as displayed by the contributions, without any reference to the potentially adoptable taxonomies. In fact, that matter will be specifically discussed in the following section (2.2).

The background analysis was carried out querying an international database (Scopus), limiting the analysis to contributions published in English from the year 2000 onwards, and excluding areas of not interest. Moreover, the authors searched for additional relevant sources looking at the references and citations of the initial set of selected contributions.

The whole research generated 37 contributions. To identify the relevant ones for the literature analysis the authors adopted the following procedure. Further details are described in the Diagram below and in Table 2.

1. Title analysis: the initial set of 3848 contributions were submitted to a title analysis. For this analysis, the authors performed a manual coding excluding the works presenting contents irrelevant for the authors' purpose. This led to the exclusion of 3184 contributions, and the identification of 664 ones eligible for the following abstract analysis.
2. Abstract analysis: this examination led to the exclusion of 566 out of 664, since the content of the abstract was not related to the smart city topics, thus they were deemed not consistent with the goal of the present research. Thus, a set of 98 contributions was obtained and considered suitable for the full text analysis.
3. Full text analysis: the full text analysis was fundamental in order to focus on those contributions that met the following criteria:
   a. Contributions providing a taxonomy for indicators/KPIs and/or
   b. Contributions providing a set of indicators/KPIs

These criteria led to the exclusion of 62 contribution and the authors obtained a final set of 36 contributions. After looking at the references and citations, 1 further contribution considered useful was added, for a total of 37 contributions obtained from the literature research.

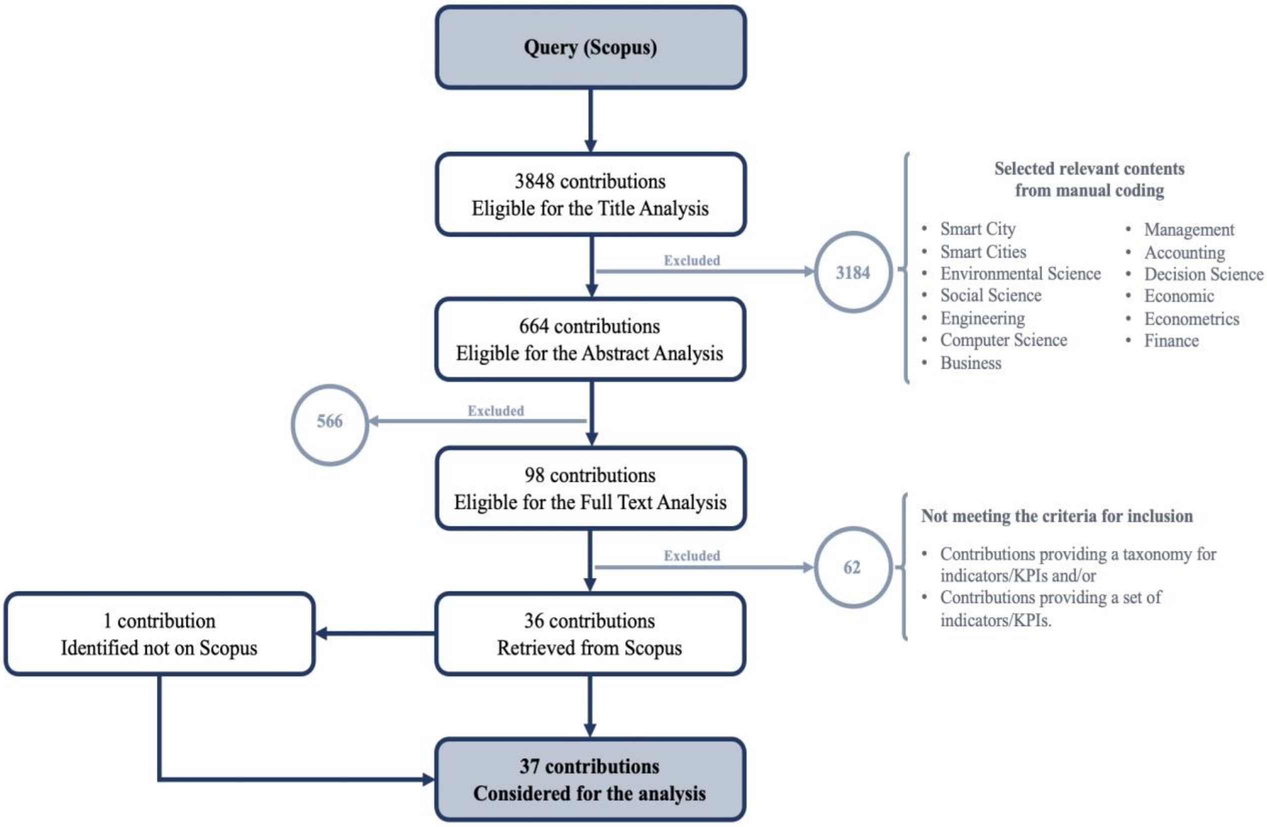

Figure 2 – Procedure for the identification of the contributions included in the literature analysis

The table below illustrates the criteria selected for the literature review.

Criteria selection for the literature review				
Keywords	**Language**	**Publication Year**	**Areas**	**Exact Keywords**
TITLE-ABS-KEY ("framework" OR "model" OR "approach" OR "assessment" OR "measurement") AND TITLE-ABS-KEY ("indicator" OR "KPI" OR "performance indicator" OR "metric") AND TITLE-ABS-KEY ("smart" OR "sustainable" OR "circular") AND TITLE-ABS-KEY (cit*)	(LIMIT-TO (LANGUAGE, "English")	PUBYEAR > 1999	LIMIT-TO (SUBJAREA, "ENVI") OR LIMIT-TO (SUBJAREA, "SOCI") OR LIMIT-TO (SUBJAREA, "ENGI") OR LIMIT-TO (SUBJAREA, "COMP") OR LIMIT-TO (SUBJAREA, "ENER") OR LIMIT-TO (SUBJAREA, "BUSI") OR LIMIT- TO (SUBJAREA, "DECI")	LIMIT- TO (EXACTKEYWORD,"KPI") OR LIMIT-TO (EXACTKEYWORD, "KPIs") OR LIMIT-TO (EXACTKEYWORD, "KPIs (Key Performance Indicators)") OR LIMIT-TO (EXACTKEYWORD, "Key Performance Indicator") OR LIMIT-TO (EXACTKEYWORD, "Key Performance Indicators") OR LIMIT-TO (EXACTKEYWORD, "Key Performance Indicators (KPI)") OR LIMIT-TO (EXACTKEYWORD, "Key Performance Indicators (KPIs)")

		OR LIMIT-TO (SUBJAREA, "ECON")	OR LIMIT-TO (EXACTKEYWORD, "Key Success Factors") OR LIMIT- TO (EXACTKEYWORD, "Performance Assessment") OR LIMIT-TO (EXACTKEYWORD, "Performance Indicators") AND LIMIT-TO (EXACTKEYWORD, "Smart City") OR LIMIT-TO (EXACTKEYWORD, "Smart Cities")

Table 2 – Criteria selected for the literature review

The table below shows the literature contributions on which this first step of the analysis is based. For each contribution information about the following are provided: i) General information, in particular authors and date of publication, and source; ii) Theoretical development, in particular the context considered for the theoretical development (sector and geographical area) and the base for the development; iii) Indicators identified; iv) Empirical application, in particular the context considered for empirical application (sector and geographical area), the methodology used for the empirical application, the method used for the prioritization of the indicators.

Literature Contributions										
General information		**Theoretical development**					**Empirical application**			
Authors and date	**Title**	**Source**	**Sector**	**Geographical Area**	**Development based on**	**Indicators**	**Sector**	**Geographical Area**	**Method**	**Prioritization**
Wiik et al. 2019	A Norwegian zero emission neighborhood (ZEN) definition and a ZEN key performance indicator (KPI) tool	IOP Conference Series: Earth and Environmental Science	Zero emissions districts	Norway	Case study	32	District	Norway	Simulation	–
Shen et al. 2018	A holistic evaluation of smart city performance in the context of China	Journal of Cleaner Production	Different	China	Literature and interviews	18	Different	China	Case study	Entropy method
Genta et al 2019	Key Performance Indicators for Sustainable Urban Development: Case Study Approach	IOP Conference Series: Earth and Environmental Science	Different	Italy	CESBA MED and Delphi methods	14	Different	Italy	Case study	–
Androulaki et al. 2014	Proposing a Smart City Energy Assessment Framework linking local vision with data sets	5th International Conference on Information, Intelligence, Systems and Applications	Energy and environment	–	Existing frameworks	16	–	–	–	Weighting

Picioroaga et al. 2018	SMART CITY: Definition and Evaluation of Key Performance Indicators	10th International Conference and Expositions on Electrical and Power Engineering	Energy and environment	–	Literature	15	Energy and environment	–	Case study	AHP
Petrova-Antonova et al. 2018	Towards a technological platform for transparent and flexible assessment of smart cities	10th International Joint Conference on Knowledge Discovery, Knowledge Engineering and Knowledge Management	Different	Europe	Literature	89	Different	Bulgaria	Simulation	–
Korachi and Bounabat 2019	Towards a Platform for Defining and Evaluating Digital Strategies for Building Smart Cities	3rd International Conference on Smart Grid and Smart Cities	Different	–	Literature and existing frameworks	129	–	–	Simulation	Weighting and capability levels
Osella et al. 2016	Toward a Methodological Approach to Assess Public Value in Smart Cities	Public Administration and Information Technology	Different	Europe	Literature	41	Different	Italy	Case Study	Core and ancillary categorization
Carli et al. 2013	Measuring and managing the smartness of cities: A framework for classifying performance indicators	International Conference on Systems, Man, and Cybernetics	Different	Italy	Literature and case study	107	Different	Italy	Case study	Weighting
Sanchez et al. 2014	On the energy savings achieved through an internet of things enabled smart city trial	International Conference on Communications	Energy	Spain	Case study	4	Energy	Spain	Case study	–
Vasallo et al. 2019	The District Energy-Efficient Retrofitting of Torrelago (Laguna de Duero-Spain)	IOP Conference Series: Earth and Environmental Science	Energy efficiency	Spain	Case study	27	Energy efficiency	Spain	Case study	–
Balaras et al. 2019	Urban sustainability audits and ratings of the built environment	Energies	Buildings and built environment	Europe	CESBA MED	29	Buildings and built environment	Europe	Simulation	Normalization, weighting and aggregation

Ambrogi et al. 2016	Contributions from research projects on the Italian power system: Accountability of sustainable energy projects	International Annual Conference: Sustainable Development in the Mediterranean Area, Energy and ICT Networks of the Future2016	Energy and Lightning	Italy	Existing framework	9	Energy and Lightning	Italy	Case study	–
Korachi and Bounabat 2019	Integrated methodological framework for smart city development	The International Conferences on ICT, Society and Human Beings, Connected Smart Cities and Web Based Communities and Social Media	Different	–	Literature	129	–	–	–	AHP
Shmelev and Shmeleva 2018	Global urban sustainability assessment: A multidimensional approach	Sustainable Development	Different	–	Existing frameworks	16	Different	–	Case study	Aggregation and weighting
Girardi and Temporelli 2017	Smartainability: A Methodology for Assessing the Sustainability of the Smart City	Energy Procedia	Energy and Mobility	Italy	Case study	36	Energy and Mobility	Italy	Case study	–
Mattoni et al. 2019	Towards the development of a smart district: The application of a holistic planning approach	Sustainable Cities and Society	Different	Italy	Literature	7	Different	Italy	Simulation	-
Da Silva et al. 2019	Sustainability indicators for urban solid waste management in large and medium-sized worldwide cities	Journal of Cleaner Production	Waste management	Brazil	Literature, surveys and national databases	49	Waste management	Brazil	Case study	–
Shahrokni et al. 2015	Implementing smart urban metabolism in the Stockholm Royal Seaport: Smart city SRS	Journal of Industrial Ecology	Energy	Sweden	Existing framework	26	Energy	Sweden	Case study and interviews	–

Andrés et al. 2018	Assessment methodology for urban excess heat recovery solutions in energy-efficient District Heating Networks	Energy Procedia	District	–	Literature and existing frameworks	28	–	–	–	–
Lopez-Carreiro and Monzon 2018	Evaluating sustainability and innovation of mobility patterns in Spanish cities. Analysis by size and urban typology	Sustainable Cities and Society	Mobility	Spain	Literature	16	Mobility	Spain	Case study	Weighting
Clemente et al. 2019	Solutions and services for smart sustainable districts: Innovative key performance indicators to support transition	International Journal of Sustainable Energy Planning and Management	District	Europe	Case study	63	–	–	–	–
Giret et al. 2018	How to choose the greenest delivery plan: A framework to measure key performance indicators for sustainable urban logistics	IFIP Advances in Information and Communication Technology	Logistics	–	Case study	21	Logistics	–	–	–
Baralis et al. 2016	Analyzing air pollution on the urban environment	39th International Convention on Information and Communication Technology, Electronics and Microelectronics	Environment	Italy	Case study	14	Environment	Italy	Simulation	–
Weerakkody et al. 2012	Utilizing a high-definition live video platform to facilitate public service delivery	IFIP Advances in Information and Communication Technology	ICT	Europe	Case study	12	Different	Europe	–	–
Akande et al. 2019	The Lisbon ranking for smart sustainable cities in Europe	Sustainable Cities and Society	Different	Europe	Existing frameworks	15	Different	Europe	Interviews surveys and public national databases	PCA
Praharaj and Han 2019	Building a typology of the 100 smart cities in India	Smart and Sustainable Built Environment	Different	India	Literature and existing frameworks	54	Different	India	Case study	Discriminant function analysis
Pinna et al. 2017	Urban policies and mobility trends in Italian smart cities	Sustainability (Switzerland)	Mobility	Italy	Literature	10	Mobility	Italy	Case study	–

Zyryanov 2019	Methods for evaluation of mobility in modern cities	IOP Conference Series: Materials Science and Engineering	Mobility	–	Case study	13	Mobility	–	–	–
Acquaviva et al. 2015	Enhancing energy awareness through the analysis of thermal energy consumption	CEUR Workshop Proceedings	Buildings	Italy	EDEN	6	Buildings	Italy	Case study	–
Priano and Guerra 2014	A framework for measuring smart cities	ACM International Conference Proceeding Series	Different	Spain	Existing frameworks	9	Different	Spain	Case study	–
Kamil et al. 2014	A study to develop critical success factors of roads maintenance management system for sustainable facility management	Jurnal Teknologi (Sciences and Engineering)	Mobility	Indonesia	Survey	14	Mobility	Indonesia	Case study	Fuzzy-AHP
Yang et al. 2013	The technological integration of digital city and ecological city – take Sino-Finland Gongqing DigiEcoCity as an example	Advanced Materials Research	Different	China and Finland	Gongqing DigiEcoCity	30	Different	China and Finland	–	–
Pompei et al. 2018	Composite Indicators for Smart Campus: Data Analysis Method	International Conference on Environment and Electrical Engineering and Industrial and Commercial Power Systems Europe	District	Europe	Literature and existing frameworks	37	District	Italy	Case study	Weighting
Williams 2018	Eco-City Comparison: West versus East	Sustainability (United States)	Different	–	Literature	22	Different	UK and China	Case study	–
Hara et al. 2016	New key performance indicators for a smart sustainable city	Sustainability (Switzerland)	Different	Japan	Existing framework	52	Different	Japan	Case study	–
Artmann et al. 2019	How smart growth and green infrastructure can mutually support each other – A conceptual framework for compact and green cities	Ecological Indicators	Different	–	Literature	83	–	–	–	–

Table 3 – Literature contributions

2.2 Contributions Analysis

As mentioned before, a detail analysis of the contribution in Table 3 led to the identification of about 1292 key performance indicators. The examined indicators stem from a broad set of approaches: literature (e.g., Picioroaga et al. 2018, Osella et al. 2016, Mattoni et al. 2019, Artmann et al. 2019), existing frameworks (e.g., Androulaki et al. 2014, Ambrogi et al. 2016, Shmelev and Shmelva 2018, Shahrokni et al. 2015), case studies (e.g., Wiik et al. 2019, Sanchez et al. 2014, Clemente et al. 2019, Giret et al. 2018), combined literature and existing frameworks (e.g., Korachi and Bounabat 2019, combined literature and interviews (Shen et al. 2019), combined CESBA MED and Delphi methods (Genta et al. 2019), surveys (Kamil et al. 2014) and others. The contributions analyzed also present different spotlights on geographical areas and methods for the empirical application. Regarding geographical area, the non-generic contributions address Norway (Wiik et al. 2019), China (Shen et al. 2019, Yang et al. 2013), Italy (e.g., Carli et al. 2013, Girardi and Temporelli 2017, Baralis et al. 2016, Pinna et al. 2017), Spain (e.g., Sanchez et al. 2014, Vasallo et al. 2019, Priano and Guerra 2014), Brazil (Da Silva et al. 2019), Sweden (Shahrokni et al. 2015), India (Praharaj and Han 2019), Indonesia (Kamil et al. 2014), Finland (Yang et al. 2013), Japan (Hara et al. 2016). With reference to the empirical application, the adopted methods are simulation (e.g., Petrova-Antonova et al. 2018, Baralas et al. 2019, Mattoni et al. 2019), case study (e.g., Vasallo et al. 2019, Pinna et al. 2017, Priano and Guerra 2014, Williams 2018, Kamil et al. 2014), combined case study and interviews (Shahrokni et al. 2015), and combined interviews, surveys and public national databases (Akande et al. 2019). Furthermore, some authors tried to prioritize the purposed key performance indicators. The methods used are different, such as the analytic hierarchy process (AHP) (Picioroaga et al. 2018, Korachi and Bounabat 2019), fuzzy-AHP (Kamil et al. 2014), principal component analysis (PCA) (Akande et al. 2019), entropy method (Shen et al. 2018), discriminant function analysis (Praharaj and Han 2019), normalization, aggregation and weighting (Balaras et al. 2019), weighting (Androulaki et al. 2014, Carli et al. 2013, Lopez-Carreiro and Monzon 2018, Pompei et al. 2018) and others.

The schemes analyzed are guided by a set of overarching goals that would characterize the assessment process and would specify the particular focus of the assessment schemes. In general, the dominant goal is to promote smart city development and enhance city competitiveness through the improvement of performance measurement systems.

The analyses presented in this section are developed in Microsoft Excel. It is important to understand that the authors first gathered all the data in order to create an entire dataset. In particular, the activity was carried out by recording all the specific details regarding the assessed schemes in a single excel sheet per each contribution. Therefore, each one is composed by the information that together constituted the backbone of the analyses presented in this section. Successively, the authors built different matrixes per each analysis, with rows corresponding to literature contributions and columns corresponding to the objects of interest. Given the complexity and the myriad of data, here are reported the main parts functional to the goals of this chapter, while extracts of the dataset are provided in Appendix B.

The building blocks of any assessment scheme are key performance indicators that can be organized and classified in many different ways. In the examined contributions, indicators are clustered into one-, two- or three-tiered indicator systems. The two-tiered systems consist of "themes" and "indicators", the three-tiered ones also present an intermediary tier of "subthemes" (i.e., the highest tier contains themes, the middle tier contains 'subthemes', and the lowest tier contains indicators). Themes can be defined as broad categories that connote major dimensions related to the objectives of smart city development. Each theme, in turn, can include several subthemes that provide further details to the themes themselves and delineate more specific targets that cities should strive to meet. Moreover, it can happen that some contributions addressing one specific smart city theme, such as Baralis et al. 2016, deploy only one tier describing indicators directly.
The research founded that approximately the 68%, 24% and 8% of the indicators systems are two-, three- and one-tiered respectively. Further details on tiers analysis can be found in Table 4.

Contribution	**Number of tiers**		
	1	**2**	**3**
Wiik et al. 2019		X	
Shen et al. 2018		X	
Genta et al 2019		X	
Androulaki et al. 2014			X
Picioroaga et al. 2018		X	
Petrova-Antonova et al. 2018			X
Korachi and Bounabat 2019		X	
Osella et al. 2016		X	
Carli et al. 2013		X	
Sanchez et al. 2014	X		
Vasallo et al. 2019		X	
Balaras et al. 2019		X	
Ambrogi et al. 2016		X	
Korachi and Bounabat 2019			X
Shmelev and Shmeleva 2018		X	
Girardi and Temporelli 2017		X	
Mattoni et al. 2019		X	

Da Silva et al. 2019			X
Shahrokni et al. 2015	X		
Andrés et al. 2018		X	
Lopez-Carreiro and Monzon 2018		X	
Clemente et al. 2019			X
Giret et al. 2018		X	
Baralis et al. 2016	X		
Weerakkody et al. 2012		X	
Akande et al. 2019		X	
Praharaj and Han 2019		X	
Pinna et al. 2017			X
Zyryanov 2019		X	
Acquaviva et al. 2015		X	
Priano and Guerra 2014		X	
Kamil et al. 2014		X	
Yang et al. 2013		X	
Pompei et al. 2018			X
Williams 2018		X	
Hara et al. 2016			X
Artmann et al. 2019			X
TOTAL	3	25	9

Table 4 – Tiers analysis of literature contributions

The table presents the observed results about themes used across schemes. It must be noticed that the fact that contributions present framework organized in different tiers led to some variety in analyzing themes. In fact, those adopting two tiers presented a higher number of themes with respect to those adopting three tiers since they organize the system with one tier less. Moreover, it must also be noticed that themes used across schemes, despite being part of the same layer, present different levels of specificity. In fact, many themes can be considered complementary or part of others and this must be considered in the creation of the theoretical framework presented in chapter 3. For example, air quality and GHG emissions themes can be considered under environment, or again, safety can be considered both under living and mobility. Thus, either this peculiarity derives from the city perspective or from the authors' interpretation of the phenomenon, it significantly increases the complexity of the analysis and must be further investigated in future works. Finally, in order to avoid bias in the whole examination and since the majority of the schemes adopted just two layers, further investigation on subthemes was not carried out. However, also that must be further examined in future works. Regarding the performed analysis, it can be noticed that there is a wide variation: 30 different themes were found, 4.2 are included, on average, in the selected schemes. To identify the most common ones, the authors calculated the frequency of appearance of each theme in the selected schemes. It is important to point out that different schemes use different terms to refer to the same or closely related themes. That is why, when it was necessary, the authors replaced certain terms with their synonyms to improve the accuracy of the process. For instance, the term “CO_2 emissions” was considered as “GHG emissions”, or the term “transportation” was replaced with “mobility” when found. Further details on the analysis are presented in Table 6.

	No of themes	**Mean**	**Median**	**Max**	**Min**	**St. Dev.**
Themes	30	4.22	4.00	10.00	1.00	2.12
Most Common	Environment, Economy, Living, Mobility, Governance, People, Energy					

Table 5 – Literature themes outlook

Themes	**%**
Environment	72
Economy	66
Living	34
Mobility	34
Governance	31
People	31
Energy	34
Infrastructure	19
Air Quality	16
Building	16
Access to services	13
Society	13
GHG Emissions	13
Education	13
ICT	13
Health	9
Urban Systems	9
Land and Material Resources	6
Innovation	6
Social Cohesion/Inclusion	6
Safety	6
Security	3
Waste	3
Water	3
Technical	3
Satisfaction	3
Family-friendliness	3
Traffic	3

Natural Resources	3
Culture	3

Table 6 – Literature themes analysis

Once the most commonly used themes were identified, the documents were examined to count the indicators related to each theme and gather all the information provided by authors concerning the KPIs presented. As shown in the table below, the number of key performance indicators proposed presents great variance, ranging from a minimum of 4 to a maximum of 129, with an average of about 35.

	Mean	**Median**	**Max**	**Min**	**St. Dev.**
Indicators	34.92	22.00	129.00	4.00	33.10

Table 7 – Literature indicators outlook

Since the broad boundaries of the most common themes, the authors carried out a preliminary screen in order to aggregate all the existing indicators within environment, economy, governance, mobility, people and living to see which ones were the more persistent indicators according to the initial set of contributions. The only exception was made for the energy theme, which was not included indeed: this is due to the fact that its frequent presence was determined by a high number of studies focusing on that specific aspect as can be noticed from the Table 6.

The environment theme is considered in all the contributions that address two or more different sectors. It accounts for the highest number of KPIs analyzed: approximately 355 indicators out of the 1292 KPIs deriving from contributions. After environment, living and economy are the ones with the second and third highest number of KPIs analyzed. In fact, they account for about 300 and 255 indicators respectively. Then, the authors' analysis led to the examination of almost 150 mobility key performance indicators, and 130 indicators related to the people theme. The theme accounting for the lowest number of KPIs analyzed is governance. In fact, about 105 indicators out of 1292 were found belonging to it.

Finally, it was fundamental to register also the different information characterizing the KPIs presented in the examined schemes. In particular, an in-depth analysis provided information about the following: i) Data owner; ii) Type of data (i.e., subjective or objective, quantitative or qualitative); iii) Relevance of the indicator (i.e., core or support/ancillary, extended or basic); iv) Perimeter of analysis (i.e., district, city, cities, etc.); v) Description of the KPI; vi) Frequency of reporting; viii) Unit of measure. Further details on the analysis are presented in Table 9.

Feature	%	Feature	%
Data Owner	32.4	KPI Description	16.21
Data Type	70.3	Frequency of Reporting	13.5
KPI Relevance	10.8	KPI Mode of Calculation	18.9
Perimeter of Analysis	86.5	Unit of Measure	64.9

Table 8 – KPI information reported in literature contributions

Approximately one third of the contributions identify a potential or actual owner of the data, about the 65-70% describe the type of data and the unit of measure of the indicator. Moreover, about the 86% of the examined schemes present the perimeter of analysis for which the set has been built. Instead, a really low percentage of contributions present an accurate and thorough description of the KPI and the procedure for its calculation. Finally, rarely the rate at which the KPI must be updated is accounted in the analyzed sets (less than 15%) and only in the 10% of the cases the authors presented a clear reference to the relevance of the indicator.

Contribution	Data owner	Data type	KPI Relevance	Perimeter of Analysis	KPI Description	Update rate	KPI Mode of Calculation	Unit of Measure
Wiik et al. 2019	X	X		X			X	X
Shen et al. 2018		X		X				X
Genta et al 2019		X		X				X
Androulaki et al. 2014		X						X
Picioroaga et al. 2018		X	X	X				X
Petrova-Antonova et al. 2018				X	X			
Korachi and Bounabat 2019				X				
Osella et al. 2016		X	X	X				X
Carli et al. 2013	X	X		X		X		X
Sanchez et al. 2014		X		X				X
Vasallo et al. 2019	X			X				
Balaras et al. 2019		X		X			X	X
Ambrogi et al. 2016	X	X		X				X
Korachi and Bounabat 2019				X				
Shmelev and Shmeleva 2018	X	X		X				X
Girardi and Temporelli 2017		X		X				X
Mattoni et al. 2019		X		X	X		X	X
Da Silva et al. 2019	X	X		X		X		X
Shahrokni et al. 2015		X		X		X		X
Andrés et al. 2018			X	X				X
Lopez-Carreiro and Monzon 2018								X
Clemente et al. 2019	X			X				

Giret et al. 2018		X		X			X	
Baralis et al. 2016		X				X		X
Weerakkody et al. 2012							X	
Akande et al. 2019	X	X		X				X
Praharaj and Han 2019		X		X				
Pinna et al. 2017	X	X		X		X		
Zyryanov 2019				X				X
Acquaviva et al. 2015		X		X	X			
Priano and Guerra 2014	X						X	X
Kamil et al. 2014		X		X				
Yang et al. 2013	X	X		X	X			X
Pompei et al. 2018		X	X	X	X			
Williams 2018		X		X	X			X
Hara et al. 2016	X	X		X				
Artmann et al. 2019				X			X	X

Table 9 – KPI information reported per each literature contribution

2.3 Literature Gaps

For each paper of literature analysed, the authors have identified the gaps of analysis and the avenues of future research highlighted by the authors.

In this section the authors report the relevant gaps emerging from existing literature. 6 different categories of limits have been identified, which are system completeness, KPIs design, range/scale of application, data collection and availability, framework testing, and stakeholder involvement. All these categories are described below, with appropriate reference to the papers that highlight each specific limit.

System Completeness: one of the main limits regards the inappropriate framework completeness revealed by 10 authors. This is intended at two different levels. First, it concerns the insufficient identification of the appropriate number of areas of the city that must be measured and monitored. Then, the proposed indicators result not sufficient for the themes identified and missing for those that must be integrated for a comprehensive framework able to provide an accurate picture of city performances. In the majority of the cases, there is the necessity of increasing areas and indicators since some information is missing. Vice versa, in other cases they must be revised because there is redundancy of data. Finally, considering this issue it must be pointed out as the authors report the need of compiling and reviewing themes and indicators on a temporal basis, ensuring the continuous improvement of the framework.

To mention few examples, Osella et al. 2016 and Andrés et al. 2018 denote a limited number of core indicators if compared to the expectations of policy makers and the idea to facilitate replication and comparability among cities. Ambrogi et al. 2016 underlines that renewable energy indicators are not sufficient, while Petrova-Antonova et al. 2018 reveals the need of indicators for land, safety and health categories. According to Da Silva et al. 2019, there is the need to include new indicators in the Brazilian waste management system. In Korachi and Bounabat 2019 the list of indicators cannot be regarded as final, since it can be modified on the basis of future assessments and tests.

KPIs Design: 9 out of the analysed papers report a lack of inadequate structure or design of the proposed KPIs. As highlighted by the analysed contributions, many issues may limit the applicability of an indicator. First of all, it can be due to some common peculiarities of indicators like the lack of details in its definition, such as the description, the methodology for calculation, the unit of measure, temporal and spatial boundaries or further specifications needed to facilitate replicability and application of the indicators. In particular, specific attention must be paid also to the issues of **subjectivity** and **redundancy of data**. Regarding the first, the fact that some KPIs are not fully implies that there may be a certain level of bias in measurement. This is very frequent when indicators are being evaluated on a qualitative scale, such as Likert scale, which affects the interpretation and reliability of data. Concerning the second, one or more KPIs may overlap with each other since they totally or partially lead to the same calculation/measurement of data. However, it can happen since different indicators have different levels of specification. Finally, a particular attention must be paid to the **time relevance**. The moment of measurement is fundamental for the comparability among different cities and to access changes and improvements of a city compared to past results. It is important to identify the precise temporal boundaries of the measure. A recurrent limit consists in the timeliness of the data, since information is often obsolete or disaggregated one with the other.

To mention some examples of indicator design limits, Wiik et al. 2019 reveals a lack of harmonization among indicators, with big differences in system boundaries of KPIs. Baralas et al. 2019 declares the need of reconsider some of its proposed indicators, adding some details in order to provide a more comprehensive definition of the measure and facilitate the comparison among different cities. In addition, according to Andrés et al. 2018, the energy indicators need further specifications in order to address the main topic thoroughly. Another example is Osella et al. 2016 highlights this gap and underlines the need of a structured data repository for different time series.

Range/Scale of Application: 11 papers recognise the difficulty in applying the indicators on a larger number of cities and/or on a different scale. Some of the analysed frameworks are specifically designed for a single region, since they leverage on case-study approaches. For this reason, their applicability at worldwide scale has not been demonstrated yet. This limit is perceived due to the fact that each performance measurement framework is affected by some context specific factors. In fact, it must be noted that some parameters, such as the national peculiarities, the geographical area and the size, inevitably influence the strategy of cities. Therefore, to assess the feasibility and the chances of success of frameworks, some background parameters should also be considered.

Examples are Shen et al. 2018 which is focused on Chinese smart city programs, or Genta et al. 2019, in which indicators are properly selected for the city of Turin. Genta et al. 2018 also reports the need of adopting a model of KPIs that allows the measurement on a larger scale, shifting from the district to the city scale. On the other side, Androulaki et al. 2014 suggests that, as avenue of further research, the framework designed for the evaluation of the city as a whole, can be also customized per sector, such as municipal buildings, providing more focused information. Balaras et al. 2019 highlight the need to extend the range of application to other regions to facilitate and improve the effectiveness and the impact of action plans and policies.

Framework Testing: 7 papers recognise limitations in the testing of the proposed framework of KPIs. Some of them has not been tested yet, therefore their application may be not immediate. Other frameworks are tested only in few near cities and the authors point out the need to expand the testing to other contexts. It must be noticed how this limit presents large room for improvement. In fact, as highlighted by the contributions, frameworks should be tested in a more and more large number of cities and/or projects in order to gather as many results and feedbacks as possible.

Examples are Korachi and Bounabat 2019 which points out that the KPIs still have to be assessed in real contexts. Lopez-Carreiro and Monzon 2018 tested its framework only in Spanish cities and identifies as a future line of research, the implementation of the framework in a larger set of cities.

Data Collection and Availability: 8 papers report the inability of collecting all the data and information needed for measuring the proposed indicators. This can happen for many different reasons such as very specific uses, detailed calculation required and so on. Moreover, in some cases data are available but still inaccurate. In other cases, data are not even available because they are not collected by the cities. These issues are really frequent, especially in less developed cities.

For instance, Da Silva et al. 2019 was only able to measure 11 out of the 49 indicators in its framework when it was tested in three Brazilian cities, showing difficulties regarding the availability of information in databases and reveal the need of drafting precise guidelines for management and data collection by local governments. Also, Shahrokni et al. 2015 has encountered many difficulties in collection data from owners and integrate them into its system during the testing of the framework.

Stakeholder Involvement: the application and the creation of a smart city framework requires the involvement of municipalities, as they are the practitioners, and the necessity of an incredible network of coordination among those latter, as it is reported in 3 papers analysed. Thus, for the correct functioning of the developed system, a systematic and continuous collaboration with stakeholders represents a fundamental prerogative. Moreover, it is fundamental also the presence of a central coordination to address different interventions towards single precise goals. The stakeholder involvement issue is more frequent in less developed countries, for example in Brazil, as Da Silva et al. 2019 reports.

Gap	**Contributions**
System Completeness	Wiik et al. 2019; Genta et al 2019; Petrova-Antonova et al. 2018; Osella et al. 2016; Ambrogi et al. 2016; Korachi and Bounabat 2019; Girardi and Temporelli 2017; Da Silva et al. 2019; Andrés et al. 2018; Giret et al. 2018.
KPIs Design	Wiik et al. 2019; Genta et al 2019; Balaras et al. 2019; Korachi and Bounabat 2019; Andrés et al. 2018; Weerakkody et al. 2012; Pinna et al. 2017; Hara et al. 2016; Osella et al. 2016.
Range/Scale of Application	Shen et al. 2018; Genta et al 2019; Androulaki et al. 2014; Osella et al. 2016; Balaras et al. 2019; Girardi and Temporelli 2017; Shahrokni et al. 2015; Clemente et al. 2019; Praharaj and Han 2019; Zyryanov 2019; Priano and Guerra 2014.
Framework Testing	Wiik et al. 2019; Petrova-Antonova et al. 2018; Korachi and Bounabat 2019; Andrés et

	al. 2018; Lopez-Carreiro and Monzon 2018; Giret et al. 2018; Artmann et al. 2019.
Data Collection and Availability	Shen et al. 2018; Osella et al. 2016; Mattoni et al. 2019; Da Silva et al. 2019; Shahrokni et al. 2015; Pinna et al. 2017; Hara et al. 2016; Artmann et al. 2019.
Stakeholder Involvement	Mattoni et al. 2019; Da Silva et al. 2019; Weerakkody et al. 2012.

Table 10 – Gaps of literature

The review enables the authors to identify the main gaps of existing literature in measuring and monitoring frameworks for Smart Cities. The recognition of existing literature gaps is fundamental for the overall work since, starting from one or more of these gaps, the authors can develop the research question of their dissertation, investigating in how to deal with an existing issue and how to contribute to the literature research regarding this theme. The research question brings the authors to build up a propter theoretical framework for Smart Cities and propose it as an answer to the literature gaps. The proposed theoretical framework and its objectives are showed in the next chapter.

3 THEORETICAL FRAMEWORK

In the previous chapter, the authors explored the vast territory of performance measurement systems presented in the literature. In doing this, an extensive examination of all the features composing those frameworks was presented. Finally, the chapter was concluded with an in-depth analysis of the gaps characterizing the assessed schemes. The acquired in-depth knowledge of the whole, raised fundamental points to be investigated by the authors, who discovered the need of a new performance measurement system able to address the gaps identified.
Therefore, this chapter is fundamental since (i) it clarifies the research questions and objectives and (ii) presents the framework proposed by the authors.

First, the chapter introduce and describe the research question which composes the objectives of this work. Successively, the main features of the framework such as the overall structure and the key performance indicators are presented.

Successively, it focuses on the structure of the framework describing the areas to classification of the indicators and the rationale behind it. The subdivision layers are presented and defined to provide a comprehensive view of the framework.

Finally, the appropriate considerations regarding key performance indicators are done, presenting the framework results. Moreover, a brief evaluation is introduced in order to prepare the reader for the next chapter aimed at testing the proposed framework.

This chapter presents the initial theoretical framework constructed by the authors. Let's rewind the journey that led to the definition of this framework. First, it should be recalled that the authors portrayed the incredibly vast concept of smart city, describing its facets, the main challenges of a city and the importance of a performance measurement system. Intrigued by such themes, particularly by the latter, the authors deep dived into smart cities literature. The result of such diving experience gave birth to chapter 2, where the features characterizing a performance measurement system are extensively explained. This led the authors to finally define the research objective. Stemming from the experience reported by the literature works, which especially highlighted the importance and centrality of the topic for the city transition towards a smarter version of itself, and from the gaps identified, there is a clear need for a new framework for the evaluation and monitoring of smart cities performances. The whole project represents the attempt to construct a performance measurement system that supports the speeding up of wide-scale deployment of smart city solutions and services in order to create impact on major societal challenges around the climate strategies and targets and the continuous growth and densification of cities. Therefore, this work aims to create a continuous improvement process through which cities are facilitated in learn from each other, create trust in solutions, and monitor progress, by means of a common integrated performance measurement framework. In particular, it must be specified what are the gaps that the framework aims to address and what are the potentials improvement that will be presented. Looking at the six main gaps found in literature, some considerations must be done. Since the framework has a theoretical origin, the range/scale of application, data collection and availability, framework testing, and stakeholder involvement could not be addressed. Thus, it could target the system completeness and the KPIs design. However, as it is extensively explained in section 3.2, it was not possible to provide a set of indicators. That is why the goal of this initial theoretical framework is to improve the **system completeness** at the level of city areas that must be identified.

It must be noted that the progression of the areas and indicators is a clear prerogative for the framework. Thus, city areas forming the framework classification and key performance indicators must be formulated in such a way that they can be integrated in the city's plan for gathering regular statistics. The outcome of the whole process, in turn, should get a regular place in the planning processes of the city. Another consideration that must be done before introducing the structure of the framework is that some parameters, such as the national peculiarities, the geographical area and the size, inevitably influence the strategy of cities. Therefore, to assess the feasibility and the chances of success of the proposed measurement system, some background parameters should also be considered.

3.1 Framework Structure

This section aims at defining the structure of the framework, in order to understand how it has been designed and conceived. First of all, the analysis presented in chapter 2 provided the authors a database composed by 37 assessed schemes, accounting for 1292 key performance indicators. Here, it is described how KPIs have been arranged and classified, while in the next section (3.2) a specific focus on indicators will be provided.

The evaluation framework has been subdivided in categories since it has a great advantage. In fact, it allows for a great flexibility, facilitating the identification of the city aspects and areas to be addressed and the subsequent creation of indicators that do not overlap with each other. As explained in chapter 1, this work is focused on the “energy pillars” of the smart city. The framework was organized in pillars (first layer) and subcategories (second layer). The definition of pillars and subcategories was carried out following the data regarding the 30 themes originated from the literature review. Stemming from those analyses, the majority of city areas have been derived from those already existing, reviewing the terms referring to them when necessary in order to provide clarity on the sector of impact. In addition, some new subcategories have been suggested in order to provide a complete system for performance measurement.

As described in the previous chapter the main themes employed in performance measurement systems are environment, economy, living, mobility, governance and people respectively. Thus, those consistent with the focus of this work, namely environment, living and economy are consequently adopted in the proposed framework. Moreover, the multitude of themes identified formed the basis for the definition of the second layer of subcategories of the framework. Next, the three pillars and the subcategories are defined to provide a clearer view of the framework structure.

3.1.1 Smart Environment

As reported in section 1.2, Smart Environment represents the growing attention to environmental sustainability of the city, through an efficient resource utilization and management system and acting against climate change, pollution, resource depletion. Practises such as recycling and clean energy consumption are key factors in Smart Environment, together with the use of sensors, devices and smart applications that drive a wise and more optimal consumption of energy, water, soil and all other natural resources. Challenges related to Smart Environment are a more optimal exploitation of the

city areas, in order to facilitate the rapid city growth, together with a more efficient use of resources, in line with their availability and scarcity in the long run.
The proposed theoretical framework identifies 8 subcategories that compose the pillar Smart Environment, in according to the need of guaranteeing system completeness to the framework, as it emerges from the literature.

The following subcategories were identified for the smart environment pillar:

- **Energy**: this subcategory aims at monitoring the energy production and consumption levels of the city, considering the different conventional sources (i.e., fossil fuels) for primary energy, the possible applications as secondary energy (e.g., electricity or thermal energy) and the final energy uses.
- **Energy – Green energy**: this subcategory aims at measuring and monitoring production and consumption levels of energy coming from renewable energy sources (RES). The authors decided to separate green energy from the previous subcategory (i.e., energy) in order to enhance the relevance of renewable sources in a Smart City, since their exploitation permits the distributed energy generation and more independence from the grid.
- **GHG Emissions**: this subcategory evaluates the level of greenhouse gases (GHG) emissions in the city. This is another very relevant theme in the current scenario, since the emissions lead to an increase in the average temperatures, causing dramatical climate and ecosystem changes. Today, the priority of reducing emissions levels is undoubtedly a common topic among national governments and international institutions, and cities are inevitably the place in which this shift has to occur.
- **Land and material resources**: this subcategory aims at measuring and monitoring the exploitation of the city natural resources, as soil, raw materials and green spaces. An important challenge for Smart Cities is to adopt an efficient exploitation of resources without compromising the city natural ecosystem and environment.
- **Pollution**: it refers to measure the level of pollutants such as O_3 and particulate matter concentrations, as PM2,5 and PM10 in the city. Air pollution is a recurrent aspect that cities are today trying to monitor and reduce, thanks to the newest technologies. A reduction in pollution would definitely arise citizens quality of life.
- **Waste:** this subcategory investigates on the city waste management system, evaluating the adoption and diffusion of material recycling solutions and other circular economy initiatives, that are drivers for more smart and sustainable cities.

- **Water**: it aims at monitoring the water management system in the city, accessing its efficiency and measuring water consumption levels. As land and material resources, water is a critical resource, and its exploitation has to be properly monitored and optimized.
- **Urban Planning**: this subcategory investigates on the city landscape, measuring the percentage areas dedicated respectively for households, commercial activities and for cultural, sport and leisure facilities. Moreover, the "unused" areas are object of evaluation.

Figure 3 – Theoretical Framework – Smart Environment subcategories

3.1.2 Smart Living

The smart living pillar, as described in section 1.2, represents the adoption of smart and efficient solutions for public lighting around the city, the so-called Smart Lighting, and efficient heating and refrigeration systems for public and private buildings, namely Smart Building. The Smart Living concept is strictly linked with digital technologies since ICT solutions are enabler of the newest housing and industrial applications to limit and optimize energy consumption, thanks to smart meters and devices. Challenges connected to Smart Living for cities are the ability of improving the energetic class of a district without compromising its historical and/or artistical heritage, the equal distribution of wealthy among the different city areas, the fight against criminality.

In the proposed theoretical framework, the authors divide Smart Living in 6 subcategories, which should guarantee a comprehensive view of the pillar, in according to the gaps identified from the literature review.

The subcategories forming the pillar Smart Living are:

- **Building**: this subcategory aims at measuring the smartness of the buildings inside a city. Buildings are classified according to the type (residential, commercial or public) and the subcategory investigates on the adoption of smart devices and applications inside the buildings and their energy and resources consumption levels.
- **Access to services**: this subcategory is relevant as it investigates on the service offered by the city to its citizens, i.e., the availability of infrastructures that enable Smart City solutions, as diffusion of smart meters, accessibility, quality of the broadband services and availability of 5G connection and fibre-optic networks.
- **Public Lighting**: this subcategory refers to the evaluation of the public lighting system in the city, both for streets and for city squares. Object of analysis are electricity consumption levels for public lighting, quality of the service and the adoption of smart and technological solutions for increase the system efficiency.
- **Energy**: this subcategory evaluates the energy performances of the city in Smart Living aspects, in particular the diffusion of energy efficiency measures and applications in buildings and infrastructures, in order to optimize energy use.
- **Safety**: it investigates on the surveillance, control and automation infrastructures used in the city, both in public buildings and in outdoor areas.
- **ICT**: this subcategory aims at measuring and monitoring the diffusion of Information and Communication Technology platforms and solutions in the city, that are key drivers for increasing citizens quality of life.

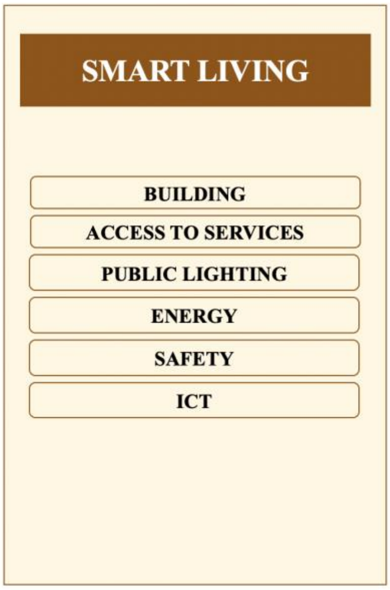

Figure 4 – Theoretical Framework – Smart Living subcategories

3.1.3 Smart Mobility

As presented in section 1.2, this pillar is focused on the promotion of sustainable transportation business models, that mainly concern electric or low emission vehicles, both private and public, autonomous driving, shared mobility, pedestrian and cycling routes. All of these solutions contribute to decrease pollution and emissions and raise local and international accessibility of the city in a sustainable and safe manner. A city is Smart in Mobility when it offers an efficient public transportation system, in line with actual citizens demand during peak hours, and smart ways for dwellers to have access to public and private transportation services, arising citizens quality of life and city attractiveness. Challenges connected to Smart Mobility are the diffusion of the propter infrastructure, such as charging stations for electric vehicles, the abundancy of sharing vehicles to cover the daily demand, the availability of pedestrian and cycling paths, the implementation of a road network that minimizes congestion, traffic and incidents and that facilitates the City growth.

The authors identify 6 subcategories for Smart Mobility, which guarantee system completeness and a comprehensive examination of the pillar.

The subcategories forming Smart Mobility in the proposed theoretical framework are:

- **Public transportation**: this subcategory aims at measuring and monitoring the performances of the public transportation system of the city. In particular, it investigates on the number of different modes offered to citizens, the availability of different routes and the network connections among different city areas.
- **Private vehicles**: it aims at showing the overall profile of the city in terms of private cars that daily circulate across. In particular it investigates on the diffusion of low-emissions vehicles, as Hybrid Electric Vehicles (HEV) and electric vehicles, as Battery Electric Vehicles (BEV) and Plug-in Hybrid Electric Vehicles (PHEV), which constitute the current e-mobility solutions. Electric mobility is one of the main solutions that are emerging today in the society, and its diffusion is no doubt fundamental in a Smart City.
- **Alternative transportation**: this subcategory aims at evaluating the diffusion of alternative mobility solutions to the conventional private vehicles and public transportation, which are the diffusion of car-pooling and sharing mobility, the availability of pedestrian and cycling routes, the possibility of use autonomous driving vehicles.
- **Mobility Infrastructure**: this subcategory investigates on the availability and diffusion of the infrastructure needed for enabling Smart Mobility solutions. In particular, infrastructures that are often very critical in the city are Electric vehicles (EV) public charging stations, which

permit the users to recharge the car in the middle of a travel, facing the recurrent problem of the limited autonomy of an electric vehicle.

- **Traffic**: it evaluates the traffic level across the different areas of the city, and the implementation of solutions for limiting congestions, as smart traffic lights, car free zones, real-time traffic monitoring systems, incentives in electric or sharing transportation.
- **Road Safety**: it considers the frequency of road accidents that happen in the city, both due to traffic congestion and for inadequate roads planning and maintenance.

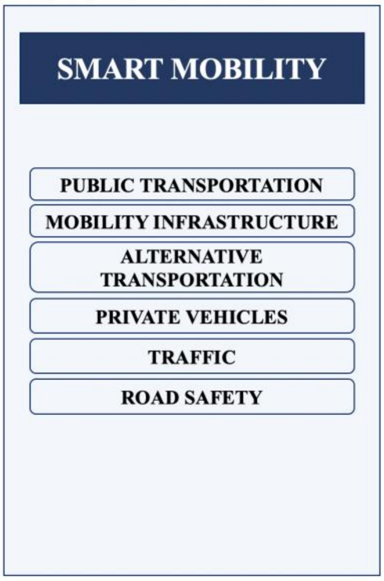

Figure 5 – Theoretical Framework – Smart Mobility subcategories

The figure below provides a final picture of the framework.

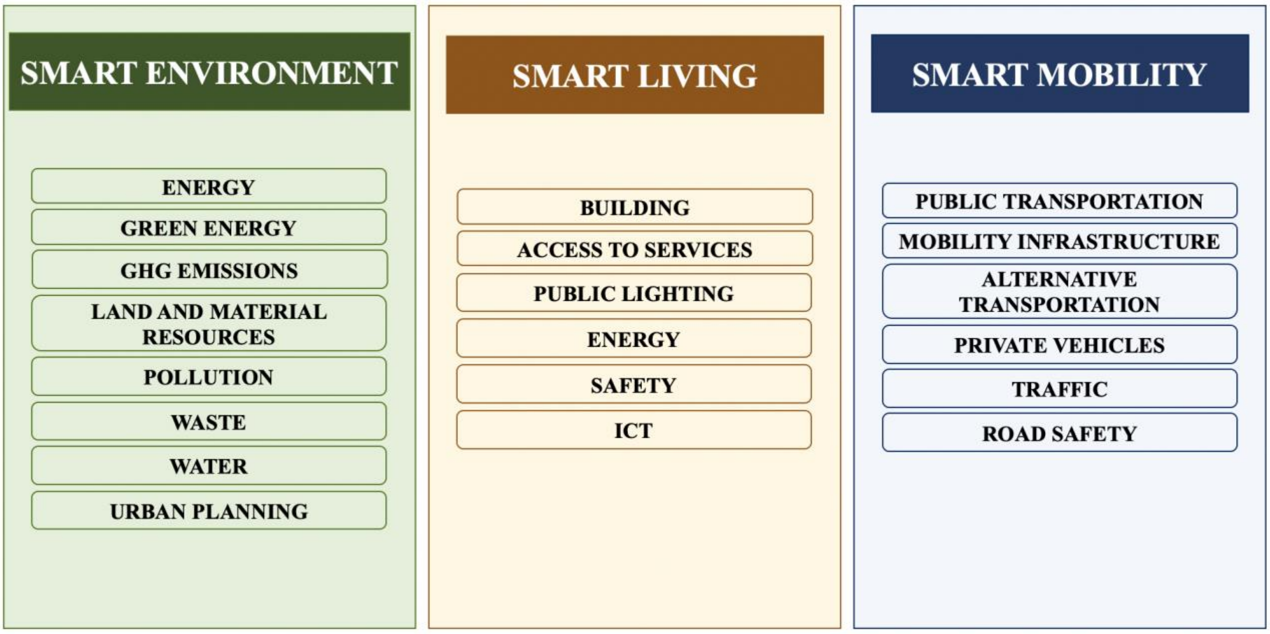

Figure 6 – Subcategories of the theoretical framework

3.2 Key Performance Indicators

As mentioned before, the overall analysis was based on about 1290 key performance indicators. After the preliminary screen described in section 2.2, about 780 could be considered as part of the smart environment, living and mobility pillars. However, in describing the indicators the authors must focus on the analysis presented in section 2.2. According to the result obtained, it must be noticed the incredibly raw amount of data that the literature analysis provided to the authors. In fact, as extensively explained in chapter 2, a very little number of KPIs were defined in an acceptable way that could make them available for review and as a base for the creation of thorough indicators. Therefore, in absence of additional data, it could not be possible to create a set of indicators for now.

In particular, to provide the reader a comprehensive perspective on key performance indicators, they must be selected and/or constructed following a series of fundamental criteria aiming at proving their viability. It can be noticed that some are more general, while others appear also as gaps identified from literature. Here, we report an appropriate the set of criteria based on those recalled by the CITYkeys project (Bosch et al. 2017).

- Relevance: each indicator should have a significant role for the evaluation process and all the indicators should have a consistent relation to the subcategories of the framework. Moreover, the indicators should be defined in a way that the possible implementation of a smart city would provide an evident change of the indicator value.
- Completeness: the set of indicators should consider all the aspects of the energy related pillars. This is why categories and subcategories have been identified, and specific indicators have to be assessed for each subcategory in order to build a comprehensive framework.
- Availability: data for the indicators should be available and easy to be collected through the different sources of data. Indicators that require, for instance, interviews of users or dwellers are not suited as the large amounts of data needed are too expensive to gather. In case data availability for a specific indicator is difficult, it has to be specified and possible alternatives for the measurement can be evaluated (i.e., shifting the perimeter of analysis from city scale to national scale).
- Measurability: an indicator has to be easily measured in an objective way. For energy-related pillars, it should not be difficult to define quantitative and objective indicators.
- Reliability: the definition and the calculation method of each indicator should be clear and not open for different interpretations. This holds for the definition itself and for the calculation methods behind the indicator.

- Familiarity: each indicator should be easy to understand in by the users.
- Non-redundancy: indicators should not be overlap with each other, since they have to measure different aspects for the pillar.
- Independence: any change in an indicator should not have an impact in the evaluation (positive or negative) of other indicators of the framework.

3.3 Framework Discussion

This brief final section aims at drawing the final considerations for the theoretical framework and paving the way for the next chapter that will presents the empirical analysis.

The objective of the work and the proposed framework are extensively presented in this chapter. As explained before, the framework presents a more complete construction in terms of areas of the city that need to be addressed. However, the advancements must be proved by the authors. That is why, the following steps are fundamental in order to provide a full understanding of the potentials for success and the results that can be obtained by the adoption of this framework. The natural consequence is a comprehensive test of the framework that the authors carried out in the next chapter. In fact, an empirical analysis is presented in order to understand to which extent the target gaps are bridged and what are the next possible development of the framework.

4 EMPIRICAL ANALYSIS

After having examined the contributions from literature, and presented the theoretical framework developed by the authors, the fourth chapter is focused on the empirical analysis aimed at testing the proposed framework. In fact, after building the theoretical framework, it must be tested in order to provide a full understanding of its potentials for success and the results that can be obtained by its adoption. In order to carry out this testing phase, the authors resort to the experience of the existing frameworks provided by the main international organizations. In fact, the selected contributions are projects and frameworks that have been developed by international institutions and organizations, that assess smart cities performance measurement systems and provide a comprehensive perspective on results obtained by testing them in wide and significant real scenarios.
The aim of such empirical analysis is twofold. Thus, chapter 3 is a key component for the overall work as it (i) answers the questions raised in the previous chapter, testing the proposed theoretical framework and (ii) it serves as a fundamental examination of the phenomenon in order to understand the next possible development of the framework for its improvement.

This chapter begins with the exhibit and a brief explanation of the contributions that form the basis of the empirical analysis, and the rationale behind the research of them.

Next, the chapter presents a deep analysis of the contributions, aimed at testing the theoretical framework, proving the consistency of its pillars and subcategories as well as the existence of other ones. Moreover, it provided significant information regarding indicators. The whole analysis was based on 17 contributions, presenting approximately 1320 KPIs. This validation phase lays the foundation for the next development of the authors' framework.

Finally, the last section exhibits a discussion on additional information that provide the reader with a full picture of the empirical analysis.

4.1 Empirical frameworks

As described above, the contributions presented in this section are mainly projects and initiatives that have been developed by international institutions and organizations with the aim of assessing measurement frameworks that can be replicated globally (e.g., ISO 37120, developed by the International Organization for Standardization). The frameworks analysed have been sought taking into account the contributions published in English from the year 2000 onwards, from two different steps. First, through a series of web searches on Google, especially on the official sites of the organizations of interest. In this regard, the research keywords employed were “smart” or “sustainable” or “circular”; “city” or “cities”; "framework" or "model" or "approach" or "assessment" or “measurement” or “system”; “key performance indicator” or "KPI" or "performance indicator" or “indicator” or "metric". The second step of the research was based on a peculiar examination of the references of the previously examined literature contributions. The whole research led to the identification of 17 main contributions that were all considered viable for examination after the verification of three main criteria. First, the projects must address the smart city topics. Second and third, the projects must provide a taxonomy for indicators/KPIs and/or a set of indicators/KPIs.

The table below shows the contributions on which this analysis is based. For each contribution information about the following are provided: i) General information, in particular authors and date of publication, and source; ii) Geographical area; iii) Indicators identified.

Empirical contributions				
Author and date	**Title**	**Source**	**Geographical Area**	**Indicators**
Bosch et al. 2017	CITYkeys indicators for smart city projects and smart cities	–	Europe	76
International Organization for Standardization 2018	Sustainable cities and communities – Indicators for city services and quality of life (ISO 37120)	–	–	128
Hynes et al. 2019	D7.1 Approach and Methodology for Monitoring and Evaluation	Positive City ExChange	Europe	33
REPLICATE project 2017	D10.2 Report on indicators for monitoring at city level	REinassance of Places with Innovative Citizenship and Technology	Europe	56

UN-HABITAT 2015	City Prosperity Index	UN-HABITAT	Ethiopia	52
STEEP project 2015	List of possible Key Performance Indicators	Systems Thinking for Comprehensive City Efficient Energy Planning	Europe	51
Smiciklas 2019	Key Performance Indicators for Smart Sustainable Cities	United for Smart Sustainable Cities (U4SSC)	–	110
Angelakoglou et al. 2019	A Methodological Framework for the Selection of Key Performance Indicators to Assess Smart City Solutions	Smart Cities	Europe	75
Bhada et al. 2009	Global City Indicators	–	–	74
International Organization for Standardization 2019	Sustainable cities and communities – Indicators for Smart Cities (ISO 37122)	–	–	80
Marijuán et al. 2017	Key Performance Indicators Guide	EU Smart Cities Information System	Europe	62
UN Statistical Commission 2020	Global indicator framework for the Sustainable Development Goals and targets of the 2030 Agenda for Sustainable Development	The 2030 Agenda for Sustainable Development	–	14*
Inter-American Development Bank (IDB) 2013	Indicators of the Emerging and Sustainable Cities Initiative	Emerging and Sustainable Cities Initiative (ESCI)	Latin America and Caribbean	117
Economist Intelligence Unit 2014	European Green City Index	–	Europe	30
DGNB system 2018	DGNB system – New buildings criteria set	–	–	128
POCACITO 2014	Report on Key Performance Indicators	POCACITO	Europe	25
Eurostat 2004	Urban Audit	–	Europe	209

Table 11 – Empirical contributions

* The authors considered only those referring to the smart cities, according to the goal 11 of the agenda.

4.2 Testing the Theoretical Framework

This section, which is the key component of this chapter, presents a series of analysis aiming at validating the theoretical framework presented by the authors in chapter 3. Again, the analyses presented in this section are developed in Microsoft Excel. It is important to understand that the authors first gathered all the data in order to create an entire dataset. In particular, the activity was carried out by recording all the specific details regarding the assessed schemes in a single excel sheet per each contribution. Therefore, each one is composed by the information that together constituted the backbone of the analyses presented in this section. Successively, the authors built different matrixes per each analysis, with rows corresponding to literature contributions and columns corresponding to the objects of interest. Given the complexity and the myriad of data, here are reported the main parts functional to the goals of this chapter, while extracts of dataset are provided in Appendix C.

The building blocks of any assessment scheme are key performance indicators that can be organized and classified in themes as described in chapter 2. The table below presents the observed results about themes used across schemes. Again, it must be noticed that the fact that contributions present framework organized in different tiers led to some variety in analyzing themes. In fact, those adopting two tiers presented a higher number of themes with respect to those adopting three tiers since they organize the system with one tier less. Moreover, it must also be noticed that themes used across schemes, despite being part of the same layer, present different levels of specificity. In fact, many themes can be considered complementary or part of others. Thus, either this peculiarity derives from the city perspective or from the authors' interpretation of the phenomenon, it significantly increases the complexity of the analysis and must be further investigated in future works. Finally, in order to avoid bias in the whole examination and since the high number of the schemes adopting just two layers, further investigation on subthemes was not carried out. However, also that must be further examined in future works. Regarding the performed analysis, it can be noticed that there is a wide variation: 41 different themes were found, 9.65 are included, on average, in the selected schemes. To identify the most common ones, the authors calculated the frequency of appearance of each theme in the selected schemes. It is important to point out that different schemes use different terms to refer to the same or closely related themes. That is why, as it has been done in the previous chapter, when it was necessary, certain terms have been replaced with their synonyms to improve the accuracy of the process. Additional information regarding the full analysis is shown in Table 13.

	No of themes	Mean	Median	Max	Min	St. Dev.
Themes	41	9.65	9.00	14.00	3.00	3.35
Most Common	Environment, Economy, Governance, Living, Mobility, People					

Table 12 – Empirical themes outlook

Themes	**%**
Environment	71
Economy	65
Governance	65
Living	65
Mobility	59
People	47
Pollution	41
Waste	41
Social	35
Water	35
Energy	35
Health	29
Education	29
ICT	29
GHG Emissions	24
Safety	24
Urban Planning	24
Finance	24
Technical	18
Traffic	18
Building	18
Building Energy	18
Employment	12
Alternative Mobility	12
Green Energy	12
Energy Efficiency	12
Culture	12
Water Management	12
Recreation	12
Public Lighting	6
Electricity	6
Food Security	6
Road Infrastructure	6
Road Safety	6
Prosperity	6
Demography	6
Security	6
Access to services	6
Telecommunication	6

Public Administration	6
Integrated Planning and Design	6

Table 13 – Empirical themes analysis

As can be noticed from the table above, a significant amount of information was identified in this analysis. In fact, it is fairly higher not only considering the overall number of themes identified, but especially considering the average number of themes presented per each framework. In fact, with respect to the literature review about 10 themes more have been distinguished and approximately 6 themes per framework more. The significance of the results obtained from this analysis is twofold. First, the authors were able to verify the quality of the theoretical framework proposed in the previous chapter, substantiating the importance of the categories defined after the literature review. In fact, all the 20 subcategories composing the framework have been identified with more or less similar terms referring to them. Second, these results allowed for a further investigation of themes in order to improve the existing framework.

Once the most commonly used themes were identified, the documents were examined in order to gather all the information provided by authors concerning the KPIs presented. A meticulous inspection of the contributions highlighted a more structured approach with respect to the previous schemes, characterized by a detailed construction of indicators, and providing a broader range of specific information. The authors initially reviewed the number of key performance indicators appearing in the contributions, that always address different aspects of the smart city. As mentioned before, a detail analysis led to the identification of 1320 key performance indicators, slightly more than in the previous literature analysis (about 1292). As shown in the table below, the number of key performance indicators proposed presents great variance, ranging from a minimum of 14 to a maximum of 209, with an average of about 78, which more than doubles that of the previous analysis (about 35).

	Mean	**Median**	**Max**	**Min**	**St. Dev.**
Indicators	77.65	74.00	209.00	14.00	48.81

Table 14 - Empirical indicators outlook

Since the broad boundaries of the most common themes, the authors carried out a preliminary screen in order to aggregate all the existing indicators within environment, economy, governance, mobility, people and living to see which ones were the more persistent indicators according to the initial set of contributions. The environment theme is considered in all the contributions that address two or more different sectors. It accounts for the highest number of KPIs analyzed: approximately 365 indicators out of the 1320 KPIs deriving from contributions. After environment, economy and governance are the ones with the second and third highest number of KPIs analyzed. In fact, they account for about 315 and 240 indicators respectively. Then, the analysis led to the examination of almost 160 living key performance indicators, and 135 indicators related to the mobility theme. The theme accounting for the lowest number of KPIs analyzed is people. In fact, about 110 indicators out of 1320 were found belonging to it.

Successively, an in-depth analysis provided information about the following: i) Data owner; ii) Type of data (i.e., subjective or objective, quantitative or qualitative); iii) Relevance of the indicator (i.e., core or support/ancillary, extended or basic); iv) Perimeter of analysis (i.e., district, city, cities, etc.); v) Description of the KPI; vi) KPI Classification (i.e., if indicators were clustered in a three-tiered system); vii) Frequency of reporting; viii) Detailed explanation of the indicator calculation methodology; ix) Unit of measure; x) Strengths and weaknesses of the KPI; xi) KPI requirements (i.e., for reporting); xii) The rationale/interpretation under the existence and monitoring of the indicator; xiii) The set of additional information, such as the target and/or the benchmark of the KPI, the expected availability, expected accessibility, expected reliability, etc.; xiv) other notes and considerations regarding the indicator. Further details on the complete analysis are shown in Table 16 and 17.

Feature	**%**	**Feature**	**%**
Data Owner	100	KPI Mode of Calculation	76.47
Data Type	100	Unit of Measure	100
KPI Relevance	82.35	Strengths and Weaknesses	47.06
Perimeter of Analysis	100	KPI Requirements	52.94
KPI Description	88.24	Rationale/Interpretation	70.59
KPI Classification	47.06	Additional Information	70.59
Frequency of Reporting	88.24	Other Notes	35.29

Table 15 – KPI information reported in empirical contributions

As can be noticed from the table above, the amount of information available from this analysis is incredibly higher than that presented in chapter 2. All the frameworks report the data owner and type as well as the perimeter of analysis and the unit of measure. Approximately 88% of the time the frequency of reporting of indicators. Moreover, apart from the other relevant data, such as the strengths and weaknesses and the rationale, this examination shed light on fundamental information that are indispensable and on which the authors can rely in order to create a set of key performance indicators. In fact, about 80-90% of the assessed schemes thoroughly report the full KPI description and the methodology for its calculation.

Contribution	Data owner	Data type	KPI Relevance	Perimeter of Analysis	KPI Description	KPI Classification	Frequency of reporting
Bosch et al. 2017	X	X	X	X	X	X	X
International Organization for Standardization 2018	X	X	X	X	X		X
Hynes et al. 2019	X	X	X	X	X		X
REPLICATE project 2017	X	X		X	X	X	X
UN-HABITAT 2015	X	X	X	X	X		X
STEEP project 2015	X	X	X	X	X	X	
Smiciklas 2019	X	X	X	X	X	X	X
Angelakoglou et al. 2019	X	X	X	X	X		
Bhada et al. 2009	X	X	X	X	X		X
International Organization for Standardization 2019	X	X	X	X	X		X
Marijuán et al. 2017	X	X	X	X	X	X	X
UN Statistical Commission 2020	X	X	X	X	X		X
Inter-American Development Bank (IDB) 2013	X	X		X	X	X	X
Economist Intelligence Unit 2014	X	X	X	X		X	X
DGNB system 2018	X	X	X	X	X		X
POCACITO 2014	X	X		X	X	X	X
Eurostat 2004	X	X	X	X			X

Table 16 – KPI information reported per each empirical contribution

KPI Methodology of Calculation	Unit of Measure	Strenghts and weaknesses	KPI Requirements	Rationale/Interpretation	Additional information	Other Notes
X	X	X	X	X	X	X
X	X	X	X	X	X	
X	X		X	X	X	X
X	X		X		X	
	X	X				X
	X	X				
X	X		X	X	X	
	X				X	
X	X	X	X	X	X	
X	X	X	X	X	X	
X	X					
X	X	X	X	X	X	X
X	X			X	X	X
	X			X		
X	X	X	X	X	X	X
X	X			X		
X	X			X	X	

Table 17 – KPI information reported per each empirical contribution

The performed analyses were able to provide a full picture regarding the validation and the lack of the theoretical framework. In particular, stemming from those results, the authors were able to prove the consistency of the city areas identified and improve them by adding missing ones. Moreover, the information gathered on key performance indicators were fundamental in order to review the indicators collected in the literature review and create the authors' own set of KPIs. The further development of the theoretical framework is presented in the next chapter, where its final version is displayed.

4.3 Discussion

As extensively explained by the analyses exhibited in the previous section, this chapter was fundamental to test the theoretical framework. First, it substantiated the importance of the city areas identified. In fact, the most common themes were validated and, in particular, all the 21 subcategories composing the theoretical framework resulted consistent and were recognized, even with terms more or less similar to those used by the authors. However, a test clearly serves also to prove the problems and discrepancies of the object of interest. This testing phase was able to spot the framework limits and provide additional data for further development. In fact, on one hand a greater number of themes was identified, highlighting the lack of specificity of the proposed framework, which needs to address a larger number of subcategories. On the other hand, with the incredible amount of exhaustive and precise data concerning indicators, the empirical framework proved the inadequacy of a measurement system composed only by city performance areas.

This last also section presents some supplementary considerations that must be done in order to give the reader a full picture of the empirical analysis. In particular, what emerged are some detailed information that can be considered as avenues for future research since they shed light on specific issues regarding the design of key performance indicators and their availability. Those issues are following described.

Incomplete Measure: the KPI isn't thorough and/or truthful since not all the dimensions or the wrong ones affecting the measurement are taken into account. This may imply different types of distortions in the outcome such as under or overestimation. For example:

- Accessibility of open data sets: quality of the data is only expressed as the openness and ease of use of data. Other aspects like accurate, available, complete, conformant, consistent, credible, processable, relevant, timely have not been taken into account (e.g., Bosch et al. 2017).
- Access to basic health care services: in order to truthfully measure the accessibility of basic health care facilities, measuring only the physical dimension of accessibility is not sufficient. The social (affordability of such services) and cultural barriers would have to be measured as well, if the 'full picture' is to be shown (e.g., Bosch et al. 2017).
- Percentage of city population living below the international poverty line: internationally, people living in extreme poverty is currently defined by the United Nations as those living on less than US$1,25 a day. Applying the current average persons per household figure to all households can lower distinctions between household size in poor and more affluent

households, that is, it could have the effect of underestimating the actual number of people who live below the poverty line (e.g., International Organization for Standardization 2018).

Interpretation/Comparability: in some cases, the KPI is measured according to different cities' policies and rules/standards, or definitions. In may also happen that a KPI is rational only for some cities. This reduces the comparability. For example:

- Annual number of public transport trips: transport systems often serve entire metropolitan areas, and not just central cities. The use of number PT trips with origins in the city itself will capture many trips whose destination is outside the city but will generally capture the impact that the city has on the regional transport network (e.g., International Organization for Standardization 2018).
- Number of registered voters as a percentage of the voting age population: voting age population is not necessarily an exact measure of the number of citizens entitled to vote as it does not take into account legal or systemic barriers to the exercise of the franchise or account for non-eligible members of the population, such as resident non-citizens or in some jurisdictions persons serving a sentence of imprisonment in a penal or correctional institution (the voting eligible population (VEP) would capture these discrepancies but it is very hard to achieve the data required to measure VEP). However, in some countries, noncitizens, such as immigrants, have been granted the legal right to vote in municipal elections before they become citizens (e.g., International Organization for Standardization 2018).
- Percentage of population living in affordable housing: the threshold figure is based on a percentage a household spends on housing relative to overall income. The specific percentage will change based on local regulations and standards regarding housing affordability. For example, in Canada the housing affordability threshold is surpassed when a household spends more than 30 % of its income on housing. In France, the threshold is 40 % (e.g., International Organization for Standardization (2018).

Recall Error: some errors are caused by differences in the accuracy or completeness of data retrieved. This can occur when study participants are asked to recall events or experiences from the past. It usually happens in surveys, interviews, questionnaires and so on. An example is:

- Under age five mortality: estimates based on household surveys data shall be obtained: a) directly, using birth history, as in demographic and health surveys; or b) indirectly, using the Brass method, as specified in the Multiple Indicator Cluster Surveys. In developing countries, household surveys are essential to the calculation of this indicator, but there are some limits to their quality. Survey data are subject to recall error, and surveys estimating under-5 deaths require large samples, because such incidences are uncommon and representative households cannot ordinarily be identified by the sampling. (e.g., International Organization for Standardization 2018).

5 PERFORMANCE MEASUREMENT FRAMEWORK

Exploring the vast territory of performance measurement systems presented in the literature (chapter 2), proposing the initial theoretical frameworks (chapter 3) and successively testing and validating its effectiveness and problems through the analysis of the main international frameworks, allowed the authors to gain an-in depth understanding of the phenomenon under scrutiny. Hence, the authors were able to improve the previously built framework and are now prepared to describe its final version of the framework which aims to get back to and eventually answer in a more exhaustive way the research question posed in Chapter 1.

First, the chapter recall the objectives of this framework and its main features such as the overall structure, the key performance indicators and the primary target groups.

Successively, it focuses on the structure of the framework describing the classification of the indicators and the rationale behind it. The subdivision layers are presented and defined to provide a comprehensive view of the framework.

Then, the entire process of definition of key performance indicators is described together with their specific features. In addition, a complete overview of the constructed framework is proposed.

Finally, the last considerations regarding the framework are done, briefly portraying the current status of the work and prepare the reader for the next chapter aimed at investigating the context specific factors characterizing the Italian picture.

This chapter presents the last version of the framework constructed by the authors. Let’s rewind the journey that led to its definition. First, it should be recalled that the authors portrayed the incredibly vast concept of smart city, describing its facets, the main challenges of a city and the importance of a performance measurement system. Intrigued by such themes, particularly by the latter, the authors deep dived into smart cities literature. The result of such diving experience gave birth to chapter 2, where the features characterizing a performance measurement system are extensively explained. This led the authors to finally define the research objective. Stemming from the experience reported by the literature works, which especially highlighted the importance and centrality of the topic for the city transition towards a smarter version of itself, and from the gaps identified, a clear need for a new framework for the evaluation and monitoring of smart cities performances has been identified. This led the authors to create the initial theoretical framework (chapter 3), which has been successively tested in chapter 4 through the experiences of the existing frameworks built by the main international institutions and organizations in order to validate its ability to bridge the literature gaps and investigate its further development. The whole process showed the way for the realization of the final version of the performance measurement framework proposed by the authors. As described before, the whole work represents the attempt to construct a performance measurement system that supports the speeding up of wide-scale deployment of smart city solutions and services in order to create impact on major societal challenges around the climate strategies and targets and the continuous growth and densification of cities. Therefore, this work aims to create a continuous improvement process through which cities are facilitated in learn from each other, create trust in solutions, and monitor progress, by means of a common integrated performance measurement framework. In particular, it must be specified what are the gaps that the framework aims to address, reviewed according to the findings emerged from the empirical analysis. Looking at the six main gaps found in literature, some considerations must be done. Unfortunately, as it will be explained in section 5.4, the authors were not able to test this framework on the Italian panorama. Therefore, the range/scale of application, data collection and availability, framework testing could not be addressed while some improvements were done in terms of involvement of stakeholders, in particular municipalities. Thus, the final framework is proposed in order to target the **system completeness** and the **KPIs design**. First, the system completeness is finally targeted at both levels. Stemming from the theoretical framework and the data obtained from the empirical analysis, the authors were able to improve the set of areas that must be accounted in assessing the city performances. Subsequently, the key performance indicators describing those categories have been constructed. Second, a comprehensive set of KPIs has been designed. Particular attention was also paid to the time relevance, subjectivity and overlapping issues. In fact, indicators provide a clear definition of time boundaries of measurement and are defined in order to be measured in a fully objective way. Concerning the overlapping issues, despite the definition ensures no overlapping between two or more indicators, complete independence in measurement must be proved by testing it on a real scenario since it can happen that some could lead to the same measurement of data, at least partially. The same consideration must be done for the additional challenge of incomplete measure identified in the empirical analysis. Finally, it was not possible to address the interpretation/comparability and recall error challenges, again, found in the empirical analysis. The full description of the framework is portrayed later in this chapter.

The proposed framework, and in particular, the constructed key performance indicators, aim at serving decision marking. This latter encompasses different decision makers at various levels of the process. Thus, the presented indicators, have two main target groups:

- Decision makers at city level who must design the smart city strategy over time. This group has also the responsibility to monitor the city transition and answer the question has the city become smarter by critically analyzing the final results.
- National governments and other bodies (e.g., European ones), that must design the smart city policies. It has also the responsibility to monitor the effect of their smart city policies on the overall attention to the designated targets. In addition, it uses indicators to compare cities.

As explained previously, it must be noted that the progression of indicators is a clear prerogative for the users just indicated. Thus, key performance indicators must be formulated in such a way that they can be integrated in the city’s plan for gathering regular statistics. The outcome of the indicator process, in turn, should get a regular place in the planning processes of the city. Of course, the proposed indicators could also be used by other groups of interest, such as educational institutions and businesses. Finally, for citizens the indicators may be powerful tools for understating the impacts of cities’ initiatives. Another consideration that must be done before introducing the structure of the framework is that some parameters, such as the national peculiarities, the geographical area and the size, inevitably influence the strategy of cities. Therefore, to assess the feasibility and the chances of success of the proposed measurement system, some background parameters should also be considered.

5.1 Framework Structure

This section aims at defining the structure of the framework, in order to understand how it has been designed and conceived. First of all, including the empirical analysis presented, the whole work provided the authors with a database composed by 54 existing indicator frameworks, accounting for 2612 key performance indicators. Here, it is described how KPIs have been arranged and classified stemming from the theoretical framework and following the finding emerged from its testing and validation. In the next section (5.2) a specific focus on indicators will be provided.

The evaluation framework has been subdivided in categories since it has a great advantage. In fact, it allows for a great flexibility, facilitating the identification of the city aspects and areas to be addressed and the subsequent creation of indicators that do not overlap with each other. As explained in chapter 1, this work is focused on the “energy pillars” of the smart city. The framework was organized in pillars (first layer) and subcategories (second layer). The definition of pillars and subcategories was carried out following starting from the theoretical framework and the findings emerged from the empirical analysis. In particular, the data regarding the 41 themes originated from the testing phase allowed the authors to validate the identified categories, but also recognize the fact that they were too narrowed. Stemming from those analyses, the pillars of the theoretical framework, namely environment, living and economy, have been maintained. Moreover, the new subcategories have been derived maintaining the previous ones and occasionally reviewing the terms referring to them in order to provide a comprehensive picture given that new subcategories have been integrated and improve the degree of intelligibility. The majority of new ones originated from the evidence of the empirical analysis. In addition, some new subcategories have been suggested in order to provide a complete system for performance measurement. Finally, different “categories” were defined in order to group together different clusters of subcategories, but it must not be considered a proper classification layer. Next, the three pillars and the subcategories are defined to provide a clearer view of the framework structure.

5.1.1 Smart Environment

As reported in section 1.2, Smart Environment looks at the environmental sustainability of the city, thanks to a wise exploitation of conventional energy sources, the integration with renewable energy sources (RES), the efficient use of resources such as water and soil and the waste reduction. The categories identified for this pillar are Energy, Ecosystem, Pollution, Waste and City Planning. Next the different subcategories aiming at comprehensively describe the smart environment pillar are described.

The following subcategories form the category Energy:

- **Energy – Electricity**: it includes indicators that analyse production and consumption levels of electric energy in the city;
- **Energy – Fuel**: it considers indicators related to the fossil fuels exploitation for energy use;
- **Energy – Green Energy**: it refers to indicators that measure energy production levels from RES plants;
- **Energy – Energy Storage**: it includes indicators related to the use of energy storage systems (ESS);
- **Energy – W2E**: it includes indicators that measure the adoption Waste-to-Energy (W2E) solutions, indeed energy production from waste recovery;
- **Smart Grid and Balancing:** it includes indicators that measure data related to the electric grid and the balancing of the production sources and consumption loads;
- **Energy**: it presents other energy indicators not classified in the previous subcategories.

The following subcategories describe the category Ecosystem:

- **GHG Emissions**: it considers indicators for measuring Greenhouse gases emissions such as CO_2 and CH_4;
- **Water Management**: it refers to indicators that monitor water management and usage;
- **Other Resources Usage**: it considers indicators for measuring the exploitation of resources such as soil and other raw materials;
- **Ecosystem**: it includes indicators that refer to the biodiversity of the city, monitoring the preservation of natural areas and native species

The following subcategories form the category Pollution:

- **Pollution**: it includes indicators for detecting and measuring pollutants such as O_3 and Particulate matter concentrations, as PM2,5 and PM10;
- **Pollution – Noise**: it assesses indicators for monitoring noise pollution levels in the city.

The following subcategories describe the category Waste:

- **Waste management**: it assesses indicators for monitoring waste management systems and landfills utilization;
- **Waste recycling and reuse**: it defines indicators related to circular economy practises for end-of-life products, such as material recycling and product reuse.

Finally, the following subcategories form the category City Planning:

- **Urban Planning**: it assesses indicators that detect the city planning and distribution of resources to the population;
- **Risk Management**: it refers to indicators that detect risk prevention and management measures on natural disaster as earthquakes and flooding.

The figure below resumes the structure of the smart environment pillar, showing the theoretical classification on the left and the final version on the right.

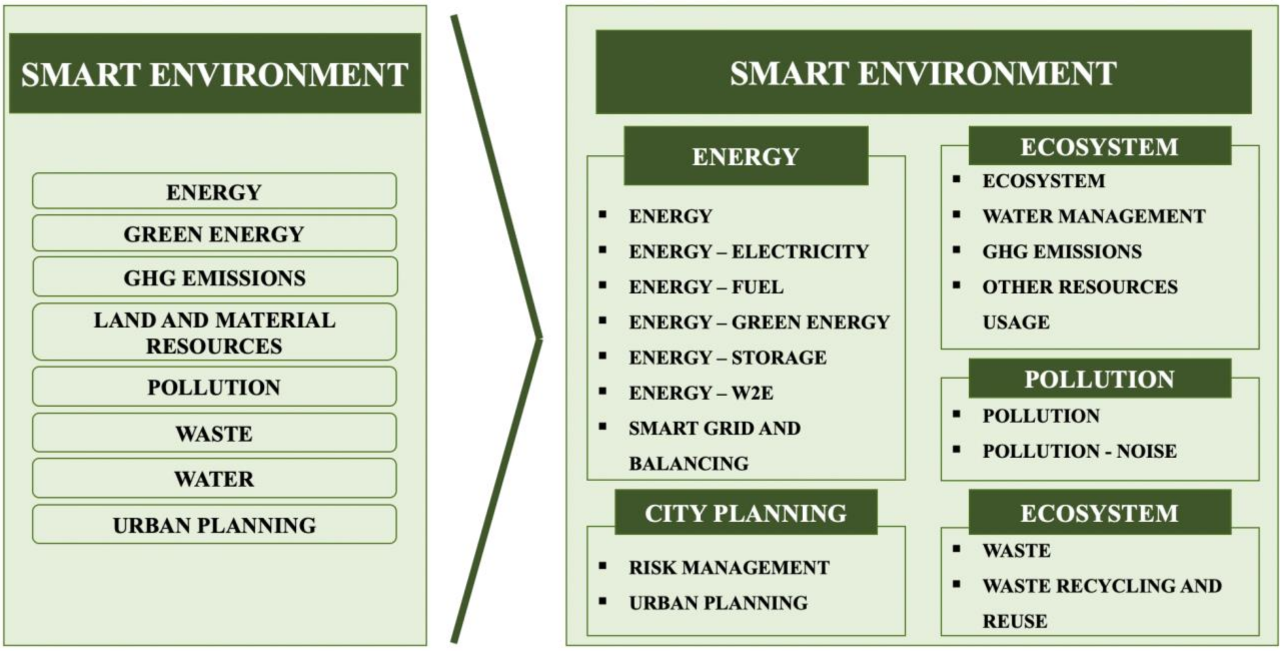

Figure 7 – Final Framework – Smart Environment subcategories

5.1.2 Smart Living

The smart living pillar, as described in section 1.2 of the work, aims at improving the urban living conditions of its citizens, through the optimization of public services and the adoption of energy efficient solutions, both of residential and public applications. The category identified for this pillar is Building Data, while the subcategories Public Lighting and Condition Profiling did not require to be grouped into categories.

The subcategories forming the category Building Data are:
Building Data: it assesses indicators for general information regarding buildings in the city;
Building Data – Energy: it defines indicators for monitoring energy consumption in public and residential buildings;
Building Data – Electricity: it defines indicators for monitoring electricity consumption;
Building Data – Green Energy: it includes indicators that assess the diffusion of residential and commercial RES plants in the city;
Building Data – Energy Storage: it assesses indicators for evaluating the diffusion of Energy Storage Systems in residential, public and commercial buildings in the city;
Building Data – Energy Efficiency: it includes indicators that assess energy efficiency levels in residential and public buildings of the city;
Building Data – Control and Automation Infrastructure: it includes indicators that evaluate automation levels of the systems installed in public buildings;
Building Data – People with Special Needs: It presents indicators that evaluate the availability of the propter infrastructure needed for people with special needs in public buildings.

The figure below resumes the structure of the smart living pillar, showing the theoretical classification on the left and the final version on the right.

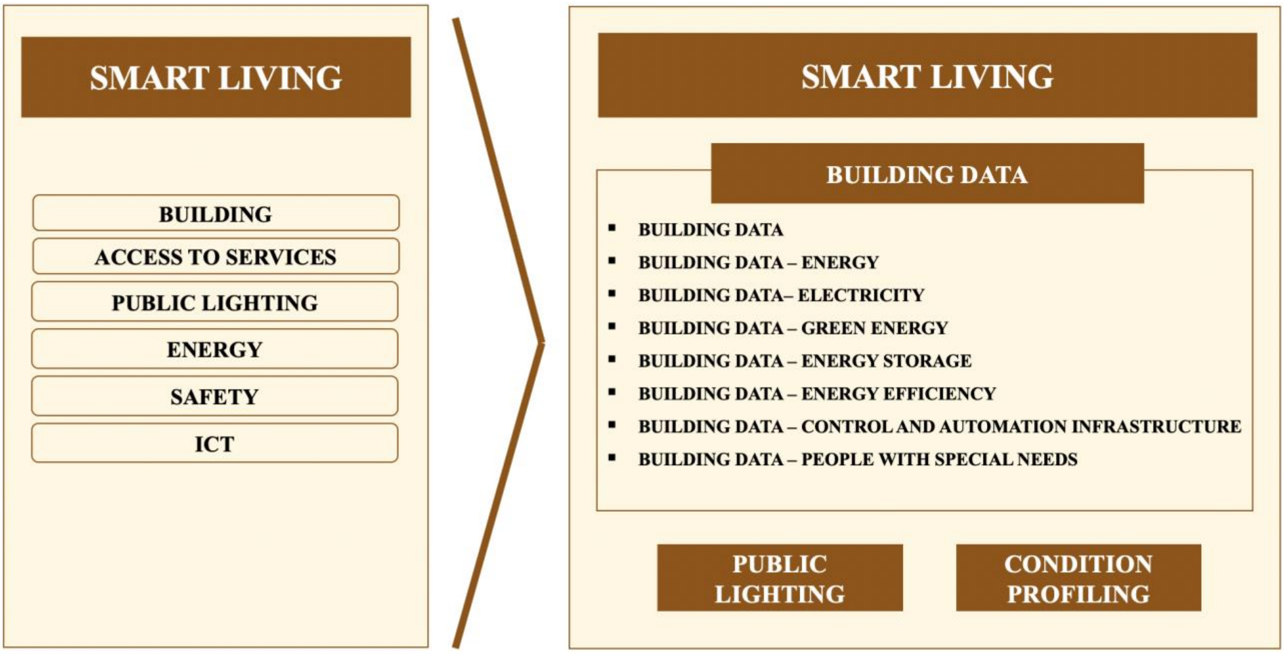

Figure 8 – Final Framework – Smart Living subcategories

5.1.3 Smart Mobility

This pillar aims at optimizing the mobility system inside city boundaries, through the diffusion of innovative and sustainable transportation solutions, such as low-emission vehicles, electric vehicles, alternative transportation, public and sharing services and smart infrastructure. The categories identified for this pillar are Infrastructure and Mobility Data. Next the different subcategories aiming at comprehensively describe the smart mobility pillar are described.

The subcategories forming the category Infrastructure are:

- **Infrastructure – Public transportation**: it reports indicators that evaluate the performance level of the infrastructure used in the public transportation system, in terms of availability and diffusion of the network;
- **Infrastructure – Bike**: it reports indicators that monitor the bike route network in the city and the availability of bike sharing solutions;
- **Infrastructure – EV Charging**: it includes indicators that assess the availability of public charging stations and points for electric vehicles (EV) in the city;
- **Parking areas**: it defines indicators that evaluate the availability of smart infrastructure in public parking areas, such as e-payment systems and real-time availability alert systems;

- **Infrastructure**: it presents indicators that monitor other information about infrastructure related to smart mobility, such as roads, traffic lights and pedestrian routes and crossings.

The subcategories forming the category Mobility Data are:

- **Public Transportation**: it assesses indicators regarding public transportation use and satisfaction of the citizens;
- **Road Safety**: it considers indicators that evaluate the level of traffic and congestion;
- **Private Vehicles**: it presents indicators that assess the amount of private cars and motorcycles in the city;
- **Green Mobility**: it defines indicators for evaluating the presence and diffusion of electric and low emissions vehicles such as Battery electric vehicles (BEV) and Plug-in Hybrid electric vehicles (PHEV), Fuel-Cell electric vehicles (FCEV) and Hybrid electric vehicles (HEV) in the city;
- **Alternative Transportation**: it includes indicators for evaluating alternative solutions in mobility, such as car sharing services and autonomous driving solutions.
- **Mobility Data**: it presents indicators that monitor other information about mobility, in particular regarding city traffic and viability.

The figure below resumes the structure of the smart mobility pillar, showing the theoretical classification on the left and the final version on the right.

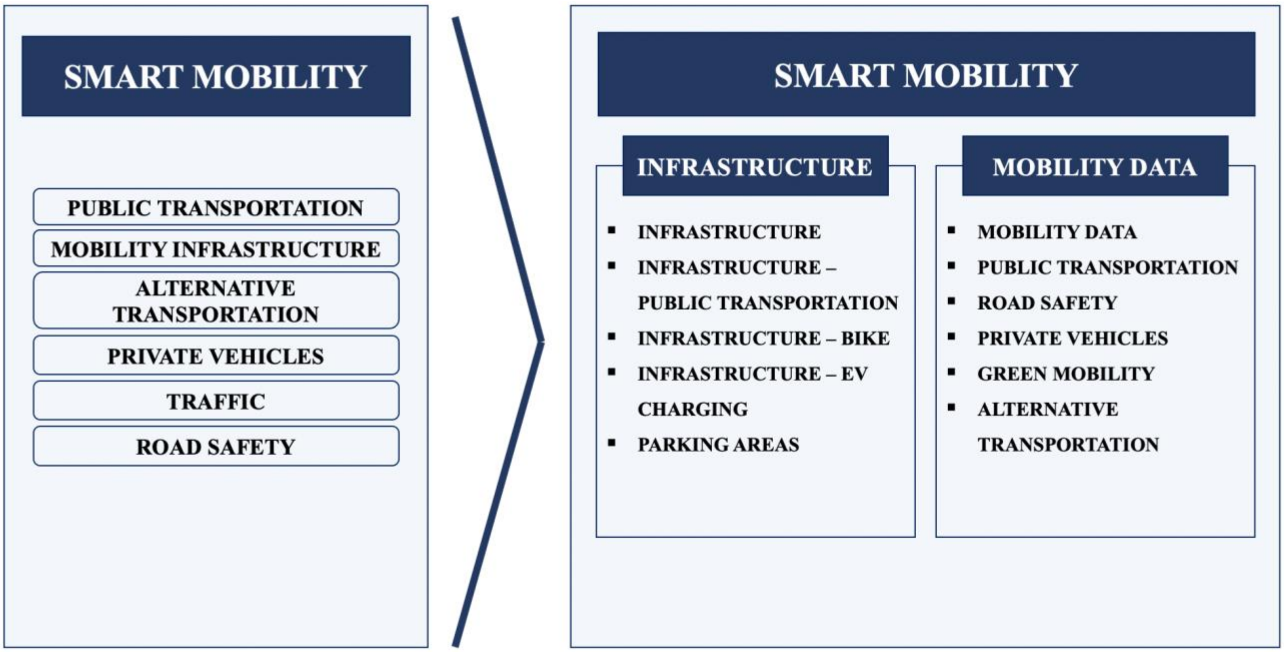

Figure 9 – Final Framework – Smart Mobility subcategories

5.2 Key Performance Indicators

This section aims at defining the structure of the indicators, in order to understand how they have been designed and conceived. First of all, including the empirical analysis presented, the whole work provided the authors with a database composed by 54 existing indicator frameworks, accounting for 2612 key performance indicators. However, since the focus of this work is on the energy-related performances, only the indicators of interest have been examined. In particular, after the preliminary screens described in chapter 2 and 4, according to which indicators where aggregated across the main themes identified, the overall number of indicators attributable to environment, living and mobility, which were those analyzed in-depth, was about 1470 out of 2612. As mentioned in chapter 4, thanks to the incredible amount of specific data gathered, according to the results presented in section 4.2, the authors were finally able to construct a comprehensive set of key performance indicators. Of course, those examined from empirical experiences also allowed a further investigation and interpretation of those examined in literature, in order to extract the maximum value from them.
The majority of the indicators presented have been derived from those investigated, especially in the empirical test, reviewing the fully or partially defined ones and recreating those presenting insufficient information. In addition, some new indicators have been suggested to fill gaps in existing frameworks. The whole process led to a set of 119 KPIs.

As described before, the goal of indicators is to monitor the progress of the city towards smart city goals. Thus, they must be used to assess to what extent overall goals have been reached or are within reach. Indicators may be also used to compare cities with each other. Moreover, to arrive the final set of indicators, the authors aimed at bridging both the system completeness and the KPIs design gaps identified in literature. Finally, of course also the criteria recalled in chapter 3, i.e., relevance, completeness, availability, measurability, reliability, familiarity, non-redundancy and independence, have been followed in their selection and creation. Next, the specific features of indicators are described. It must be specified that the complete set of KPIs is presented in Appendix A, while is not presented here in order to facilitate the reader in understanding the whole work. However, they must be closely analysed since they are the backbone of this final framework.

The KPIs are defined according to the following features. i) Name of the indicator; ii) Description, in particular the full description of the characteristics and boundaries of the indicator; iii) Calculation, in particular all the information that must be taken into account for the calculation and the formula for the measurement; iv) Unit or Measure; v) Perimeter of analysis, in particular the spatial scale of the indicator measurement; vi) Frequency of reporting, in particular how frequently the indicator must be updated and reported; vii) Scoring (on a scale from 1 to 5). In particular, it must be specified that this value has been added only afterwards the survey of Italian cities presented in chapter 6 and here it is explained why. The scoring is the aggregated value of three dimensions: cost of collecting the data, availability of tools for collecting the data, and capability of interacting with third parties for collecting the data. Note that since those values are clearly different for different types of cities, the proposed value could not be comprehensive for all types of cities. Thus, it is generic, and it has been evaluated on average according to the results obtained from the survey; vii) Notes, in particular additional notes regarding the nature or the evaluation of the indicator.

5.3 Overall Structure

In this section, an overall picture of the framework will be presented. This represents only skeleton of the system. In fact, as mentioned above, the key performance indicators are fully presented in Appendix A.

Pillar	Category	Subcategory	KPI
Smart Environment	Energy	Energy	Final energy consumption per capita
			Energy intensity
			Energy used in recycling
		Energy - Electricity	Electricity production per capita
			Electricity consumption per capita
			Electricity in the energy mix
			Percentage of city population with authorized electrical services
		Energy - Fuel	Fuel energy consumption per capita
		Energy – Green Energy	Renewable energy generated within the city
			The percentage of total renewable energy sources (RES) self-supply
		Energy – Storage	RES power installed
			RES storage capacity installed
			Grid storage capacity per total city energy consumption

	Energy – W2E	Percentage of city's solid waste that is treated in energy-from-waste plants
	Smart Grid and Balancing	Average number of electrical interruptions
		Average length of electrical interruptions
		Smart meters
City Planning	Risk Management	Population living in disaster-prone areas
		Natural disaster related deaths
		Disaster risk management in city planning
		Critical infrastructures
	Urban Planning	Brownfield redevelopment
		Green and water spaces
		Commercial and industrial activities
		Residential areas
		Transport areas
		Areas for social infrastructures
		Unused Areas
		Basic service proximity
		Population density
		Housing located in informal settlements
Ecosystem	Ecosystem	Number of native species
		Ecosystem protected areas
		Urban ecological footprint
		Climate resilience strategy
		Urban heat island
	Water Management	Water consumption
		Population served by wastewater collection
		Water losses
		Population with potable water supply service
		Water service interruptions
		Smart water meters
		Real-time water quality tracking
	Other Resources Usage	Domestic material consumption
	GHG Emissions	CO2 emissions
Pollution	Pollution	air quality index
		PM 2.5 concentration

			NOx concentration
			Air quality monitoring stations
		Pollution – Noise	Noise pollution
	Waste	Waste	Solid waste collection
			Municipal solid waste
			Waste drop-off centers telemetering
			Sensor-enabled public garbage bins
		Waste Recycling and Reuse	Recycling rate
			Hazardous waste recycled
Smart Living	Building Data	Building Data	Total number of residential buildings
			Total number of public buildings
			Total number of commercial buildings
			average age of the buildings
			Number of historic and artistic buildings and views
		Building Data - Energy	Thermal energy consumption of public buildings
		Building Data - Electricity	Electricity consumption of public buildings
		Building Data – Green Energy	Green "prosumer" residential buildings
			Green "prosumer" public buildings
			Green "prosumer" commercial buildings
		Building Data – Energy Storage	Residential buildings with an energy storage system
			Public buildings with an energy storage system
			Commercial buildings with an energy storage system
		Building Data – Energy Efficiency	BEMS in public buildings
			Public building sustainability certifications
			Residential buildings with "energetic class A" or higher levels
			Public buildings with "energetic class A" or higher levels
			New buildings with energetic class A or higher levels
			Buildings refurbished to higher energetic class
		Building Data – Control and Automation Infrastructure	Public buildings equipped for monitoring indoor air quality

		Building Data – People with special needs	Public buildings completely accessible by persons with special needs
			Barrier-free areas in public buildings
	Public Lighting	Public Lighting	Electricity consumption of public street lighting
			Light performance management system in public street lighting
			New installed and refurbished public lighting systems
			Number of service suspensions in public lighting
			Average duration of service suspensions in public lighting
			Maintenance costs associated with public lighting
	Condition Profiling	Condition Profiling	Durations exposure to daylight during winter
			Durations exposure to daylight during summer
			Daily average temperature registered during winter
			Daily average temperature registered during summer
Smart Mobility	Infrastructure	Infrastructure	Marked pedestrian crossings equipped with accessible pedestrian signals
			City streets covered by real-time online traffic alerts and information
			Percentage of traffic lights that are intelligent/smart
			Pedestrian infrastructure
			Road density
			Periodic maintenance of roads
		Infrastructure – Bike	Length of bike route network
			Cycle lanes availability
			Bike sharing coverage
		Infrastructure – EV Charging	Public charging stations for e-vehicles in the city area
			Public charging points for e-vehicles in the city area
		Parking Areas	Public parking spaces equipped with e-payment systems
			Public parking spaces equipped with real-time availability systems
			Length of public transport system

		Infrastructure – Public Transportation	Public transport lines equipped with a publicly accessible real-time system
			Public transport network covered by a unified payment system
			Smart proximity to public transport
	Mobility Data	Mobility Data	City commuters using a travel mode to work other than a personal vehicle
			Average commute time
			Traffic index
		Private Vehicles	Number of personal automobiles per capita
			Number of two-wheeled motorized vehicles per capita
		Green Mobility	Number of Electric vehicles (EV) registered in the city
			Percentage of vehicles registered in the city that are low-emission vehicles
		Alternative Transportation	Number of autonomous driving vehicles
			Access to car sharing solutions for city travels
			Number of users of sharing transportation per 100 000 population
		Road Safety	Traffic accidents per 100 000 population
			Transportation deaths per 100 000 population
		Public Transportation	Public transport use
			Average age of public transport fleet

Table 18 – Structure of the proposed framework

5.4 Framework Discussion

This brief final section aims at drawing the final considerations for the final version of the framework and paving the way for the next chapter.

The objective of the work and the proposed framework are extensively presented in this chapter. As explained before, the proposed framework presents great advancements in terms of system completeness and KPIs design with respect to the initial version. However, again, the advancements must be proved by the authors. That is why, the following steps are fundamental in order to provide a full understanding of the potentials for success and the results that can be obtained by the adoption of this final performance measurement framework. The natural consequence is a comprehensive test of the framework on real field scenarios, that unfortunately authors were not able to carry out due to matters of time and availability of stakeholders. However, the first step in this direction is to start to collaborate with municipalities in order to gather data regarding context specific factors, which are fundamental for practical utilization of frameworks, as explained earlier. The goal is to start using this framework in Italy, since it is the country where the authors can more easily reach interlocutors and speed up the whole process. In the next chapter, it is presented a survey of Italian cities aimed at investigating what are the main issues and factors affecting the adoption of a smart city performance measurement framework. The information gathered from the survey are fundamental to adjust the proposed monitoring framework according to the country needs, in order to better respond the current priorities and challenges of Italian cities.

6 SURVEY OF ITALIAN CITIES

The sixth chapter is fully dedicated to a survey the authors have conducted on the main issues and limitations in the application of Smart City KPI monitoring frameworks in the Italian context.
From the literature review carried out in chapter 2, it emerges that in many cases there are some context-specific factors that have to be taken into consideration during the development of KPI monitoring frameworks for Smart Cities, as they limit the range of application of the framework (section 2.3). With the survey the authors try to investigate on the main priorities, challenges and issues for Italian cities in measuring and monitoring their performances, in order to define the context-specific factors of the Italian landscape.
Indeed, since the presence of context-specific factors influences the application and validity of the framework in a specific geographical region, the aim of chapter 6 is to define the main issues and limitations in the application of KPI monitoring frameworks for the energy pillars of Smart City in the Italian context, considering as targeted audience the main actors involved in the development, implementation and monitoring of the Smart City energy solutions in Italian cities and towns in year 2020. Once identified the main peculiarities of the Italian context, the authors' proposed framework can be effectively tested Italian cities. However, the testing phase of the framework in Italian cities has not be done by the authors of the work yet and can be considered as an avenue for future research.

The chapter begins illustrating the object of research, the targeted audience of the survey and the survey structure. A clear description of the methodology followed in the development and application of the survey is reported, explaining how the recipients of the survey have been selected and contacted. In addition, the questions that have been addressed to the recipients are also showed, with a reference to the specific literature gap that is object of the analysis.

Then, a precise analysis of the results of the survey is carried out, starting from each specific question and the considerations that emerge from the related answers. Cities are divided in 3 categories according to their size (e.g. number of inhabitants), since they may have different issues in the monitoring of Smart City energy aspects.

Finally, the overall marks that the survey arises are reported and discussed, highlighting the main difficulties for Italian cities in measuring and monitoring Smart City performances.

6.1 Objectives, targeted audience and structure of the survey

6.1.1 Objective of the survey

The survey has been developed by the authors of this work, in collaboration with the Energy&Strategy Group of Politecnico di Milano. It is composed of different sections, corresponding to the different issues that are today hampering the diffusion and implementation of KPI monitoring frameworks for Smart Cities in the energy pillars, therefore in Smart Environment, Smart Living and Smart Mobility.

The main goal of the survey is to assess which are the main issues in the application of KPI monitoring frameworks for Italian Cities, according to the actors that in 2020 have been responsible of one or more aspects related to the energy pillars of the Smart City. The survey enables the authors to identify the context-specific factors of the Italian landscape that influence the applicability and validation of the proposed monitoring framework, as reported in chapter 2.3 regarding the existing difficulties in extending the geographical range of application of a framework. After the identification of the main peculiarities of the Italian context, the framework can be effectively tested and implemented by Italian cities, and the actual implementation of the framework in Italian context can be considered as an avenue for future research.

The main objects of evaluation are the current gaps of literature regarding monitoring frameworks as KPI design, data availability and stakeholder involvement, that have been found the literature and assessed in chapter 2.3. In particular for **KPIs design** the issues investigated regard mainly applicability of the measure, data interpretation and KPI conditions, while for **data collection and availability** the main gaps object of the survey are difficult data collection and inaccurate or unavailable data. Furthermore, for the gap of **stakeholder involvement** it is investigated in which way the city deals with external data owners, such as public or private companies and statistics entities. For each of the identified gaps, the aim is to assess how much the issue is relevant and in which specific Smart City energy pillars and subcategories it mainly occurs, according to the different experiences of the Italian cities that took part to the survey.

6.1.2 Targeted Audience

The targeted audiences of the survey are the actors responsible of the Smart City projects in Italian Cities, especially for the energy aspects, therefore environment, living and mobility.

The authors considered cities of different sizes and belonging to all geographical areas in Italy, starting from the metropolitan cities and the capital of each Italian province, to arriving to each single town and municipality.

Different ways have been followed for the diffusion of the survey, dividing all the municipalities in Italy in 2 categories:

- Category 1: metropolitan cities and the capital of each Italian province (107 cities);
- Category 2: all the remaining cities, towns and municipalities in Italy.

For cities belonging to category 1 the authors looked for the direct contacts of the actors responsible of implementing Smart City projects and measuring the performances. It has been possible to identify the persons currently in charge of these responsibilities and their related contacts looking on the municipal website of each of the selected 107 cities. In particular, for actors responsible of Smart City energy aspects, different roles have considered inside the city, which belong to two different streams:

- **Members of the Municipality** with a delegation on Smart City themes or on energy aspects of the city, in particular figures such as city mayors, executives, secretary-generals and assessors to mobility and/or environment, environmental sustainability, infrastructure, waste, energy, urban planning, urban health, public green areas, innovation, digital transformation;
- **Heads of city departments** responsible of Smart City development or of energy aspects of the city, in particular figures such as general directors, secretary-generals, heads and managers responsible of Smart City and/or urban planning, environment, environmental sustainability, ecology, mobility, public lighting, infrastructures, waste, energy, digital transformation, public affairs.

There have been collected from 2 to 5 contacts for each of the 107 metropolitan cities or capitals of each Italian province, in order to cover the majority of the Smart City energy aspects and have more probability of receiving a feedback. These figures have been contacted personally through e-mail. In total, 319 different persons were contacted, firstly in August 2020 and then again in October 2020 for the ones that did not replied the first time. In the end, 58 out of these 319 contacts replied to the survey, corresponding to 20 out of the 107 cities contacted. 15 of the recipient cities belong to the North part of Italy, 2 cities are in Central part of Italy and 3 cities are present in the South.

For the remaining Italian cities, towns and municipalities, that belong to category 2, it was unfeasible to identify each person responsible of one or more energy aspects of Smart Cities. Therefore, the authors used a free-public access database containing 1 reference e-mail for each Italian single municipality, in particular the related certified electronic mail (PEC). The database can be found on the website page of the portal "Italia in dettaglio", in section "e-mail e PEC dei comuni italiani" (Reti e sistemi 2019).

After having found the database on the website, the following Visual Basic function has been used in order to obtain the data on Microsoft Excel:

```
Public Function Estrai_Indirizzi (ByVal Collegamento As Excel.Range)
Estrai_Indirizzi = Replace(Collegamento.Hyperlinks(1).Address, “mailto:”, “”)
End Function
```

The survey was sent to these PEC mails in September 2020. As the contacts were just reference mails and they were not addressed to a specific person responsible of Smart City aspects, just 28 answers out of 7890 contacts of the database have been received. Moreover, it is clear that the majority of small size towns may not implement Smart City projects and/or keep track of related performances. However, these further answers undoubtedly enriched the survey, since in this way the sample is very various, with a mixture of big and small-size Italian cities and municipalities.

The authors decided to address the survey only to Italian cities and towns because the aim is to assess the context-specific factors that especially characterize the Italian landscape. Moreover, since all the targeted audience is composed by Italian speakers, the survey is written in Italian language. In the end, the authors managed to contact and receive feedbacks from 32 cities and municipalities which totally account for 4.9 Million of inhabitants, corresponding to the 8% of total Population in Italy. For this reason, the results of the survey can be considered robust and reliable, therefore a relevant source of information for additional analysis.

6.1.3 Survey Structure

The survey is composed by **8 Sections**, in which there is one or more questions depending on the previous answers. The sections are referred to current gaps of monitoring frameworks that arise in KPI design, data collection and availability and stakeholder involvement, which have been found and reported in chapter 2.3.

In particular, for each section it is assessed whether the identified gap is effectively a recurrent issue for the city in the implementation of the monitoring framework, in which Smart City pillars and subcategory of the proposed framework the issue is mostly relevant, and the main reasons of the reported difficulty.

In **section 1** it is assessed whether there is difficulty in data collection for KPI implementation, in which specific subcategories it is the most complex to collect robust data and whether this difficulty is determined by the absence of reliable tools and devices for data collection and measurement. For a precise and rigorous data collection it is fundamental to have accurate infrastructure available, that can properly store historical values and analyze the variations in different time series. The expectation is that not all the Italian cites can benefit from a reliable data collection system.

This section is referred to the current literature gap of **data collection and availability**, which emerges both in chapter 2.3. In particular the section investigates on the issues of difficult data collection and inaccurate or unavailable data.

In **section 2** there is again a reference to the difficulty in data collection of KPI implementation. It is wondered if the problems related to data collection are caused by the expensiveness of the data collection system. Actually, the authors imagine that not all the cities can stand the demand needed to punctually measure and keep track of the performance of the city, in terms of money, time and resources allocated. In the section it is also investigated in which specific energy pillars and subcategory the issue is mostly relevant.

This section is linked with the current literature gap of **data collection and availability**, regarding the issues of difficult data collection and inaccurate or unavailable data.

Section 3 assesses whether there is a difficulty in the interaction with third-party entities which are the owners of the data the city needs to measure the indicators. Third parties are mainly transmission system operators (TSO), distributor system operators (DSO), other private or public companies, public entities, statistics entities and citizens, therefore stakeholders that the members of the Municipality and the heads of city departments have to deal with in order to obtain useful data for the measurement of the KPIs. The expectation is that it is not always easy to interact with the data owners, since they might be not interested in divulgating the data. In the section it is investigated also the main reasons at the basis of this issue.

This section refers to the limitations regarding the gap of literature **stakeholder involvement**, a theme described in chapter 2.3.

In **section 4** it is wondered if the way in which the data is collected is coherent or not with the KPI conditions and specifications. In order to become useful information, data has to be precise, punctual and well-determined. Only the expressed data is required for the KPI calculation, and it has to refer to the right time period and space which is object of analysis. This is fundamental in order to guarantee standardization of the KPI framework, avoid problems of measure interpretation and facilitate comparability with past years or with different cities.

This is connected to 2 existing issues that emerge from the review and analysis presented in previous chapters. For sure, it is connected with the gaps in **data collection and availability**, since inaccurate and not coherent data are a common problem evidenced in data collection and availability. It also involves the gaps in **KPIs design**, in case the data collected is incoherent with the timeframe required by the indicator conditions and specifications. Furthermore, an inconsistent implementation of the indicator hampers its correct interpretation and comparability with other cities.

In **section 5** it is investigated whether cities exclusively use internal sources of data for the computation of the indicator, in order to overcome issues related to stakeholder involvement. It is also assessed for which specific energy measures the exclusive use of internal sources of data is the most recurrent.

This section refers to the existing gaps in **data collection and availability**, in particular the difficult data collection, and with the difficulties in **stakeholder involvement**.

Section 6 evaluates which measurement systems are mainly adopted by cities for data collection, in case data collection is done through internal sources. In particular, there are two possible types of solutions that cities can adopt:

- The use of simple measurement devices, such as sensors;
- The implementation of a real monitoring system, mainly through software applications.

This is again connected to the existing gaps in **data collection and availability,** referring to the difficulties in data collection, as described in chapter 2.3.

Section 7 is instead focused on the utilization of external data sources for data collection and the implementation of the indicator. It is assessed which are the actors that cities have to interface in order to get the required data. The expectations are that in many cases the use of external data sources is necessary, otherwise the indicator results very complex and onerous to calculate.
This section referred to the existing issues in **stakeholder involvement**.

Finally, **section 8** investigates on the main criticalities related to the development and implementation of a framework of indicators for Smart Cities. It is assessed whether there are problems in defining the correct formula of one or more indicators and whether there are issues of interpretation of the measure in an objective way. It is also questioned whether there are issues in the comparability of the indicators among different cities.
This section is related to the issues in **KPIs design**, in particular with limits such as applicability of the measure and data interpretation.

The table below summarizes the different parts that compose the survey and which limits described in chapter 2.3 each section refers to.

Section	**Question**	**Gap investigated**
1	Absence of reliable tools and devices for data collection	Data collection and availability
2	Expensiveness of the data collection system	Data collection and availability
3	Difficulty in the interaction with third parties	Stakeholder involvement
4	Incoherency between data collected and KPI conditions	KPIs design, Data collection and availability
5	Exclusive use of internal sources of data	Data collection and availability, Stakeholder involvement
6	Adoption of internal measurement systems	Data collection and availability
7	Inclusion of external sources of data	Stakeholder involvement
8	Difficulty in KPI design and use	KPIs design

Table 19 – Description of the survey sections

6.2 Analysis of Results

In this section the results of the survey are reported and analyzed, considering each part separately. For each part, it is reported not only the overall feedback received, which considers all the answers received from all the different cities and municipalities that took part to the survey, but also the different results considering 3 different groups of municipalities and cities, divided by the size (e.g., number of inhabitants):

- Group 1: small to medium size municipalities: this includes all the municipalities that have contributed to the survey and that have less than 50 000 inhabitants;
- Group 2: medium to big size cities: this includes all the towns and cities that have contributed to the survey and that have between 50 000 and 250 000 inhabitants;
- Group 3: big size cities: this includes all the cities that have contributed to the survey and that have more than 250 000 inhabitants.

For some of the issues object of investigation, in the related section it is reported also the subcategories of the authors' proposed framework in which the issue is particularly evident, according to the recipients. In this way it is possible to punctually adjust the indicators of the proposed framework that belong to a subcategory, on the basis of the issues reported by the survey regarding that subcategory, and effectively test the framework in the Italian context in real cases.

Section 1: Absence of reliable tools and devices for data collection

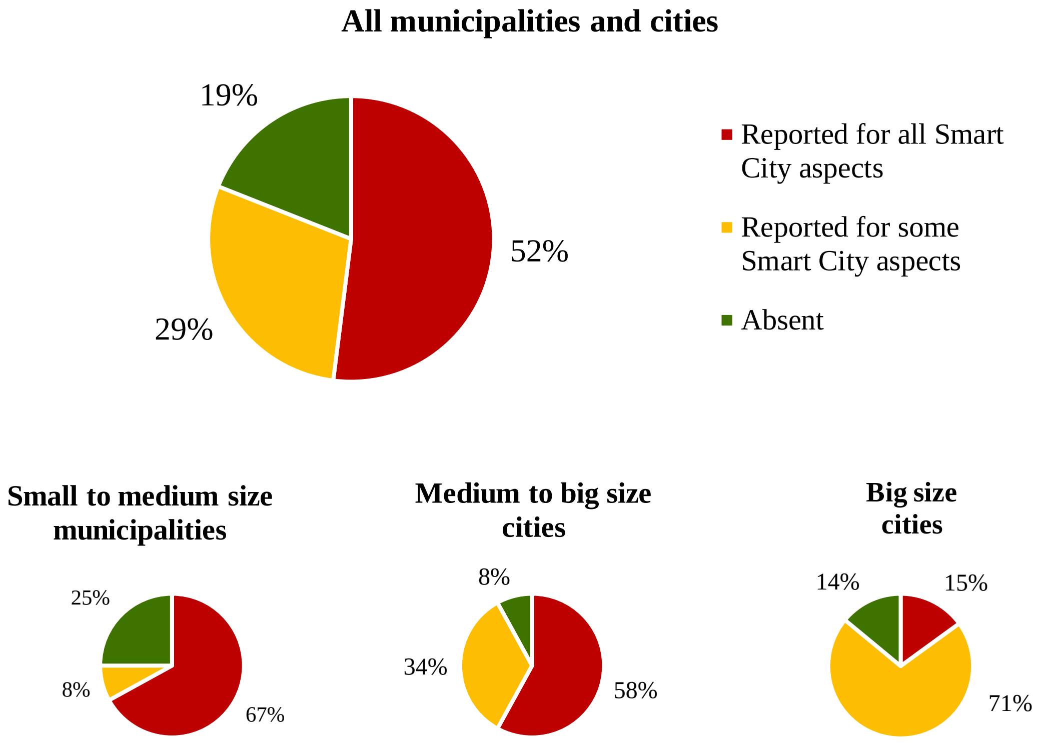

Figure 10 – Results of section 1 of the survey

Considering all the sample analyzed, for more than 80% of the municipalities and cities there is a difficulty in data collection, caused by the unavailability of reliable and consistent tools and devices for data measuring and collection.

This issue is particularly evident in small to medium municipalities, while it is less impactful in bigger urban centers. This is because big size cities may have more resources involved and dedicated to Smart City monitoring frameworks and can usually benefit from the latest technologies available, which indeed offer the most efficient services.

This criticality is reported for all Smart City aspects in more than the 50% of the municipalities and cities interviewed.

In some cities the issue is not reported for all Smart City aspects but just to some of them. In particular, this problem is particularly redundant for indicators referring to subcategories Energy and Energy efficiency of Smart Environment and to subcategory Mobility Data – Public transportation of Smart Mobility.

Section 2: Expensiveness of the data collection system

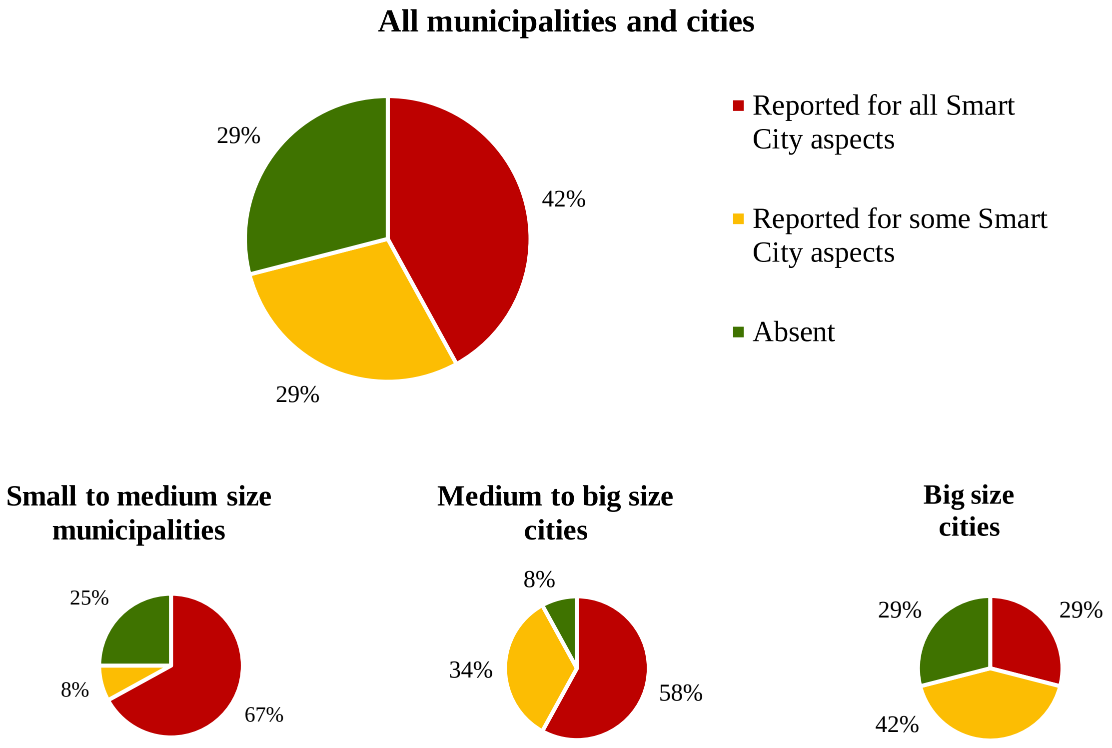

Figure 11 – Results of section 2 of the survey

More than 70% of the sample analyzed reports that the data collection system is too expensive in terms of money and resources to allocate, causing difficulties in data collection and measurement of defined indicators.

In line with part 1, this issue is particularly redundant in small to medium municipalities, while it is less evident in bigger cities. This is because big size cities can undoubtedly invest more money and resources to Smart City monitoring systems, while small town may have limited budget available and dedicated for data collection systems.

This criticality is reported for all Smart City aspects in almost half of the municipalities and cities interviewed.

In some cities the issue is not reported for all Smart City aspects but just to some of them. In particular, this problem is particularly recurrent for indicators referring to the subcategory Energy – Electricity of Smart Environment and for indicators that refer to subcategories Mobility data and Mobility data – Public transportation of Smart Mobility.

Section 3: Difficulty in the interaction with third parties

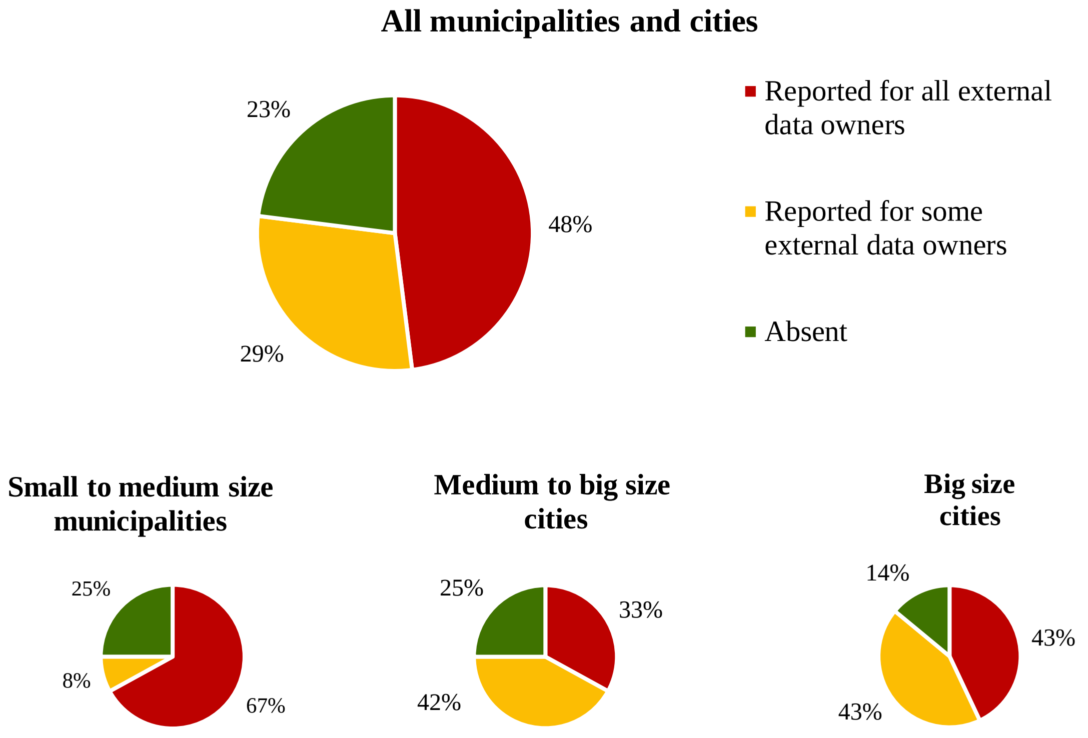

Figure 12 – Results of section 3 of the survey

From part 3 of the survey, it emerges that in the 77% (48% + 29%) of the cases there are issues in the interaction with third parties that are external data owners, as transmission or distributor system operators (TSO or DSO), private or public companies and statistics entities.

In general, there is low interest of private companies in collaborating with public entities, due to different objectives and priorities. In fact, private companies may consider this collaboration a no-value-added activity, as it required dedicated time and resources and brings low or no economic return. The main challenging themes are the concept of data ownership and the lack of a national or regional legislation that can provide the necessary support for data management and exchange. Moreover, the cost of the infrastructure needed for a periodic or real-time exchange of data between the municipality and third parties is an additional hurdle to this collaboration.

This issue is less predominant the bigger the municipality is, probably because external data owners are more willing to cooperate with big size cities, in order to get more return in terms of visibility and image. For instance, having cooperated with a metropolitan city for the measurement of energy consumption may be a major source of advertising for the private company, compared to cooperate with a small municipality.

Section 4: Incoherency between data collected and KPI conditions

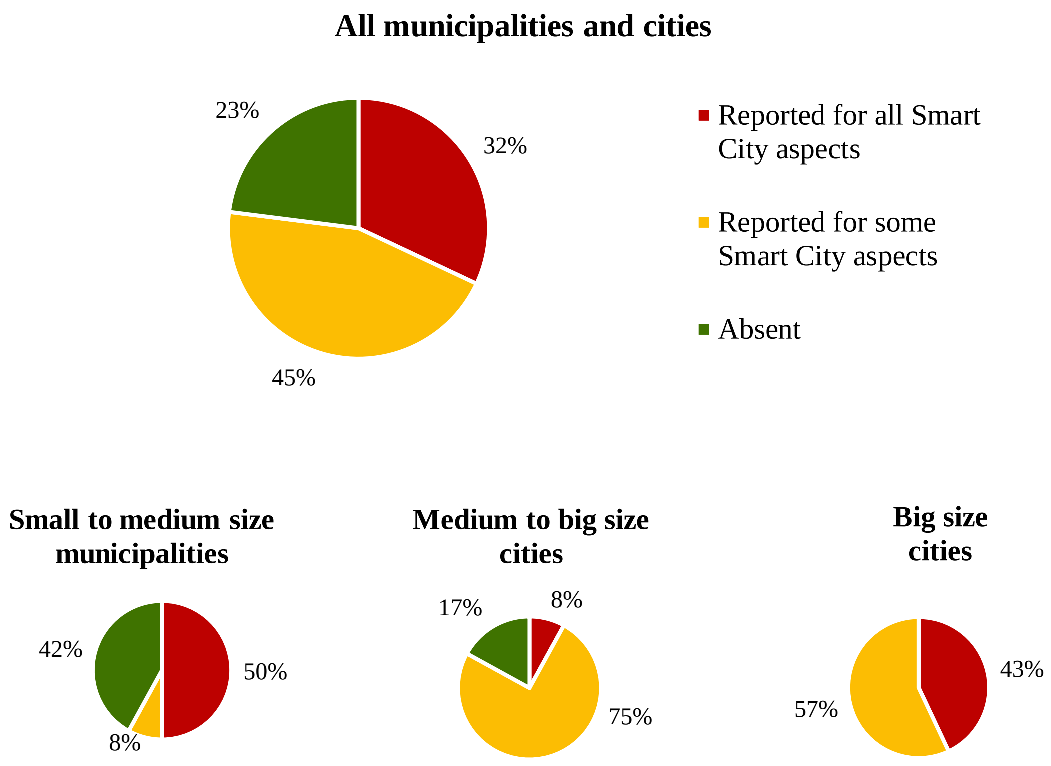

Figure 13 – Results of section 4 of the survey

The way in which data is collected is not coherent with the indicator conditions and requirements in more than 75% of the sample analyzed, and it is particularly relevant for big cities.

Of course, at the basis of this issue there can be different gaps, which range from a weak data collection system, in which data collected are not the ones that are required, or it may occur due to gaps in KPI design, if the measure is not clearly defined and leads to subjective interpretations, that hamper comparability among cities. It may be also a problem of time relevance, if data collected are not referring to the same time frame the indicator aims to measure and there is not a standardized frequency of reporting of the indicator.

This problem is particularly recurrent in indicators of Smart Environment referring to subcategories Energy – Electricity, Ecosystem – GHG Emissions and Pollution, and for Smart Living indicators that refers to subcategory Building data – Electricity.

Section 5: Exclusive use of internal sources of data

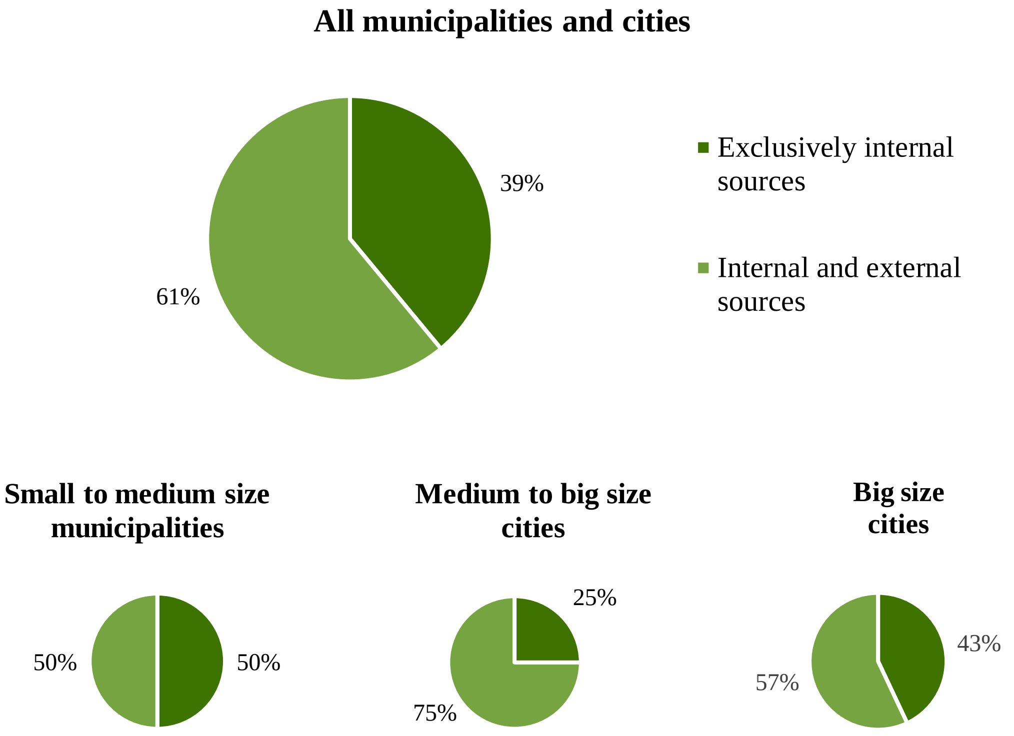

Figure 14 – Results of section 5 of the survey

Almost 40% of the municipalities and cities that took part to the survey use only internal sources of data for the calculation of the indicators.

This percentage is really higher than the authors' expectations, considering that data owners are often third parties external to the members of the municipality and the city department, therefore interaction with them is often necessary and/or the quickest way to obtain the needed measure.

The main threat is that cities that only use internal sources of data for monitoring Smart City performances may not have a comprehensive view of all the aspects related to Smart Cities, since they may not have all the data required for a broader and more complete perspective.

According to the survey there is not a common trend for which this situation is more common, if compared to the number of inhabitants of the city or municipality.

The Smart City areas related to energy measures in which this situation is more recurrent are the subcategories Energy, Green Energy and Urban Planning for Smart Environment, subcategories Building data – Energy and Building Data – Control and Automation Infrastructure for Smart Living and subcategory Mobility Data for Smart Mobility.

Section 6: Adoption of internal measurement systems

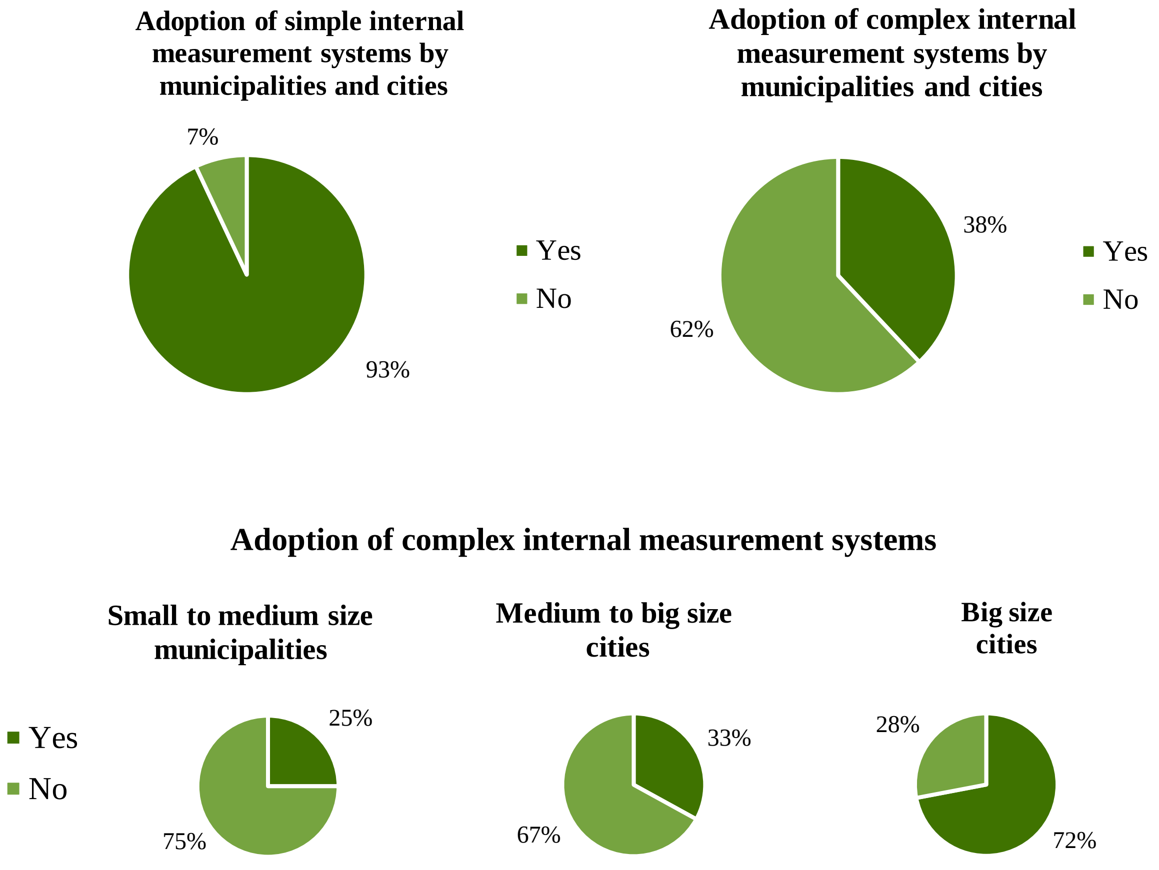

Figure 15 – Results of section 6 of the survey

Due to the issues related with the interaction with external data owners, municipalities and cities have activated iniativies and procedures for the direct collection of data needed for the indicators measurement. From the survey it emerges that almost every city and municipality (93% of the answers) has adopted simple internal measurement systems, which aim just at the data collection and not to the actual implementation of a monitoring systems. The use of simple internal measurement systems is very spread, regardless of the size of the municipality or city. The most common measurement systems for the data collection are sensors (up to 52% of the cities adopting) and manual control devices (14% of the city adopting).

In addition to or instead of simple internal measurement systems, the 38% of the cities and municipalities have adopted complex internal measurement systems, since they have installed monitoring platform for data collection, storage and reporting, mainly through appropriate software and infrastructure that permit on-time data monitoring.

The implementation of complex internal monitoring systems is more spread in big size cities.

Section 7: Inclusion of external sources of data

From the survey it is reported that the 61% of the cities and municipalities currently use external sources of data for the calculation of Smart City performance indicators.

According to the results, the number of third parties that provide useful data related regarding Smart Environment, Smart Living and Smart Mobility to the municipality and city departments is very various. Data owners can be divided in the three following categories:

- **Public companies**, among which there are mainly reported municipal utilities, water management companies, waste management utilities, sanitary entities, public transport companies and subsidiary companies;
- **Private companies**, such as utilities or energy providers, private research centers and private entities;
- **Public and/or statistics entities**, such as regions and provinces, national Ministries, public universities and research centers, GSE (“Gestore dei Servizi Energetici”), national databases, firms’ databases and ISTAT (“Istituto Nazionale di Statistica”).

From the survey it emerges that small and medium municipalities have frequent difficulties in the interaction with third parties that are data owners, while these issues are less relevant in bigger cites. In particular, the main hurdles are reported in the interaction with private companies, and this criticality is regardless of the size of the city. Instead, public and/or statistics entities such as universities, research centers and ISTAT are usually more willing to collaborate, even though universities and research centers are often not the real owners of the data and may need additional data and information from national or regional databases, utilities and public entities.

Section 8: Difficulty in KPIs design and use

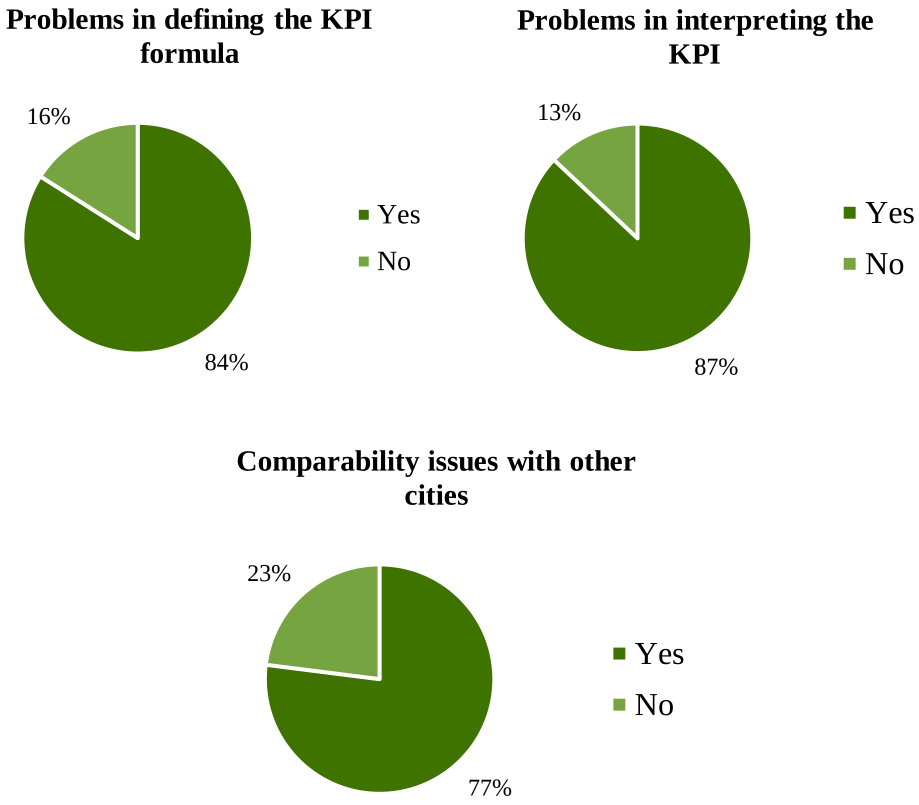

Figure 16 – Results of section 8 of the survey

From the survey it emerges that all these issues related to KPI design are widely spread in the Italian context.

In particular, the 84% of the answers reported to have problems in defining the correct formula for the indicator, which is related to the issues of KPI definition and applicability.

The 87% of the answers have encountered problems in the correct development of the indicators, in order the measure to be easily understandable and objective. This value certifies the problems of subjectivity of the indicators, which should be defined in a standardized manner.

Finally, the 77% reported problems during the implantation and usage phase, in particular in comparing measures and results with other cities. This value assesses the limitations in comparability of the indicators among cities which differ per size, geographical areas and/or different priorities.

There is not a common trend between size of the municipality and the diffusion of these issues.

6.3 Overall considerations

The survey reports diffused interest from Italian cities and municipalities in implementing monitoring systems for Smart Environment, Smart Living and Smart mobility.

However, the high level of interest is not supported by an adequate level of implemented monitoring systems and reference frameworks.

Cities and municipalities find relevant issues in the collection of data need for the implementation and calculation of the Key Performance Indicators for Smart Cities in energy aspects.

The gaps related to data availability and collection are mainly related to:

- Absence of reliable tools and devices for data collection, often due to outstanding costs associated for their procurement and implementation; Undoubtedly, medium and big size cities have more sophisticated and efficient monitoring systems compared to small municipalities.
- Recurrent difficulties in the interaction with third parties, which are the owners of the data needed for KPI implementation and calculation and that are rarely willing to collaborate with municipalities and city departments. In particular, this issue is more evident in small municipalities.

Another issue reported is the lack of a national or regional legislation, that shall provide guidelines for the process of mapping, elaboration and management of data and related measures. This current absence hampers data collection and the subsequent development of a framework of indicators.

In addition, the survey certifies a lack of standardization in the definition and implementation of indicators, due to the absence of a univocal reference framework for monitoring energy aspects in Smart Cities. This issue is at the basis of inconsistent data collected, problems in defining KPI formula, subjective measures and impossibility in comparing indicators among different municipalities and cities.

With this consistent analysis, the authors identify the main issues for Italian cities in the implementation of monitoring frameworks for energy pillars of the Smart City. These considerations are very useful for actually test the framework in real cases in Italian cities, considering the context-specific factors that emerge from the analysis, in order to properly validate the framework. However, the practical testing phase has not been done by the authors yet and can be considered as a possible avenue of further research.

7 CONCLUSIONS

This chapter marks the end of a long and incredible journey through the open water of smart cities performance measurement systems. Let's now recapitulate the main phases of such voyage. First, it should be recalled that the authors portrayed the incredibly vast concept of smart city, describing its facets, the main challenges of a city and the importance of a performance measurement system. Intrigued by such themes, particularly by the latter, the authors deep dived into smart cities literature. The result of such diving experience gave birth to **chapter 2**, where the features characterizing a performance measurement system are extensively explained. In addition, several gaps emerged from the literature review, raising fundamental points and, in turn, leading to the research questions and objectives. The acquired in-depth knowledge of the whole, allowed the authors to present, in **chapter 3**, a first theoretical framework for monitoring energy performances aimed at answering those questions. In order to prove the advancements brought to theory and validate the proposed model, the framework itself has been tested and validated in **chapter 4**, throughout a deep dive into the main empirical projects carried out by international institutions and organizations. Furthermore, this phase shed light on additional peculiarities and lessons learnt, enabling the authors to revise the theoretical framework, enriching and improving its design and potentials. This brought to life the final performance measurement system developed by the authors, whose logic and value are expounded in **chapter 5.** The inherited learning allowed the authors to properly set up and conduct a survey in order to comprehend the peculiar traits of the Italian big picture, examining the problems perceived by Italian cities and paving the way for testing the framework on real field scenarios. The survey is illustrated in **chapter 6**. Before officially sealing the work, it is important to evaluate the overall contribution that the built smart city framework brings to methodology and practice. The other side of the picture must be discussed too, consisting in the limitations and lacunae of the work. Finally, the avenues for future research originated from limitations and opportunities of development are also indicated.

7.1 Theoretical Contribution

The research design carried out in this work makes many interwoven methodological contributions to the academic literature related to smart cities performance measurement systems. The goal of this section is to present them, sometimes recalling some concepts presented in previous chapters.

First, the set of collected primary data and information is, on average, broader and more detailed than those used in previous studies. The database created according to the literature review accounted for 37 assessed schemes and a total number of 1292 key performance indicators. A particular contribution brought is also related to the multiple levels of analysis, which guaranteed the deeper insights and a comprehensive view of the phenomenon. In fact, the examined systems were of two different types. On one hand, those focused on specific aspects and areas of a city and providing very specific information. On the other, those aiming at addressing the whole picture of a city. Moreover, also the testing phase must be considered, which allowed the authors to base their work on an overall number of 54 frameworks analyzed and 2612 KPIs. This provided a vast understanding of the whole structure and peculiarities characterizing smart cities frameworks.

Then, it must be discussed the whole work contribution to the gaps identified in literature, which raised the real need of a novel performance measurement framework. First, the authors' model brings significant improvements in terms of **system completeness** at both levels. The final framework encompasses a comprehensive set of city areas for energy pillars that must be assessed, achieved in first place by the initial version of the theoretical framework and revised and advanced with its final development presented in chapter 5. The spheres identified are composed by 119 key performance indicators. This relevant number of KPIs is fairly higher than that of existing literature systems, on average, and allows for a broader perspective on the energy-related performance of smart cities. Thus, the steps forwards achieved in terms of completeness, obtained thanks to the incredible amount of data and information from which the proposed performance measurement system stems from, has two main resulting benefits. The first is related to the city awareness of the detailed measures to be reported and monitored, as will be discussed later. The second is the intrinsic effect of accelerating the process of creating a system which is as much as possible comprehensive.

Second, the indicators forming the framework were selected and created in order to address the problems related to the **KPIs design.** In fact, the strict set of criteria extensively described in chapter 3 has been followed in order to arrive to a final set of indicators. To quick recap those criteria, they were relevance, completeness, availability, measurability, reliability, familiarity, non-redundancy and independence. In addition, particular attention was paid to the time relevance, subjectivity and overlapping issues. In fact, indicators provide a clear definition of time boundaries of measurement and require specific different frequencies of reporting. Moreover, they are created in order to face another gap present in the existing frameworks, which is the subjectivity issue. Thus, KPIs are classified and constructed in a way that the boundaries of definition and calculation are fully objective. Finally, the design of indicators was carried out in a way that ensures no overlapping issues between two or more measures. Thus, the boundaries of definition and calculation of KPIs must not lead to the same measurement of data. However, complete independence in measurement must be proved by testing it on a real scenario since it can happen that some indicators could lead to the measurement of same data, at least partially. The same consideration must be done for the additional challenge of incomplete measure identified in the empirical analysis. That is why they will be specified within limits and avenues for future research.

Finally, the last literature gap addressed by this work is the **involvement of stakeholders**. In fact, thanks to the survey of Italian cities a first contact with municipalities has been made. However, it is more a matter of framework practice, that is why is extensively described in the next section.

Unfortunately, as reported in previous chapter, this work is not able to address further theoretical challenges identified in literature. The table below provides an overview of the gaps targeted and facilitates the reader in approaching the section 7.3 of limits and avenues for future research.

Gap	**Status**
System Completeness	Addressed
KPIs Design	Addressed
Range/Scale of Application	Unaddressed
Framework Testing	Unaddressed
Data Collection and Availability	Unaddressed
Stakeholder Involvement	Partially Addressed

Table 20 – Literature gaps addressed outlook

7.2 Contribution to Practice

After having delineated the theoretical contributions brought during the whole project, it is important to outline also the contributions made by the built performance measurement system to its applications into real field scenarios. The goal of this section is to present the contributions to practice, sometimes recalling some concepts presented in previous chapters.

The whole work represents the attempt to construct a performance measurement system that supports the speeding up of wide-scale deployment of smart city solutions and services in order to create impact on major societal challenges around the climate strategies and targets and the continuous growth and densification of cities. However, it must be understood that this framework doesn't aim or pretend to be a complete and ultimate solution. This is not only because this work is not fully exhaustive and presents limitations, as it will be extensively described in the next chapter, but also because as experienced in human and urban history, the concept of city is destined to evolve and will always present new challenges to be faced by civilizations. That is why, such work, wants to be the starting or mid stage of a process of continuous improvement aimed at fostering and accelerating the transition towards smart cities. Thus, the first practical contribution is the provision of a consistent framework to be applied by cities to learn from each other, create trust in solutions and monitor their progress. In doing this, the framework targets two main groups:

- Decision makers at city level who must design the smart city strategy over time and monitor the city transition. In fact, it can be applied by municipalities with different characteristics (e.g., geographical area, demography) with a more or less developed smart city strategy and regardless of whether it already adopts a measurement system or not.
- National governments and other bodies (e.g., European ones), that must design the smart city policies. It has also the responsibility to monitor the effect of their smart city policies on the overall attention to the designated targets. In addition, it uses indicators to compare cities.

Of course, the proposed indicators could also be used by other groups of interest, such as educational institutions and businesses. For citizens, the indicators may be powerful tools for understating the impacts of cities' initiatives. Furthermore, it must be noted that some parameters, such as the national peculiarities, the geographical area and the size, inevitably influence the strategy of cities. Therefore, to assess the feasibility and the chances of success of the proposed measurement system, some background parameters should also be considered.

The second practical contribution consists in the beginning collaboration with municipalities in order to test this framework. The objective is to start using this framework in Italy, since it is the country where the authors can more easily reach interlocutors and speed up the whole process. Thus, in chapter 6 it is presented a survey of Italian cities aimed at investigating what are the main issues and factors affecting the adoption of a smart city performance measurement framework. The information gathered from the survey are fundamental to adjust the proposed monitoring framework according to the country needs, in order to better respond the current priorities and challenges of Italian cities.

7.3 Limitations and Avenues for Future Research

While the contributions have already been made clear, it is equally important to be transparent about the limitations of the work. The first goal of this section is to present them, while the thorough picture is captured by even going through the avenues for future research. In fact, in this final section, the authors look also ahead to the future to assess paths of improvements and further developments. In fact, although the proposed framework helps advance the theory and gives a valuable tool to practitioners, much remains to be done, since important issues that would deserve special attention have not been adequately investigated yet. In particular, there are several lines of inquiry springing from the overall research which need to be addressed in order to enhance the value of the proposed framework.

The first limitation is related to the boundaries of the performance measurement system and subsequently the **system completeness**. In fact, the proposed framework is focused on the energy pillars of the smart city, therefore Smart Environment, Smart Living and Smart Mobility. The implication of such peculiarity is that the model cannot be applied to all the areas of the city, but for now it must be narrowed to the areas of interest. Therefore, a primary avenue regards the completion of the performance measurement system with the key performance indicators for the other three smart city pillars that remained unaddressed in this project. Thus, the realization of the indicators of Smart Economy, Smart Governance and Smart People are fundamental objectives to be pursued by future works. However, the importance of such pathway is grander. In fact, as marked out before, this work must be the first or N of a continuous improvement process. The categories and indicators composing the system must be periodically updated and renewed according to the cities needs and challenges.

The second limitation is related to the **design** of key performance indicators. In fact, as described in the previous sections of this chapter, despite numerous advancements has been brought to the frameworks existing in literature, the overlapping issue cannot be considered fully solved. In fact, complete independence in measurement must be proved by testing it on a real scenario since it can happen that some indicators could lead to the measurement of same data, at least partially. Thus, another avenue for future research regards the further investigation of the overlapping issues together with the additional design problems spotted during the testing phase presented in chapter 4, namely those related to the complete measure and the interpretation and comparability of indicators. Moreover, it must be noticed that the room for improvement concerning the composition of indicator is significant. In fact, through their practice more and more details, such as strengths and weaknesses, target and benchmark, expected accessibility and so on, can be added in order to provide a more comprehensive understanding of measures and benefits in decision making.

The other limitation of the work regards the **testing** phase of the framework on a real field scenario. In fact, since the proposed performance measurement system has not been tested, it might lack of complete validation, which means that its actual usefulness must be still endorsed by practitioners. However, the authors believe that, based on how the whole work has been structured and carried out, the proposed framework provides a valuable strategic tool for practitioners, who can especially appreciate its clarity, profundity, and applicability. Of course, the gaps of **data collection and availability** and **range/scale of application**, which are strictly dependent on tests, have still not been addressed. Thus, the future works should test this framework starting from Italian cities in order to further examine the just describe issues and improve the proposed model.

Finally, the last limitation is related to the relatively small number (i.e., 32) of cities that participated in the survey. As described in chapter 6, these cities account for approximately 4.9 million people, about the 8% of the country population. Despite the relevant amount of data gathered, this limitation does not allow to have a complete angle on the Italian picture. Therefore, since the proposed framework has not been developed in collaboration with the municipalities and it has not been tested, the issue related to the **involvement of stakeholders** is not solved and must be further addressed. Thus, future works should aim at starting a process of progressive adjustment and improvement of the framework according to the needs and challenges of municipalities in order put it into practice. Clearly, the room for improvement are incredible. First Italian cities must be involved, on the basis of the context-specific factors identified, then the European ones, and successively new horizons can be explored.

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APPENDICES

APPENDIX A: SMART CITY INDICATORS

1. Smart Environment

1.1. Energy

KPI n 1	**Final energy consumption per capita**
Description	This indicator assesses the final energy consumption of the city taking into account all forms of energy (e.g., electricity, gas, fuels) and for all functions monitored by the city (public transport, buildings, ICT, industry, etc.). The final energy consumption is the energy actually consumed by the end-user. This in contrast with primary energy use, 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, a more common indicator for evaluating energy consumption.
Calculation	Total use of final energy (MWh) within a city divided by the number of residents in city. The result indicates the total energy consumption per year in megawatt hours per capita. The calculation of the indicator can be facilitated from breaking down the energy consumption of various sectors (e.g., buildings, transport, industry, etc.). All forms of energy need to be taken into account, including electricity production, natural gas or thermal energy for heating and cooling and fuels. These will be given in different units of energy (kWh, GJ, m3), but they all have to be calculated or converted to MWh of energy in order to be able to sum up the separately calculated energy generations and achieve the total energy consumption of the city.
Unit of measure	MWh/capita/year
Perimeter of analysis	City
Frequency of reporting	Yearly
Scoring	4
Notes	This indicator has a quite complex calculation. That is why it might not be always possible to calculate it at city scale.

KPI n 2	**Energy intensity**
Description	Energy intensity is the ratio between gross inland energy consumption (GIEC) and PPP (power purchasing parity) gross domestic product (GDP), calculated for a calendar year. The indicator measures the energy consumption of an economy and its overall energy efficiency. Cities with more energy intensity per local GDP means that they consume more energy to produce the same amount of goods measured in GDP units.
Calculation	GIEC is calculated as the sum of the gross inland consumption of the five sources of energy: solid fuels, oil, gas, nuclear and renewable sources. It is measured in 1000 tons of oil equivalent (ktoe), while GDP is expressed in millions of euros at the current year market prices. The alternative, in order to monitor trends avoiding the impact of inflation, could be to express GDP at a reference year market price (e.g. 2010, 2020).
Unit of measure	ktoe/mln euros
Perimeter of analysis	City (or Nation)
Frequency of reporting	Yearly
Scoring	5
Notes	This indicator has a really complex calculation and implies a very well-structured data collection system. That is why it is designed more for future evaluations, while nowadays its measurement might be more feasible at national scale. Moreover, it must be specified that cities with similar economical structures must be considered in comparing this indicator. For example, an industrial city should be compared with another industrial one, a city based on tertiary services with another similar, and so on.

KPI n 3	**Energy used in recycling**
Description	The indicator assesses the efficiency of the recycling activities within the city, registering the amount of annual energy used in order to cover the benefits coming from recycling activities.
Calculation	Quantity of energy used all the recovery and recycling facilities/Amount of waste entering all the waste recovery and recycling facilities.
Unit of measure	kWh / t
Perimeter of analysis	City (or Nation)
Frequency of reporting	Yearly
Scoring	5
Notes	This indicator has a quite complex calculation. That is why it might not be always possible to calculate it at city scale.

1.2 Energy- Electricity

KPI n 4	**Electricity production per capita**
Description	This indicator assesses the total value of electricity per capita generated by all functions.
Calculation	Total production of electricity (MWh) within a city divided by the number of residents in city. The result indicates the total electricity production per year in megawatt hours per capita. The calculation of the indicator can be facilitated from breaking down the energy production deriving from various sources.
Unit of measure	kWh/capita/year
Perimeter of analysis	City
Frequency of reporting	Yearly
Scoring	4
Notes	/

KPI n 5	**Electricity consumption per capita**
Description	This indicator assesses the total value of electricity per capita consumed by all functions.
Calculation	Total consumption of electricity (MWh) within a city divided by the number of residents in city. The result indicates the total electricity consumption per year in megawatt hours per capita. The calculation of the indicator can be facilitated from breaking down the energy consumption of various sectors (e.g., buildings, transport, industry, etc.).
Unit of measure	kWh/capita/year
Perimeter of analysis	City
Frequency of reporting	Yearly
Scoring	4
Notes	/

KPI n 6	**Electricity in the energy mix**
Description	This indicator assesses the electrification rate of the city, indicating the percentage of electricity in the total energy consumption mix
Calculation	It is calculated as the ratio between the total value of electricity consumption and the total value of final energy consumption within the city. The result shall then be multiplied by 100 and expressed as a percentage.
Unit of measure	%
Perimeter of analysis	City
Frequency of reporting	Yearly
Scoring	4
Notes	/

KPI n 7	**Percentage of city population with authorized electrical services**
Description	This indicator shows the number of people with authorized electrical services in the city.
Calculation	It is calculated as the ratio between the number of people with authorized electrical service and the population of the city. The result shall then be multiplied by 100 and expressed as a percentage.
Unit of measure	%
Perimeter of analysis	City
Frequency of reporting	Yearly
Scoring	3
Notes	/

1.3 Energy – Fuel

KPI n 8	**Fuel energy consumption per capita**
Description	This indicator assesses the total value of fuel energy per capita consumed by all functions. In particular, this indicator accounts for petroleum products and oil, natural gas, gasoline, diesel fuel and heating oil. Note that the nuclear component is not included.
Calculation	Total use of fuel energy within a city divided by the number of residents in city. The result indicates the total energy consumption per year in GJ per capita. The calculation of the indicator can be facilitated from breaking down the energy consumption of various functions. All forms of energy specified in the description need to be taken into account. These will be given in different units of energy (GJ, m3), but they all have to be calculated or converted to GJ of energy in order to be able to sum up the separately calculated energy generations and achieve the total energy consumption of the city.
Unit of measure	GJ
Perimeter of analysis	City
Frequency of reporting	Yearly
Scoring	4
Notes	This indicator has a quite complex calculation. That is why it might not be always possible to calculate it at city scale.

1.4 Energy – Green Energy

KPI n 9	**Renewable energy generated within the city**
Description	This indicator is the percentage of total energy derived from the renewable systems installed in the city as a share of the city's total energy consumption. Renewable energy shall include both combustible and non-combustible renewables. Non-combustible renewables include geothermal, solar, wind, hydro, tide and wave energy. The combustible renewables include biomass (fuelwood, vegetal waste, ethanol) and animal products (animal materials/waste and sulphite lyes). Municipal waste (waste produced by the residential, commercial and public service sectors that are collected by local authorities for disposal in a central location for the production of heat and/or power) and industrial waste are not considered a renewable source for energy production.
Calculation	The share of renewable energy produced within the city is calculated as the total consumption of electricity generated from renewable sources divided by total energy consumption.
Unit of measure	%
Perimeter of analysis	City
Frequency of reporting	Yearly
Scoring	4
Notes	/

KPI n 10	**Percentage of total renewable energy sources (RES) self-supplied**
Description	Self-supply refers to green power use by a consumer whereby the consumer owns the renewable electricity generator and is responsible for its maintenance and operation. In this way the consumer is generating and supplying their own green power. This indicator shows the impact of self-supply over the total renewable energy generated annually within the city.
Calculation	It is calculated as the ratio between the amount of renewable electricity self-supplied and the total consumption of renewable electricity. The result shall then be multiplied by 100 and expressed as a percentage.
Unit of measure	%
Perimeter of analysis	City (or Nation)
Frequency of reporting	Yearly
Scoring	4
Notes	This indicator has a quite complex calculation. That is why it might not be always possible to calculate it at city scale.

KPI n 11	**RES power installed**
Description	It resumes the overall installed renewable capacity accounting for both residential and utility scale.
Calculation	It represents the cumulate value of MW installed in the city and it is obtained summing all the capacities within the city in the current year plus the cumulate value obtained from the previous years.
Unit of measure	MW
Perimeter of analysis	City
Frequency of reporting	Yearly
Scoring	4
Notes	/

1.5 Energy - Storage

KPI n 12	**RES storage capacity installed**
Description	It t resumes the overall RES storage capacity installed at residential scale.
Calculation	It represents the cumulate value of MWh installed in the city and it is obtained summing all the capacities within the city in the current year plus the cumulate value obtained from the previous years.
Unit of measure	MWh
Perimeter of analysis	City
Frequency of reporting	Yearly
Scoring	4
Notes	/

KPI n 13	**Grid storage capacity per total city energy consumption**
Description	This indicator assesses the energy storage capacity of the city's grid and evaluates it as the portion of the overall final energy consumed annually. Note that it refers to the utility scale.
Calculation	It is calculated as the total amount of energy stored annually on the city grids (GJ) divided by the city total final energy consumption (GJ). The result shall then be multiplied by 100 and expressed as a percentage.
Unit of measure	%
Perimeter of analysis	City
Frequency of reporting	Yearly
Scoring	4
Notes	/

1.6 Energy – W2E

KPI n 14	**Percentage of city's solid waste that is treated in energy-from-waste plants**
Description	The indicator measures the portion of city's solid waste that is treated annually for energy generation.
Calculation	It is calculated as the value of tons of solid waste disposed in energy-from-waste plants divided by the total value of tons of city solid waste generated within the city. The result shall then be multiplied by 100 and expressed as a percentage.
Unit of measure	%
Perimeter of analysis	City
Frequency of reporting	Yearly
Scoring	4
Notes	A similar useful indicator could evaluate the percentage of energy demand recovered by waste treatment, showing the electrical and thermal energy produced from wastewater treatment, solid waste and other liquid waste treatment and other waste heat resources, as a share of the city’s total energy mix for a given year.

1.7 Smart Grid and Balancing

KPI n 15	**Average number of electrical interruptions**
Description	The indicator shows the average number of electrical interruptions per customer per year.
Calculation	It shall be calculated as the total number of customer interruptions divided by the total number of customers served. The result shall be expressed as the average number of electrical interruptions per customer per year.
Unit of measure	#customers/year
Perimeter of analysis	City
Frequency of reporting	Monthly
Scoring	3
Notes	/

KPI n 16	**Average length of electrical interruptions**
Description	The indicator shows the average annual hours of electrical service interruptions per household.
Calculation	It is obtained by summing the number of hours of interruption, multiplying them by the number of households impacted by the interruptions and divide the overall value by the total number of households within the city.
Unit of measure	Hours
Perimeter of analysis	City
Frequency of reporting	Monthly
Scoring	4
Notes	/

KPI n 17	**Smart meters**
Description	Smart meters play a fundamental role in the development of smart grids. This indicator assesses the diffusion of smart meters within the city.
Calculation	It is calculated as the ratio between the number of smart electricity meters installed and the total number of electricity meters installed. The result shall then be multiplied by 100 and expressed as a percentage.
Unit of measure	%
Perimeter of analysis	City
Frequency of reporting	Yearly
Scoring	3
Notes	/

1.8 Risk Management

KPI n 18	**Population living in disaster-prone areas**
Description	This indicator evaluates the percentage of inhabitants living in natural hazards (such as cyclones, drought, floods, earthquake, volcanoes and landslides) prone areas.
Calculation	The indicator is calculated as the number of city inhabitants living in natural hazard prone areas divided by the total number of city's inhabitants. The numerator is obtained by using historical and other data on hazards and on vulnerability. The result shall then be multiplied by 100 and expressed as a percentage.
Unit of measure	%
Perimeter of analysis	City (or Nation)
Frequency of reporting	Yearly
Scoring	3
Notes	Note that in some cases the calculation of this indicator could involve a significant area and number of people, especially in developing countries. That is why it might result as the 100% of the population and be more meaningful at national scale.

KPI n 19	**Natural disaster related deaths**
Description	This indicator reports the annual number of deaths per 100,000 inhabitants caused by natural disasters within the city.
Calculation	It is obtained as the number of annual natural disaster related deaths divided by the city's population. Then, the result is multiplied by 100,000.
Unit of measure	#/100,000
Perimeter of analysis	City
Frequency of reporting	Yearly
Scoring	3
Notes	/

KPI n 20	**Disaster risk management in city planning**
Description	The goal of this indicator is to assess whether disaster risk management practices such as for disaster prevention, prediction, control and emergency response are examined in city planning.
Calculation	It evaluates the presence of disaster risk management plans within the city.
Unit of measure	Yes/No
Perimeter of analysis	City
Frequency of reporting	Yearly
Scoring	1
Notes	/

KPI n 21	**Critical infrastructures**
Description	The indicator assesses the percentage of critical infrastructure present in the city that are at risk due to inadequate construction or placement in areas of non-mitigable risk.
Calculation	It is calculated as the number of infrastructures with inadequate construction or located in hazard prone areas divided by the total number of city's infrastructures. The list of criteria that must be met for adequate construction and data regarding hazard prone areas are provided by the municipality, which keeps track of historical and other data on hazards and on vulnerability.
Unit of measure	%
Perimeter of analysis	City
Frequency of reporting	Yearly
Scoring	4
Notes	/

1.9 Urban Planning

KPI n 22	**Brownfield redevelopment**
Description	Brownfield is a term used in urban planning to describe “land which is or was occupied by a permanent structure, including the curtilage of the developed land and any associated fixed surface infrastructure.” (Bosch et al. 2017). Many brownfields are contaminated as a result of previous industrial or commercial uses. Brownfield remediation and regeneration represents a valuable opportunity, not only to prevent the loss of pristine countryside and reduce ground sealing, but also to enhance urban spaces and remediate the sometimes-contaminated soils.
Calculation	The indicator is calculated as the brownfield area redeveloped in the last year (km^2) divided by the total brownfield area in the city (km^2).
Unit of measure	%
Perimeter of analysis	City (or District)
Frequency of reporting	Yearly
Scoring	4
Notes	/

KPI n 23	**Green and water spaces**
Description	Green and water spaces are regarded as an index representing the degree of the nature conservation and improving the public health and quality of life as they are directly related to the natural water circulation, environmental purification and the green network. This indicator reflects the ratio of green and water space area from total city land area. Green areas are forest and park areas that are partly or completely covered with grass, trees, shrubs, or other vegetation. Water areas here meaning lakes, ponds, rivers.
Calculation	It is calculated annually with the following formula: ((water areas (km^2) + green space areas (km^2))/total city area (km^2)) * 100
Unit of measure	%
Perimeter of analysis	City
Frequency of reporting	Yearly
Scoring	3
Notes	/

KPI n 24	**Commercial and industrial activities**
Description	It reports the share of areas designated for commercial and industrial activities within the city.
Calculation	It is calculated as the sum of commercial and industrial areas (km^2) divided by the total city area (km^2). The result shall then be multiplied by 100 and expressed as a percentage. To calculate the numerator the brownfield areas must not be considered.
Unit of measure	%
Perimeter of analysis	City
Frequency of reporting	Yearly
Scoring	2
Notes	/

KPI n 25	**Residential areas**
Description	It reports the share of residential areas within the city.
Calculation	It is calculated as the sum of residential areas (km^2) divided by the total city area (km^2). The result shall then be multiplied by 100 and expressed as a percentage. To calculate the numerator the brownfield areas must not be considered, while the informal settlements areas must be considered.
Unit of measure	%
Perimeter of analysis	City
Frequency of reporting	Yearly
Scoring	2
Notes	/

KPI n 26	**Transport areas**
Description	It reports the share of areas designated for transport activities within the city. It encompasses all the transport areas: those for public transportation, private vehicles, vehicles sharing and all those concerning pedestrians.
Calculation	It is calculated as the sum of transport areas (km^2) divided by the total city area (km^2). To calculate the numerator the brownfield areas must not be considered.
Unit of measure	%
Perimeter of analysis	City
Frequency of reporting	Yearly
Scoring	2
Notes	/

KPI n 27	**Areas for social infrastructures**
Description	It reports the share of areas designated for social infrastructures within the city. Social infrastructures include assets that accommodate social services.
Calculation	It is calculated as the sum of areas for social infrastructures (km^2) divided by the total city area (km^2). The result shall then be multiplied by 100 and expressed as a percentage. To calculate the numerator the brownfield areas must not be considered.
Unit of measure	%
Perimeter of analysis	City
Frequency of reporting	Yearly
Scoring	2
Notes	/

KPI n 28	**Unused Areas**
Description	The indicator assesses the proportion of unused areas withing the city. It must be reported annually, and it includes all types of lands, such as contaminated ones.
Calculation	It is calculated as the sum of unused areas (km^2) divided by the total city area (km^2). The result shall then be multiplied by 100 and expressed as a percentage. To calculate the numerator the brownfield redeveloped areas must not be considered.
Unit of measure	%
Perimeter of analysis	City
Frequency of reporting	Yearly
Scoring	3
Notes	/

KPI n 29	**Basic service proximity**
Description	Basic services such as water, sanitation, drainage, energy, and transport are key ingredients for the economic and social development of urban areas. This indicator concerns the rapid accessibility of basic services. It assesses the share of inhabitants living near at least one basic service.
Calculation	It is calculated as the number of inhabitants having access to a basic service within 300 metres divided by the city population.
Unit of measure	%
Perimeter of analysis	City
Frequency of reporting	Yearly
Scoring	3
Notes	/

KPI n 30	**Population density**
Description	Population density is often used as a simple relative measure of how an organism responds to local conditions. If conditions are not good for the species, the density will be low (organisms will have died or moved out of the sampled area), whereas if conditions are good the density will be high (organisms will have reproduced and/or immigrated into the area). In this way, changes in density can provide insight into the natural history of the preferences and tolerances of individuals of the species.
Calculation	It is calculated annually as the number of individuals per unit geographic area, namely number per square meter.
Unit of measure	#/km^2
Perimeter of analysis	City
Frequency of reporting	Yearly
Scoring	1
Notes	/

KPI n 31	**Housing located in informal settlements**
Description	Informal settlements, can be defined as residential areas where a group of housing units has been constructed on land to which the occupants have no legal claim, or which they occupy illegally.
Calculation	It is calculated annually as the number of housing constructed in such areas divided by the total number of housing within the city. The result shall then be multiplied by 100 and expressed as a percentage.
Unit of measure	%
Perimeter of analysis	City
Frequency of reporting	Yearly
Scoring	3
Notes	/

1.10 Ecosystem

KPI n 32	**Number of native species**
Description	Urbanization affects biodiversity through urban sprawl/habitat fragmentation, loss of fertile agricultural lands, and spread of invasive alien species. A loss in biodiversity threatens food supplies, lessens opportunities for recreation and tourism, and impacts a diverse range of medicinal and practical uses, varieties of wood, and energy. It also interferes with essential ecological function, such as carbon sequestration and air filtering. Native species are plants and animals that originated and live in an area without any human intervention. On the contrary, introduced, or non-native species, have been brought to their current locations by humans and often become invasive, or too pervasive for the environment. There are two types of native species: indigenous and endemic. Indigenous species are native species that are found in multiple locations, whereas endemic species are only found in a specific, unique location.
Calculation	Three key taxonomic groups are the most surveyed worldwide, i.e., plants, birds and butterflies. A city is requested to list the number of native species that it has data on. The full list can be found in the User’s Manual for the City Biodiversity Index (Borsch et al. 2017)
Unit of measure	# of specie
Perimeter of analysis	City (or Nation)
Frequency of reporting	Yearly
Scoring	3
Notes	Note that in some cases the calculation of this indicator could involve a significant area and number of people, especially in developing countries. That is why it might result as the 100% of the population and be more meaningful at national scale.

KPI n 33	**Ecosystem protected areas**
Description	A protected area is a clearly defined geographical space, recognized, dedicated and managed, through legal or other effective means, to achieve the long-term conservation of nature with associated ecosystem services and cultural values.
Calculation	The indicator is reported annually and is calculated as the surface (marine and terrestrial) of protected areas (km^2) divided by the entire municipality surface area (km^2). The result shall then be multiplied by 100 and expressed as a percentage.
Unit of measure	%
Perimeter of analysis	City
Frequency of reporting	Yearly
Scoring	2
Notes	/

KPI n 34	**Urban ecological footprint**
Description	The Ecological Footprint as defined by the Ecological Footprint standards calculates how much biologically productive area is required to produce the resources required by the human population and to absorb humanity's carbon dioxide emissions. In other words, it is a geographical measure of an urban population's demand on natural capital. Approximately 90 percent of all leading Ecological Footprint practitioners worldwide have joined Global Footprint Network and have agreed to adhere to these standards and to use a common set of data.
Calculation	The Ecological Footprint of a person is calculated by adding up all of people's demands that compete for biologically productive space, such as cropland to grow potatoes or cotton, or forest to produce timber or to sequester carbon dioxide emissions. All of these materials and wastes are then individually translated into an equivalent number of global hectares. To accomplish this, an amount of material consumed by that person (tons per year) is divided by the yield of the specific land or sea area (annual tons per hectare) from which it was harvested, or where its waste material was absorbed. The number of hectares that result from this calculation are then converted to global hectares using yield and equivalence factors. The sum of the global hectares needed to support a person is that person's total Ecological Footprint. The Ecological Footprint of a group of people, such as a city or nation, is simply the sum of the Ecological Footprint of all the residents of that city or nation.
Unit of measure	Global hectares (gha)
Perimeter of analysis	City (or Nation)
Frequency of reporting	Yearly
Scoring	5
Notes	Note that in some cases the calculation of this indicator could involve a significant area and number of people, especially in developing countries. That is why it might result as the 100% of the population and be more meaningful at national scale.

KPI n 35	**Climate resilience strategy**
Description	Urban areas in Europe and worldwide are increasingly experiencing the pressures arising from climate change and are projected to face aggravated climate-related impacts in the future. Several cities and towns across Europe are already pioneering adaptation action and many others are taking first steps to ensure that cities remain safe, livable and attractive centers for innovation, economic activities, culture and social life. This indicator assesses to what extent the city has a resilience strategy and action plan.
Calculation	The indicator provides a qualitative measure and is rated on a seven-point Likert scale. 1. No action has been taken yet 2. The ground for adaptation has been prepared 3. Risks and vulnerabilities have been assessed 4. Adaptation options have been identified 5. Adaptation options have been selected 6. Adaptation options are being implemented 7. Monitoring and evaluation is being carried out.
Unit of measure	Likert
Perimeter of analysis	City
Frequency of reporting	Yearly
Scoring	2
Notes	/

KPI n 36	**Urban heat island**
Description	This indicator focuses on the urban heat island (UHI) effect, the difference in air temperature between the city and its surroundings. The UHI effect is caused by the absorption of sunlight by (stony) materials, the lack of evaporation and the emission of heat caused by human activities. The effect is at its highest point after sunset and can reach up to 9℃ in e.g., Rotterdam. Due to the UHI effect, urban areas experience more heat stress than the countryside.
Calculation	Whether there is one or several measurement stations in the built environment, compare the air temperature measurements of these stations with a station outside the city which functions as a reference station, and look for the largest temperature difference (hourly average) during the summer months.
Unit of measure	°C UHImax
Perimeter of analysis	City
Frequency of reporting	Yearly
Scoring	3
Notes	/

1.11 Water Management

KPI n 37	**Water consumption**
Description	Water management and supply of safe drinking water have become a global issue. Due to changes in the climate, there has been an increase of either extreme dry and warm seasons in some countries or rainy seasons connected with floods in other areas. Water scarcity varies greatly between countries, even between regions inside the countries, even between regions inside the country.
Calculation	It shall be calculated as the total amount of the city’s water consumption in liters per day divided by the total city population.
Unit of measure	Litre/capita
Perimeter of analysis	City
Frequency of reporting	Yearly
Scoring	4
Notes	/

KPI n 38	**Population served by wastewater collection**
Description	The treatment of urban wastewater is fundamental to ensuring public health and environmental protection. Urban wastewater treatment in all parts of Europe has improved over recent decades. This indicator assesses the annual percentage of population connected to urban wastewater treatment accounting for primary, secondary and tertiary treatment.
Calculation	It shall be calculated as the number of people served by wastewater collection divided by the city population.
Unit of measure	%
Perimeter of analysis	City
Frequency of reporting	Yearly
Scoring	4
Notes	/

KPI n 39	**Water losses**
Description	Before reaching the users, a part of the water supplied might be lost through leakage or illegal tapping. In cities with old and deteriorating water reticulation systems, a substantial proportion of piped water may be lost through cracks and flaws in pipes – for example up to 30 per cent of water is lost in this way in some countries in Eastern Europe. The percentage of water loss (unaccounted for water) represents the percentage of water that is annually lost from treated water entering distribution system and that is accounted for and billed by the water provider. This includes actual water losses, e.g., leaking pipes, and billing losses, e.g. delivered through informal or illegal connection.
Calculation	It shall be calculated as the volume of water supplied minus the volume of customer billed water divided by the total volume of water supplied. The result shall then be multiplied by 100 and expressed as a percentage.
Unit of measure	%
Perimeter of analysis	City
Frequency of reporting	Yearly
Scoring	5
Notes	/

KPI n 40	**Population with potable water supply service**
Description	The lack of access to safe water and sanitation is one of the main challenges related to water. This indicator aims at monitoring the percentage of city population with potable water supply service.
Calculation	It shall be calculated as the number of people served by potable water supply service divided by the city population. The result shall then be multiplied by 100 and expressed as a percentage.
Unit of measure	%
Perimeter of analysis	City
Frequency of reporting	Yearly
Scoring	3
Notes	/

KPI n 41	**Water service interruptions**
Description	The indicator shows the average annual hours of water service interruptions per household.
Calculation	It is obtained by summing the number of hours of interruption, multiply them by the number of households impacted by the interruptions and divide the overall value by the total number of households within the city.
Unit of measure	hours
Perimeter of analysis	City
Frequency of reporting	Monthly
Scoring	3
Notes	/

KPI n 42	**Smart water meters**
Description	Smart water meters play a fundamental role in the development of smart grids. This indicator assesses the diffusion of smart water meters within the city.
Calculation	It shall be calculated as the number of smart water meters installed divided by the total number of water meters installed within the city. The result shall then be multiplied by 100 and expressed as a percentage.
Unit of measure	%
Perimeter of analysis	City
Frequency of reporting	Yearly
Scoring	4
Notes	/

KPI n 43	**Real-time water quality tracking**
Description	The indicator assesses the percentage of annual drinking water tracked by real-time, water quality monitoring station.
Calculation	It shall be calculated as the amount of drinking water that has undergone water quality monitoring divided by the total amount of drinking water distributed. The result shall then be multiplied by 100 and expressed as a percentage.
Unit of measure	%
Perimeter of analysis	City
Frequency of reporting	Yearly
Scoring	3
Notes	/

1.12 Other Resources Usage

KPI n 44	**Domestic material consumption**
Description	The indicator 'domestic material consumption' (DMC) considers the domestic material extraction (i.e. the amount of raw material extracted from the natural environment, except for water and air), including both imports (added) and exports (deducted) through their simple product weight when crossing the city limits. A city with almost no domestic extraction and importing all necessary resources indirectly in the form of mainly finished products will have a much lower DMC compared to a resource rich city.
Calculation	Domestic Material Consumption (DMC) is calculated as the Direct Material Input (DMI) minus exports. DMI measures the direct input of materials for the use in the economy and equals Domestic Extraction (DE) plus imports.
Unit of measure	tons/capita
Perimeter of analysis	City
Frequency of reporting	Yearly
Scoring	5
Notes	/

1.13 GHG Emissions

KPI n 45	**CO2 emissions**
Description	Greenhouse gases (GHGs) are gases in the atmosphere that absorb infrared radiation that would otherwise escape to space; thereby contributing to rising surface temperatures. There are six major GHGs: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6). The warming potential for these gases varies from several years to decades to centuries. CO_2 accounts for a major share of Green House Gas emissions in urban areas. The main sources for CO_2 emissions are combustion processes related to energy generation and transport. Tons of CO_2 emissions per capita can therefore considered a useful indicator to assess the contribution of urban development on climate change.
Calculation	The CO2 emissions measured in tonnes per capita shall be measured as the total amount of direct CO2 emissions in tonnes (equivalent carbon dioxide units) generated over a calendar year by all activities within the city, including indirect emissions outside city boundaries (numerator) divided by the current city population (denominator). The result shall be expressed as the total direct CO2 emissions per capita in tonnes. The Global Protocol for Community-Scale GHG Emissions (GPC), (2012 Accounting and Reporting Standard) refers to a multi-stakeholder consensus-based protocol for developing international recognized and accepted community-scale greenhouse gas accounting and reporting. This protocol defines the basic emissions sources and categories within sectors for a community-scale GHG inventory, in order to standardize GHG inventories between communities and within a community over time. The protocol provides accounting methodologies and step-by-step guidance on data collection, quantification, and reporting recommendations for each source of emissions. Both emissions sources and sector categorizations reflect the unique nature of cities and their primary emissions sources. These include emissions from: 1) Stationary Units, 2) Mobile Units, 3) Waste, and 4) Industrial Process and Product Use sectors. For further specifications, refer to the full GPC methodology. Local governments shall be expected to provide information (i.e., quantified emissions) for each of these emission sources. In order to address the issue of inter-city sources of emissions that transcend more than one jurisdictional body, the GPC integrates the GHG Protocol Scope definitions, as follows: 1. Scope 1 emissions: All direct emission sources from activities taking place within the community's geopolitical boundary. 2. Scope 2 emissions: Energy-related indirect emissions that result as a consequence of consumption of grid-supplied electricity, heating and/or cooling, within the community's geopolitical boundary. 3. Scope 3 emissions: All other indirect emissions that occur as a result of activities within the community's geopolitical boundary.
Unit of measure	%
Perimeter of analysis	City
Frequency of reporting	Yearly
Scoring	4
Notes	/

1.14 Pollution

<table>
<tr><th>KPI n 46</th><th>Air quality index</th></tr>
<tr><td>Description</td><td>Air quality is expressed in the concentration of major air pollutants. At this moment from a human health perspective most important are particulates (PM10, PM2.5), NO$_2$ (as indicator of traffic related air pollution) and ozone (important for smog). The concentration levels of these pollutants together define the air quality. For this indicator we use the year average air quality index. It is a distance to target indicator that provides a relative measure of the annual average air quality in relation to the European limit values (annual air quality standards and objectives from EU directives). If the index is higher than 1: for one or more pollutants the limit values are not met. If the index is below 1: on average the limit values are met.</td></tr>
<tr><td>Calculation</td><td>
<table>
<tr><th>Pollutant</th><th>Target value / limit value</th><th>Subindex calculation</th></tr>
<tr><td>NO$_2$</td><td>Year average is 40 µg/m3</td><td>Year average / 40</td></tr>
<tr><td>PM10</td><td>Year average is 40 µg/m3</td><td>Year average / 40</td></tr>
<tr><td>PM10 daily</td><td>Max. number of daily averages above 50 µg/m3 is 35 days</td><td>Log(number of days+1) / Log(36)</td></tr>
<tr><td>Ozone</td><td>25 days with an 8-hour average value >= 120 µg/m3</td><td>Number of days with 8-hour average >=120 / 25</td></tr>
<tr><td>SO$_2$</td><td>Year average is 20 µg/m3</td><td>Year average / 20</td></tr>
<tr><td>Benzene</td><td>Year average is 5 µg/m3</td><td>Year average / 5</td></tr>
</table>

The overall city index is the average of the sub-indices for NO$_2$, PM10 (both year average and the number of days >=50 µg/m3 sub-index) and ozone for the city background index. For the traffic year average index, the averages of the sub-indices for NO$_2$ and PM10 (both) are being used. The other pollutants (including PM2.5) are used in the presentation of the city index if data are available, but do not enter the calculation of the city average index. They are treated as additional pollutants in other specific measures. The main reason is that not every city is monitoring this full range of pollutants.</td></tr>
<tr><td>Unit of measure</td><td>Index</td></tr>
<tr><td>Perimeter of analysis</td><td>City</td></tr>
<tr><td>Frequency of reporting</td><td>Yearly</td></tr>
<tr><td>Scoring</td><td>4</td></tr>
<tr><td>Notes</td><td>/</td></tr>
</table>

KPI n 47	**PM 2.5 concentration**
Description	Fine particulate matter can cause major health problems in cities. According to the WHO (Borsch et a. 2017), any concentration of particulate matter (PM) is harmful to human health. PM is carcinogenic and harms the circulatory system as well as the respiratory system. As with many other air pollutants, there is a connection with questions of environmental justice, since often underprivileged citizens may suffer from stronger exposure. The evidence on PM and its public health impact is consistent in showing adverse health effects at exposures that are currently experienced by urban populations in both developed and developing countries. The range of health effects is broad but are predominantly to the respiratory and cardiovascular systems.
Calculation	The indicator is obtained dividing the total PM2.5 emissions (g) by the city population.
Unit of measure	g/capita
Perimeter of analysis	City
Frequency of reporting	Yearly
Scoring	4
Notes	/

KPI n 48	**NOx concentration**
Description	Nitrogen oxides (NO and NO_2) are major air pollutants, which can have significant impacts on human health and the environment. NO contributes to ozone layer depletion and, when exposed to oxygen, can transform into NO_2. NO_2 contributes to the formation of photochemical smog and at raised levels can increase the likelihood of respiratory problems. Nitrogen dioxide inflames the lining of the lungs, and it can reduce immunity to lung infections. This can cause problems such as wheezing, coughing, colds, flu and bronchitis. Increased levels of nitrogen dioxide can have significant impacts on people with asthma because it can cause more frequent and more intense attacks. NO_2 chemically transforms into nitric acid and contributes to acid rain. Nitric acid can corrode metals, fade fabrics, and degrade rubber. When deposited, it can also contribute to lake acidification and can damage trees and crops, resulting in substantial losses. Nitrogen dioxide is part of the exhaust gases of motor vehicles, but also emanates from other combustion processes, related for example to domestic heating and industrial processes.
Calculation	The indicator is obtained dividing the total NOx emissions (g) by the city population.
Unit of measure	g/capita
Perimeter of analysis	City
Frequency of reporting	Yearly
Scoring	4
Notes	/

KPI n 49	**Air quality monitoring stations**
Description	It is fundamental to monitor the air quality within the city. This indicator assesses the number of real-time remote air quality monitoring stations per squared kilometers (km^2).
Calculation	It is simply calculated as the total number of real-time remote air quality monitoring stations divided by the city's land area in km^2.
Unit of measure	#/km^2
Perimeter of analysis	City
Frequency of reporting	Yearly
Scoring	2
Notes	/

1.15 Pollution – Noise

KPI n 50	**Noise pollution**
Description	Prolonged exposure to noise can lead to significant health effects, both physical and mental. This indicator assesses the number of inhabitants exposed to noise >55 dB(A) at day and nighttime.
Calculation	It is calculated with the following formula: (#inhabitants exposed to noise > 55dB(a)/total number of inhabitants) * 100. Noise pollution shall be calculated by mapping the noise level during the day (Ln) likely to cause annoyance, identifying the areas of the city where Ln is greater than 55 dB(A) and estimating the population of those areas as a percentage of the total city population. The result shall be expressed as the percentage of the population affected by noise pollution.
Unit of measure	%
Perimeter of analysis	City
Frequency of reporting	Monthly
Scoring	2
Notes	/

1.16 Waste

KPI n 51	**Solid waste collection**
Description	The proper discharge, transportation and treatment of solid waste is one of the most important components of life in a city and one of the first areas in which governments and institutions should focus. Solid waste systems contribute in many ways to public health, the local economy, the environment, and the social understanding and education about the latter. A proper solid waste system can foster recycling practices that maximize the life cycle of landfills and create recycling micro-economies; and it provides alternative sources of energy that help reduce the consumption of electricity and/or petroleum-based fuels. This indicator measures the percentage of city population with regular solid waste collection.
Calculation	It is calculated as the number of people served by regular solid waste collection divided by the total city population. The result shall then be multiplied by 100 and expressed as a percentage.
Unit of measure	%
Perimeter of analysis	City
Frequency of reporting	Monthly
Scoring	3
Notes	/

KPI n 52	**Municipal solid waste**
Description	This indicator provides a measure of how much waste a city is producing and the level of service a city is providing for its collection. Municipal waste shall refer to waste collected by or on behalf of municipalities. The data shall only refer to the waste flows managed under the responsibility of the local administration including waste collected on behalf of the local authority by private companies or regional associations founded for that purpose. Municipal waste should include waste originating from: — households; — commerce and trade, small businesses, office buildings and institutions (e.g., schools, hospitals, government buildings). The definition should also include: — bulky waste (e.g., white goods, old furniture, mattresses); — garden waste, leaves, grass clippings, street sweepings, the content of litter containers, and market cleansing waste, if managed as waste; — waste from selected municipal services, i.e., waste from park and garden maintenance, waste from street cleaning services (e.g. street sweepings, the content of litter containers, market cleansing waste), if managed as waste. The definition shall exclude: — waste from municipal sewage network and treatment; — municipal construction and demolition waste.
Calculation	The total collected municipal solid waste per capita shall be expressed as the total municipal solid waste produced in the municipality per person. This indicator shall be calculated as the total amount of solid waste (household and commercial) generated annually (in tons) divided by the total city population.
Unit of measure	tons/capita
Perimeter of analysis	City
Frequency of reporting	Monthly
Scoring	3
Notes	/

KPI n 53	**Waste drop-off centers telemetering**
Description	This indicator measures the percentage of waste drop-off centres equipped with telemetering.
Calculation	It is calculated as the number of waste drop-off centres (containers) for garbage disposal equipped with telemetering devices divided by the total waste drop-off centres within the city.
Unit of measure	%
Perimeter of analysis	City
Frequency of reporting	Yearly
Scoring	2
Notes	/

KPI n 54	**Sensor-enabled public garbage bins**
Description	This indicator measures the percentage of public garbage bins that are sensor-enabled.
Calculation	It is calculated as the number of public garbage bins that are sensor-enabled divided by the total number of public garbage bins in the city.
Unit of measure	%
Perimeter of analysis	City
Frequency of reporting	Yearly
Scoring	2
Notes	/

1.17 Waste Recycling and Reuse

KPI n 55	**Recycling rate**
Description	Many cities generate more solid waste than they can dispose of. Higher levels of municipal waste contribute to greater environmental problems and therefore levels of collection, and also methods of disposal, of municipal solid waste are an important component of municipal environmental management. Solid waste systems contribute in many ways to public health, the local economy, the environment, and the social understanding and education about the latter. A proper solid waste system can foster recycling practices that maximize the life cycle of landfills and create recycling microeconomies; and it provides alternative sources of energy that help reduce the consumption of electricity and/or petroleum-based fuels.
Calculation	The percentage of city's solid waste that is recycled shall be calculated as the total amount of the city’s solid waste that is recycled in tonnes divided by the total amount of solid waste produced in the city in tonnes. The result shall then be multiplied by 100 and expressed as a percentage. Recycled materials shall denote those materials diverted from the waste stream, recovered, and processed into new products following local government permits and regulations. Hazardous waste produced in the city and recycled shall be reported separately.
Unit of measure	%
Perimeter of analysis	City
Frequency of reporting	Yearly
Scoring	4
Notes	/

KPI n 56	**Hazardous waste recycled**
Description	Hazardous waste is a waste with properties that make it dangerous or capable of having a harmful effect on human health or the environment. It is generated from many sources, ranging from industrial manufacturing process wastes to batteries and may come in many forms, including liquids, solids gases, and sludges.
Calculation	The percentage of city's solid waste that is recycled shall be calculated as the total amount of the city’s hazardous waste that is recycled in tonnes divided by the total amount of hazardous waste produced in the city in tonnes. The result shall then be multiplied by 100 and expressed as a percentage. Recycled materials shall follow local government permits and regulations
Unit of measure	%
Perimeter of analysis	City
Frequency of reporting	Yearly
Scoring	4
Notes	/

2. Smart Living

2.1 Building Data

KPI n 57	**Total number of residential buildings**
Description	The indicator assesses the total number of residential buildings that are present in the city at current year, considering both private houses and condominiums.
Calculation	The indicator is calculated as the total number of residential buildings within the city or district.
Unit of measure	#
Perimeter of analysis	City (or district)
Frequency of reporting	Yearly
Scoring	1
Notes	/

KPI n 58	**Total number of public buildings**
Description	Public building refers to a government-owned or leased building that functions as a municipal and administrative office, library, public recreation centre, hospital, school, fire station or police station.
Calculation	The indicator is calculated as the total number of public buildings within the city.
Unit of measure	#
Perimeter of analysis	City
Frequency of reporting	Yearly
Scoring	1
Notes	/

KPI n 59	**Total number of commercial buildings**
Description	Commercial buildings refer to private units that are used for commercial purposes such as shopping centres, supermarkets, private offices, galleries, shops.
Calculation	It is calculated as the total number of commercial buildings within the city or district.
Unit of measure	#
Perimeter of analysis	City (or district)
Frequency of reporting	Yearly
Scoring	1
Notes	/

KPI n 60	**Average age of the buildings**
Description	The indicator is a measure of the age and innovativeness of the district or city.
Calculation	Sum of the age of construction of the all the buildings divided by total number of buildings of the district or city.
Unit of measure	Years
Perimeter of analysis	City (or district)
Frequency of reporting	Yearly
Scoring	2
Notes	/

KPI n 61	**Number of historic and artistic buildings and views**
Description	The indicator is a measure of the historic and artistic attractiveness of the district or city.
Calculation	Number of historic and artistic buildings and views in the city.
Unit of measure	#
Perimeter of analysis	City
Frequency of reporting	Yearly
Scoring	2
Notes	/

2.2 Building Data – Energy

KPI n 62	**Thermal energy consumption of public buildings**
Description	The indicator considers the thermal final energy consumed in a year by public buildings. Public building refers to a government-owned or leased building that functions as a municipal and administrative office, library, recreation centre, hospital, school, fire station or police station.
Calculation	It is calculated as total thermal energy consumed by public buildings within a city per year divided by total floor space of these buildings.
Unit of measure	MWh / m^2
Perimeter of analysis	City
Frequency of reporting	Yearly
Scoring	5
Notes	The indicator can be furtherly split considering the final use of the energy consumption, which consists in heating, cooling, ventilation, hot water and lighting.

2.3 Building Data – Electricity

KPI n 63	**Electricity consumption of public buildings**
Description	The indicator considers the electrical energy consumed in a year by public buildings. Public building refers to a government-owned or leased building that functions as a municipal and administrative office, library, recreation centre, hospital, school, fire station or police station.
Calculation	It is calculated as total electrical energy consumed by public buildings within the city per year divided by total floor space of these buildings.
Unit of measure	MWh / m^2
Perimeter of analysis	City
Frequency of reporting	Yearly
Scoring	5
Notes	The indicator can be furtherly split considering the final use of the energy consumption, which consists in heating, cooling, ventilation, hot water and lighting.

2.4 Building Data – Green Energy

KPI n 64	**Green "prosumer" residential buildings**
Description	A green prosumer is a building that consumes and produces energy from Renewable Energy Sources (RES) plants, either for self-consumption or consumption by others. Thus, it is connected in a bidirectional flow with the grid.
Calculation	Number of residential buildings within the city which produce and consume green energy and are connected to the grid divided by total number of residential buildings within the city at current year.
Unit of measure	%
Perimeter of analysis	City
Frequency of reporting	Yearly
Scoring	3
Notes	/

KPI n 65	**Green "prosumer" public buildings**
Description	A green prosumer is a building that consumes and produces energy from Renewable Energy Sources (RES) plants, either for self-consumption or consumption by others. Thus, it is connected in a bidirectional flow with the grid.
Calculation	Number of public buildings within the city which produce and consume green energy and are connected to the grid divided by total number of public buildings within the city at current year.
Unit of measure	%
Perimeter of analysis	City
Frequency of reporting	Yearly
Scoring	2
Notes	/

KPI n 66	**Green "prosumer" commercial buildings**
Description	A green prosumer is a building that consumes and produces energy from Renewable Energy Sources (RES) plants, either for self-consumption or consumption by others. Thus, it is connected in a bidirectional flow with the grid.
Calculation	Number of commercial buildings within the city which produce and consume green energy and are connected to the grid divided by total number of commercial buildings within the city at current year.
Unit of measure	%
Perimeter of analysis	City
Frequency of reporting	Yearly
Scoring	3
Notes	/

2.5 Building Data – Energy Storage

KPI n 67	**Residential buildings with an energy storage system**
Description	An energy storage system (ESS) is an infrastructure such as a lithium-ions battery that permits to storage part of the energy produced by a renewable energy source plant, when the production of energy is higher that the consumption.
Calculation	Number of residential buildings within the city which produce and consume green energy and have installed an energy storage system divided by total number of residential buildings within the city at current year.
Unit of measure	%
Perimeter of analysis	City
Frequency of reporting	Yearly
Scoring	4
Notes	/

KPI n 68	**Public buildings with an energy storage system**
Description	An energy storage system (ESS) is an infrastructure such as a lithium-ions battery that permits to storage part of the energy produced by a renewable energy source plant, when the production of energy is higher that the consumption.
Calculation	Number of public buildings within the city which produce and consume green energy and have installed an energy storage system divided by total number of public buildings within the city at current year.
Unit of measure	%
Perimeter of analysis	City
Frequency of reporting	Yearly
Scoring	3
Notes	/

KPI n 69	**Commercial buildings with an energy storage system**
Description	An energy storage system (ESS) is an infrastructure such as a lithium-ions battery that permits to storage part of the energy produced by a renewable energy source plant, when the production of energy is higher that the consumption.
Calculation	Number of commercial buildings within the city which produce and consume green energy and have installed an energy storage system divided by total number of commercial buildings within the city at current year.
Unit of measure	%
Perimeter of analysis	City
Frequency of reporting	Yearly
Scoring	4
Notes	/

2.6 Building Data – Energy Efficiency

KPI n 70	**BEMS in public buildings**
Description	The indicator aims to evaluate the presence of Building energy management systems (BEMS) in public buildings. BEMS technological infrastructures to optimize energy management such as smart meters and monitoring and regulation ICT solution devices for temperature, solar radiation, CO_2 emission and energy consumption in lighting.
Calculation	It is calculated as the number of public buildings within the city with BEMS divided by total number of public buildings within the city in current year.
Unit of measure	%
Perimeter of analysis	City
Frequency of reporting	Yearly
Scoring	3
Notes	/

KPI n 71	**Public building sustainability certifications**
Description	Buildings with Sustainability certifications generally use less energy and water, increase the recycling levels and are more comfortable for occupants. Only sustainability certifications for ongoing operations and maintenance are considered. Standards to be included are: BREEAM, LEED, CASBEE, BOMA BEST, BCA Green Mark and Passive House (Smiciklas 2019). Other standards that are equivalent to the above can be reported. Certifications for design should not be included as the design stage normally is only 5-10% of a building total life cycle impact.
Calculation	Area of public buildings with sustainability certification to a recognized standard in current year divided by total area of public buildings. Data can be sourced from the facilities group within the city and through the websites of the certification agencies such as BREEAM, LEED and CASBEE (Smiciklas 2019).
Unit of measure	%
Perimeter of analysis	City
Frequency of reporting	Yearly
Scoring	4
Notes	/

KPI n 72	**Residential buildings with "energetic class A" or higher levels**
Description	The concept of energetic class of a building is based on the idea that, for each building, it is possible to calculate accurately defined indexes of energetic performance regarding heating, sanitary water, climatization and ventilation. The overall values of the indexes define the energetic class of the building, which can have the following values: A+++ (the most energy efficient), A++, A+, A, B, C, D, E, F or G (the least energy efficient).
Calculation	Number of residential buildings explicitly classified as building with "energetic class A" or higher levels in the city or district at the end of the year divided by total number of residential buildings in the city or district. If the energetic class of a building is not explicitly declared by authorized entities, the building is not considered as building of "energetic class A".
Unit of measure	%
Perimeter of analysis	City (or district)
Frequency of reporting	Yearly
Scoring	3
Notes	/

KPI n 73	**Public buildings with "energetic class A" or higher levels**
Description	The concept of energetic class of a building is based on the idea that, for each building, it is possible to calculate accurately defined indexes of energetic performance regarding heating, sanitary water, climatization and ventilation. The overall values of the indexes define the energetic class of the building, which can have the following values: A+++ (the most energy efficient), A++, A+, A, B, C, D, E, F or G (the least energy efficient).
Calculation	Number of public buildings explicitly classified as building with "energetic class A" or higher levels in the city at the end of the year divided by total number of public buildings in the city or district. If the energetic class of a building is not explicitly declared by authorized entities, the building is not considered as building of "energetic class A".
Unit of measure	%
Perimeter of analysis	City
Frequency of reporting	Yearly
Scoring	3
Notes	/

KPI n 74	**New buildings with energetic class A or higher levels**
Description	The indicator considers the percentage of new residential, public and commercial buildings that have been built with energetic class A or higher levels. Buildings are considered new if they have been built within the last 5 years from the year of the indicator reporting.
Calculation	It is calculated as the number of new buildings built within 5 years with energetic class A or higher levels divided by total number of new buildings built within the last 5 years in the city. Residential, public and commercial buildings are counted. Data can be sourced from dedicated city departments.
Unit of measure	%
Perimeter of analysis	City
Frequency of reporting	Yearly
Scoring	4
Notes	/

KPI n 75	**Buildings refurbished to higher energetic class**
Description	The indicator evaluates the percentage of buildings refurbished that, thanks to the intervention, have increased their energetic class. Therefore, the refurbishment has improved energy efficiency and lessened the environmental impacts. Only the refurbishments of the last 5 years from the year of the indicator reporting are counted.
Calculation	It is calculated as the number of buildings that, within the last 5 years, have been refurbished to higher energetic class divided by total number of buildings refurbished within the last 5 years in the city. Residential, public and commercial buildings are counted. Data can be sourced from dedicated city departments.
Unit of measure	%
Perimeter of analysis	City
Frequency of reporting	Yearly
Scoring	4
Notes	/

2.7 Building Data – Control and Automation Infrastructure

KPI n 76	**Public buildings equipped for monitoring indoor air quality**
Description	The monitoring of indoor air quality includes primary pollutants such as CO, Benzene, Acetaldehyde and formaldehyde and it is done through appropriate sensors and meters.
Calculation	Total number of public buildings equipped to monitor indoor air quality at current year divided by total number of public buildings in the city. Data can be sourced from the local authorities, officials, or the Ministry or Department responsible for public buildings.
Unit of measure	%
Perimeter of analysis	City
Frequency of reporting	Yearly
Scoring	3
Notes	/

2.8 Building Data – People with special needs

KPI n 77	**Public buildings completely accessible by persons with special needs**
Description	Public buildings are completely accessible by persons with special needs if they guarantee all these requirements: accessible parking spaces, accessible main entrance, automatic doors, sufficient light, accessible washrooms and elevators to all floors.
Calculation	Number of public buildings completely accessible by persons with special needs at current year divided by total number of public buildings in the city. Data can be sourced from local authorities, officials, or the Ministry or Department responsible for public buildings.
Unit of measure	%
Perimeter of analysis	City
Frequency of reporting	Yearly
Scoring	2
Notes	/

KPI n 78	**Barrier-free areas in public buildings**
Description	The indicator measures the share of squared metres of public buildings that are accessible by persons with special needs.
Calculation	The indicator is calculated as the squared meters accessible by persons with special needs in public buildings at current year divided by total squared meters of public buildings in the city.
Unit of measure	%
Perimeter of analysis	City
Frequency of reporting	Yearly
Scoring	4
Notes	/

2.9 Public Lighting

KPI n 79	**Electricity consumption of public street lighting**
Description	The indicator measures the electric energy consumption for public street lighting per kilometre of lighted street. More efficient public street lighting systems have reduced maintenance costs, improved public safety and reduced crime rates, improved road and traffic safety and increased economic productivity.
Calculation	Total electricity consumption of public street lighting in a year in the city divided by total length of streets where lights are present
Unit of measure	kWh / Km
Perimeter of analysis	City
Frequency of reporting	Yearly
Scoring	5
Notes	/

KPI n 80	**Light performance management system in public street lighting**
Description	Light performance management system refers to the ability to monitor light points, set schedules for switching off/on and adjust light levels by dimming with an ICT-based system, which is connected via a communication network to the light points. A light point is any single source of public street lighting, such as a streetlight, light pole or streetlamp.
Calculation	Number of light points of public street lighting within the city controlled by a light performance management system divided by total number light points of the city. Data can be sourced from city departments or ministries responsible for street lighting inventory and street light management.
Unit of measure	%
Perimeter of analysis	City
Frequency of reporting	Yearly
Scoring	4
Notes	/

KPI n 81	**New installed and refurbished public lighting systems**
Description	The new installations or the refurbishment of existing street light systems are considered in this indicator if they bring to improve energy efficiency of the street lighting system, for example upgrading ballasts or the use of the LED technology. A light point is any single source of public street lighting, such as a streetlight, light pole or streetlamp. Just the new installations and the refurbishments done within the last 5 years from the year of the indicator reporting are considered.
Calculation	Number of refurbished and newly installed light points within the last 5 years in the city divided by total number of light points in the city. Data can be sourced from city departments or ministries responsible for street lighting inventory.
Unit of measure	%
Perimeter of analysis	City
Frequency of reporting	Yearly
Scoring	4
Notes	/

KPI n 82	**Number of service suspensions in public lighting**
Description	The indicator is a measure of the quality of the lighting service in the district or city and assesses the number of service suspensions in public lighting in the city in a year.
Calculation	It is calculated as the number of service suspensions of public lighting in a year in the district or city.
Unit of measure	#
Perimeter of analysis	City
Frequency of reporting	Yearly
Scoring	2
Notes	/

KPI n 83	**Average duration of service suspensions in public lighting**
Description	The indicator is a measure of the quality of the lighting service in the district or city and assesses the average duration of service suspensions in public lighting in the city in a year.
Calculation	It is calculated as the average duration of service suspensions of public lighting in a year in the district or city.
Unit of measure	Minutes
Perimeter of analysis	City
Frequency of reporting	Yearly
Scoring	4
Notes	/

KPI n 84	**Maintenance costs associated with public lighting**
Description	The indicator assesses the public lighting costs for maintenance in the city at current year
Calculation	It is calculated as the amount of costs of maintenance associated with public lighting during a year divided by kilometres of the city lighted.
Unit of measure	€ / km
Perimeter of analysis	City
Frequency of reporting	Yearly
Scoring	4
Notes	/

2.10 Condition Profiling

KPI n 85	**Durations exposure to daylight during winter**
Description	The indicator is a measure of the daylight exposure of the city during winter period, therefore from January 1st to March 20th plus from December 21st to December 31st for the northern Hemisphere.
Calculation	It is calculated as the average of the amount of time with daylight in the city during winter. It is important to collect the data of duration exposure to daylight in every day of the considered period, in order to have a robust and consistent sample for calculating the average.
Unit of measure	hours / day
Perimeter of analysis	City
Frequency of reporting	Yearly
Scoring	5
Notes	/

KPI n 86	**Durations exposure to daylight during summer**
Description	The indicator is a measure of the daylight exposure of the city during summer period, therefore from June 21st to September 22nd for the northern Hemisphere.
Calculation	It is calculated as the average of the amount of time with daylight in the city during summer. It is important to collect the data of duration exposure to daylight in every day of the considered period, in order to have a robust and consistent sample for calculating the average.
Unit of measure	hours / day
Perimeter of analysis	City
Frequency of reporting	Yearly
Scoring	5
Notes	/

KPI n 87	**Daily average temperature registered during winter**
Description	The indicator is a measure of the daily average temperature registered in the city during winter period, therefore from January 1st to March 20th plus from December 21st to December 31st for the northern Hemisphere.
Calculation	It is calculated as the average of the daily average temperature registered in the city during winter. It is important to collect the data of the average temperature registered in the city in every day of the considered period, in order to have a robust and consistent sample for calculating the average.
Unit of measure	Celsius degrees / day
Perimeter of analysis	City
Frequency of reporting	Yearly
Scoring	5
Notes	/

KPI n 88	**Daily average temperature registered during summer**
Description	The indicator is a measure of the daily average temperature registered in the city during summer period, therefore from June 21st to September 22nd for the northern hemisphere.
Calculation	It is calculated as the average of the daily average temperature registered in the city during summer. It is important to collect the data of duration exposure to daylight in each day of the considered period, in order to have a robust and consistent sample for calculating the average.
Unit of measure	Celsius degrees / day
Perimeter of analysis	City
Frequency of reporting	Yearly
Scoring	5
Notes	/

3. Smart Mobility

3.1 Infrastructure

KPI n 89	**Marked pedestrian crossings equipped with accessible pedestrian signals**
Description	The indicator evaluates the percentage of marked pedestrian crossings equipped with accessible pedestrian signals. Accessible pedestrian signals are devices that communicate when a crossing is safe or not to enter either using visual, audible and/or vibrotactile communication.
Calculation	The indicator is calculated as the number of marked pedestrian crossing equipped with accessible pedestrian signals divided by total number of marked pedestrian crossings.
Unit of measure	%
Perimeter of analysis	City
Frequency of reporting	Yearly
Scoring	2
Notes	/

KPI n 90	**City streets covered by real-time online traffic alerts and information**
Description	The indicator assesses the percentage of city streets covered by real-time online traffic alerts and information. There should be considered all local roads, streets and major and minor arterial roads of the city. "Real-time" traffic alerts and information correspond to traffic information that is instantaneously available and reflects current traffic levels at any given time.
Calculation	Length of streets (in kilometres) within the city covered by real-time online traffic alerts and information divided by total length of all the streets (in kilometres) within city boundaries. Data can be sourced from dedicated city departments, or institutions that manage and communicate information regarding traffic of a particular region.
Unit of measure	%
Perimeter of analysis	City
Frequency of reporting	Yearly
Scoring	5
Notes	/

KPI n 91	**Percentage of traffic lights that are intelligent/smart**
Description	Intelligent/smart traffic lights are traffic light systems that utilize ICT technologies and algorithms to control vehicle and pedestrian traffic flow. Multiple traffic lights at the same intersection for traffic heading in the same direction are counted as a single traffic light.
Calculation	It is calculated as the number of traffic lights in the city that are intelligent or smart divided by total number of traffic lights in the city. Data can be sourced from dedicated city departments.
Unit of measure	%
Perimeter of analysis	City
Frequency of reporting	Yearly
Scoring	3
Notes	/

KPI n 92	**Pedestrian infrastructure**
Description	The indicator assesses the percentage of the city designated as a pedestrian or car free zone. automobile or truck traffic is prohibited (except for emergency vehicles or occasional deliveries or taxis).
Calculation	Total area of pedestrian or car free zones (in squared kilometres) divided by total city area (in squared kilometres). Data can be sourced from city Geographical Information Systems (GIS) data or city planning departments.
Unit of measure	%
Perimeter of analysis	City
Frequency of reporting	Yearly
Scoring	2
Notes	/

KPI n 93	**Road density**
Description	It considers the ratio between the kilometres of public roads (for cars) and the total squared kilometres of the area of the city. It is a measure of the space used for road mobility.
Calculation	It is calculated as total kilometres of public roads within the city divided by total squared kilometres of city area
Unit of measure	Km / km^2
Perimeter of analysis	City
Frequency of reporting	Yearly
Scoring	2
Notes	/

KPI n 94	**Periodic maintenance of roads**
Description	Average number of interventions for periodic road maintenance in the last 5 years per each public road.
Calculation	It is calculated as the sum of the interventions for road maintenance in the last 5 years, divided by total number of public roads in the city.
Unit of measure	Ratio
Perimeter of analysis	City
Frequency of reporting	Yearly
Scoring	3
Notes	/

3.2 Infrastructure- Bike

KPI n 95	**Length of bike route network**
Description	The indicator assesses the length of the bike route network per 100 000 population. The bike route network includes bicycle lanes and paths. Bicycle lanes refer to part of a carriageway designated for cycles and distinguished from the rest of the road by markings. Bicycle paths are an independent road designated just for cycles.
Calculation	Total kilometres of bicycle paths and lanes divided by one 100 000th of the city's total population. Data can be sourced from dedicated city departments.
Unit of measure	km per 100 000 inhabitants
Perimeter of analysis	City
Frequency of reporting	Yearly
Scoring	2
Notes	/

KPI n 96	**Cycle lanes availability**
Description	The indicator measures the ratio between the length of the bike route network and the length of public roads (for cars). It is a solid indicator of the physical availability of cycling infrastructure in comparison to the infrastructure for cars, the mode of transport it wants to replace.
Calculation	Total kilometres of bicycle paths and lanes divided by total kilometres of streets for conventional transportation (cars). Data can be sourced from dedicated city departments.
Unit of measure	%
Perimeter of analysis	City
Frequency of reporting	Yearly
Scoring	2
Notes	/

KPI n 97	**Bike sharing coverage**
Description	The indicator assesses the availability of bicycles for bike sharing, considering all the different companies and typologies that are present in the city, in comparison with city total population.
Calculation	It is calculated as the number of bikes available for bike sharing in the city divided by total city population. Data can be found from private companies that are bike sharing providers and/or from dedicated city departments.
Unit of measure	Ratio
Perimeter of analysis	City
Frequency of reporting	Yearly
Scoring	4
Notes	/

3.3 Infrastructure - EV-Charging

KPI n 98	**Public charging stations for e-vehicles in the city area**
Description	Electric vehicles include cars (BEVs or PHEVs), buses and motorcycles that runs fully or partially on a battery-powered electric motor. A charging station is publicly accessible equipment that supplies electric energy for recharging battery electric vehicles. A public charging station is for example a public parking area and can be composed by 1 or more charging points.
Calculation	Total number of public charging stations for e-vehicles in the city divided by one 100th of total city area. A station with more changing points is counted as 1.
Unit of measure	# / 100 km^2
Perimeter of analysis	City
Frequency of reporting	Yearly
Scoring	2
Notes	/

KPI n 99	**Public charging points for e-vehicles in the city area**
Description	Electric vehicles include cars (BEVs or PHEVs), buses and motorcycles that runs fully or partially on a battery-powered electric motor. A charging point is each single wall-box or infrastructure that recharges battery electric vehicles. One or more charging points compose a charging station.
Calculation	Total number of public charging points for e-vehicles in the city divided by total one 100th of total city area. 10 charging points (i.e., 10 wall-boxes) that are in the same unique charging station (i.e., public parking area) should be counted as 10.
Unit of measure	# / 100 km^2
Perimeter of analysis	City
Frequency of reporting	Yearly
Scoring	3
Notes	/

3.4 Parking Areas

KPI n 100	**Public parking spaces equipped with e-payment systems**
Description	the indicator assesses the percentage of public parking spaces equipped with e-payment systems. Public parking lots have to be considered by their capacity, and street parking have to be counted by individual paid spaces. An e-payment system is a way of paying for goods and services through an electronic medium without the use of cash; Examples are credit cards or online/mobile applications.
Calculation	Number of public parking spaces equipped with an e-payment system as a payment method divided by total number of public parking spaces in the city. Data can be sourced from dedicated city departments or from organisations (public or private) that handle e-payment systems in the city for public parking.
Unit of measure	%
Perimeter of analysis	District
Frequency of reporting	Yearly
Scoring	2
Notes	/

KPI n 101	Public parking spaces equipped with real-time availability systems
Description	The indicator assesses the percentage of public parking spaces equipped with real-time availability systems. Public parking lots have to be considered by their capacity, and street parking have to be counted by individual paid spaces. Real-time availability systems for public parking spaces include any form of technology that provides instantaneous information on the availability of public parking spaces, through mobile and/or online applications.
Calculation	It is calculated as the number of public parking spaces that are equipped with real-time availability systems divided by total number of public parking spaces in the city. Data can be sourced from dedicated city departments.
Unit of measure	%
Perimeter of analysis	District
Frequency of reporting	Yearly
Scoring	3
Notes	/

3.5 Infrastructure – Public Transportation

KPI n 102	Length of public transport system
Description	Public transport includes rail, metro, buses, tramways, buses and other passenger transport services inside the city. If possible, data from each type of transport system should be included and listed individually.
Calculation	It is calculated as the total length (in kilometres) of the public transport systems operating within the city. Transport systems covering the same route have to be counted separately. For example, if a bus and a tram cover the same 1-km route, this counts for 2 km.
Unit of measure	Km
Perimeter of analysis	City
Frequency of reporting	Yearly
Scoring	2
Notes	/

KPI n 103	Public transport lines equipped with a publicly accessible real-time system
Description	The indicator defines the percentage of public transport lines equipped with a publicly accessible real-time system. A real-time system gives timely information on transit usage and current volumes of users on public transport lines, with the aim of planning transportation routes and modes in the most efficient way. The information provided should be available to the public to allow access for all citizens.
Calculation	Number of public transport lines that are equipped with a publicly accessible real-time system to provide people with real-time operation information divided by total number of public transport lines within the city.
Unit of measure	%
Perimeter of analysis	City
Frequency of reporting	Yearly
Scoring	3
Notes	/

KPI n 104	Public transport network covered by a unified payment system
Description	The indicator assesses the percentage of the city's public transport network covered by a unified payment system. A unified payment system is an integrated mobility payment system that allows transit users to plan, book and pay for multiple modes of transit (such as bus, trams and subways) to get them from point A to point B, thanks to an ICT/technology-based user interface such as smart cards or mobile ticketing, and unified pricing structures.
Calculation	Number of city public transport modes connected by a unified payment system divided by city's total number of public transport modes.
Unit of measure	%
Perimeter of analysis	City
Frequency of reporting	Yearly
Scoring	2
Notes	/

KPI n 105	Smart proximity to public transport
Description	Population is considered living close to public transport if it is maximum 0,5 km far from the nearest public station that runs frequently (i.e., at least every 20 minutes during peak periods). Peak periods are considered in the morning and in the evening, when traffic volume is highest.
Calculation	It is calculated as the number of inhabitants living within 0,5 km of public transit running at least every 20 min during peak periods divided by total district or city population.
Unit of measure	%
Perimeter of analysis	District
Frequency of reporting	Yearly
Scoring	3
Notes	/

3.6 Mobility Data

KPI n 106	City commuters using a travel mode to work other than a personal vehicle
Description	The indicator assesses the percentage of city commuters using a travel mode to work other than a personal vehicle. Non personal vehicle modes include carpools, bus, minibus, train, tram, light rail, ferry, bicycles and walking. In case multiple modes are used, the indicator considers the primary travel mode, by distance travelled using that mode.
Calculation	Transportation other than a private vehicle as their primary way to travel to work divided by total number of commuters working in the city. Data can be taken from population surveys.
Unit of measure	%
Perimeter of analysis	City
Frequency of reporting	Yearly
Scoring	5
Notes	Data is mainly gathered from population surveys; therefore, the reliability of the measure depends also by the sample of the survey

KPI n 107	**Average commute time**
Description	Commute time for workers is defined as a one-way commute (not round trip) and include only travel from home to place of employment.
Calculation	Average time in minutes that it takes a working person to travel from home to place of employment. Data can be sourced from population surveys or city departments.
Unit of measure	Minutes
Perimeter of analysis	City
Frequency of reporting	Yearly
Scoring	5
Notes	Data is mainly gathered from population surveys; therefore, the reliability of the measure depends also by the sample of the survey

KPI n 108	**Traffic index**
Description	The indicator considers the difference between travel time during peak periods and travel time at free flow periods. The difference between travel time during peak periods and during free flow periods depends also by the distance travelled, for this reason the difference furtherly is divided by the distance travelled. the indicator is a measure of the city congestion.
Calculation	The indicator is defined as the difference between the average travel time for commuters during peak periods and the average travel time for commuters at free flow periods. This difference has to be furtherly divided by total number of kilometers travelled. Data can be sourced from population surveys or local transportation authorities.
Unit of measure	Minutes / km
Perimeter of analysis	City
Frequency of reporting	Yearly
Scoring	5
Notes	Data is mainly gathered from population surveys; therefore, the reliability of the measure depends also by the sample of the survey

3.7 Private Vehicles

KPI n 109	**Number of personal automobiles per capita**
Description	The total number of registered personal automobiles refers to private automobiles used for personal use and does not include automobiles that are used for the delivery of goods and services by commercial enterprises. Automobiles that are electric powered are included.
Calculation	It is calculated as the number of registered personal automobiles in a city at the end of the year divided by total city population.
Unit of measure	#/person
Perimeter of analysis	City
Frequency of reporting	Yearly
Scoring	3
Notes	/

KPI n 110	**Number of two-wheeled motorized vehicles per capita**
Description	Two-wheeled motorized vehicles include scooters and motorcycles, while it does not include non-motorized vehicles such as bicycles.
Calculation	It is calculated as the number of registered two-wheeled motorized vehicles in a city at the end of the year divided by total city population.
Unit of measure	#/person
Perimeter of analysis	City
Frequency of reporting	Yearly
Scoring	3
Notes	/

3.8 Green Mobility

KPI n 111	**Number of Electric vehicles (EV) registered in the city**
Description	The indicator evaluates the diffusion of electric vehicles in the city. It considers Battery Electric Vehicles (BEV) and Plug-In Hybrid Electric Vehicles (PHEV).
Calculation	It is calculated as the number of registered Electric Vehicles in the city at the end of current year including private, public and service vehicles.
Unit of measure	#
Perimeter of analysis	City
Frequency of reporting	Yearly
Scoring	4
Notes	/

KPI n 112	**Percentage of vehicles registered in the city that are low-emission vehicles**
Description	Low-emission vehicles include electric, hybrid and hydrogen-fuel-cell-driven vehicles. Low-emission vehicles shall be certified under appropriate exhaust emission standards and the vehicle shall meet other special requirements applicable to conventional or clean-fuel vehicles and their fuels.
Calculation	Number of registered and approved low-emission vehicles registered in the city at the end of the year divided by total number of vehicles registered in the city at the end of the year. Data can be sources from city departments, or institutions that oversee vehicle registration.
Unit of measure	%
Perimeter of analysis	City
Frequency of reporting	Yearly
Scoring	4
Notes	/

3.9 Alternative Transportation

KPI n 113	**Number of autonomous driving vehicles**
Description	Autonomous driving vehicles refer to vehicles that are self-driving, therefore they do not need for a human driver. Autonomous vehicles could reduce traffic fatalities by eliminating accidents caused by human error.
Calculation	Number of autonomous driving vehicles registered in the city, considering both private vehicles and sharing vehicles. Data can be sourced from city departments or institutions that monitor vehicle registration.
Unit of measure	#
Perimeter of analysis	City
Frequency of reporting	Yearly
Scoring	5
Notes	/

KPI n 114	**Access to car sharing solutions for city travels**
Description	The indicator assesses the availability of car sharing solutions in the city. Car-sharing decreases the need for parking space, less vehicles are on the road and less pollution is emitted.
Calculation	Number of cars available for sharing per 100.000 inhabitants. Data can be sourced from vehicle sharing companies or service providers in the city.
Unit of measure	# per 100 000 inhabitants
Perimeter of analysis	City
Frequency of reporting	Yearly
Scoring	3
Notes	/

KPI n 115	**Number of users of sharing transportation per 100 000 population**
Description	Sharing transportation refers to any transportation modes in which individuals can utilize assets owned by another individual or organization, such as ride-sharing services and automobile-sharing services.
Calculation	Total number of users actively using sharing transportation divided by One 100 000th of the city's total population. Data can be sourced from dedicated city departments or from sharing transportation service organizations.
Unit of measure	# per 100 000 inhabitants
Perimeter of analysis	City
Frequency of reporting	Yearly
Scoring	5
Notes	It might be challenging for cities to have access to the required data because of the contrasts in many countries between municipal authorities and sharing transportation providers.

3.10 Road Safety

KPI n 116	**Traffic accidents per 100 000 population**
Description	This indicator considers accidents due to any mode of transportation (automobile, public transport, walking, bicycling, etc.) within city limits.
Calculation	It is calculated as the number of transportation accidents of any kind in 1 year divided by one 100 000th of the city's total population.
Unit of measure	# per 100 000 inhabitants
Perimeter of analysis	City
Frequency of reporting	Yearly
Scoring	2
Notes	/

KPI n 117	**Transportation deaths per 100 000 population**
Description	This indicator considers deaths due to any mode of transportation (automobile, public transport, walking, bicycling, etc.) within city limits, even if death does not occur at the site of the incident but is directly attributable to the accident.
Calculation	It is calculated as the number of fatalities related to transportation of any kind in 1 year divided by one 100 000th of the city's total population.
Unit of measure	# per 100 000 inhabitants
Perimeter of analysis	City
Frequency of reporting	Yearly
Scoring	2
Notes	/

3.11 Public Transportation

KPI n 118	**Public transport use**
Description	Transport trips include trips via heavy rail metro or subway, commuter rail, light rail streetcars and tramways, organized bus, trolleybus, and other public transport services.
Calculation	Total annual number of transport trips originating in the city divided by total city population. Cities calculate only the number of transport trips with origins in the city itself. Data can be sourced from official transport surveys, revenue collection systems (e.g., number of fares purchased), and national censuses.
Unit of measure	# of trips / person
Perimeter of analysis	City
Frequency of reporting	Yearly
Scoring	5
Notes	/

KPI n 119	**Average age of public transport fleet**
Description	The indicator is a measure of the grade of innovation of the public transportation system. Newest solutions should guarantee more energy efficient performances.
Calculation	It is calculated as the average age of all the public transportation modes (buses, metro, trains, trams) that serve the city at current year.
Unit of measure	Years
Perimeter of analysis	City
Frequency of reporting	Yearly
Scoring	3
Notes	/

APPENDIX B: LITERATURE FRAMEWORKS

For reasons of space the authors could not be able to present the entire database of contributions. However, some of them are presented in order to provide the reader a full understanding of the work done.

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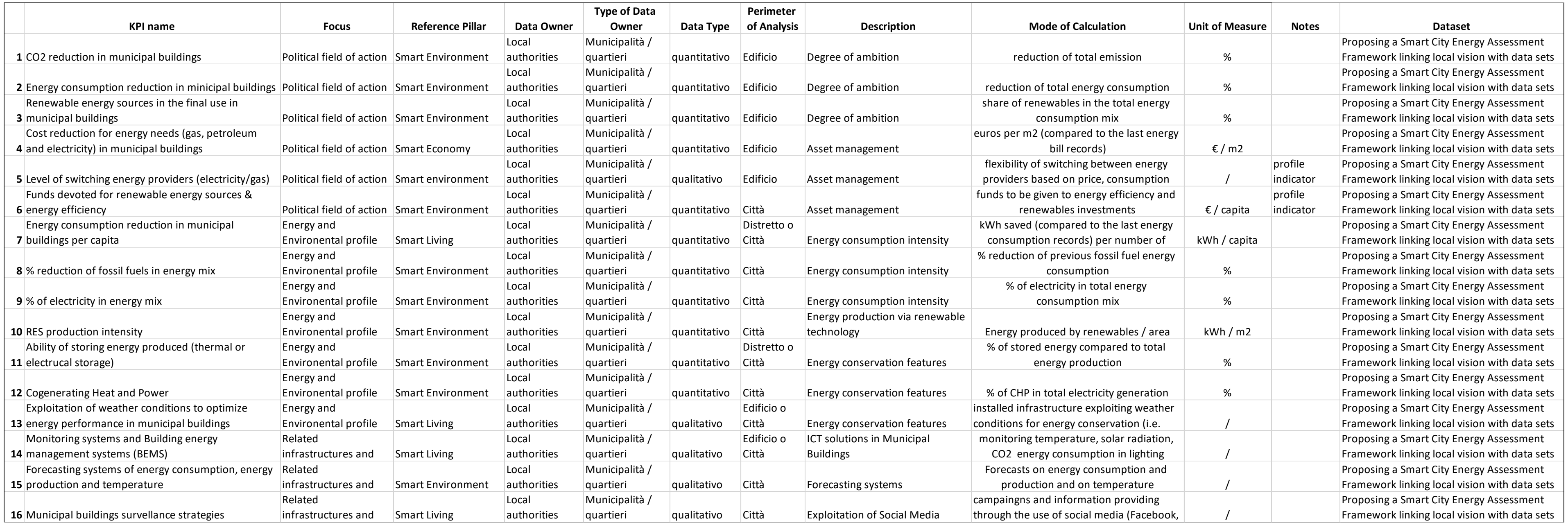

	KPI name	Focus	Reference Pillar	Data Owner	Type of Data Owner	Data Type	Perimeter of Analysis	Description	Mode of Calculation	Unit of Measure	Notes	Dataset
1	CO2 reduction in municipal buildings	Political field of action	Smart Environment	Local authorities	Municipalità / quartieri	quantitativo	Edificio	Degree of ambition	reduction of total emission	%		Proposing a Smart City Energy Assessment Framework linking local vision with data sets
2	Energy consumption reduction in minicipal buildings	Political field of action	Smart Environment	Local authorities	Municipalità / quartieri	quantitativo	Edificio	Degree of ambition	reduction of total energy consumption	%		Proposing a Smart City Energy Assessment Framework linking local vision with data sets
3	Renewable energy sources in the final use in municipal buildings	Political field of action	Smart Environment	Local authorities	Municipalità / quartieri	quantitativo	Edificio	Degree of ambition	share of renewables in the total energy consumption mix	%		Proposing a Smart City Energy Assessment Framework linking local vision with data sets
4	Cost reduction for energy needs (gas, petroleum and electricity) in municipal buildings	Political field of action	Smart Economy	Local authorities	Municipalità / quartieri	quantitativo	Edificio	Asset management	euros per m2 (compared to the last energy bill records)	€ / m2		Proposing a Smart City Energy Assessment Framework linking local vision with data sets
5	Level of switching energy providers (electricity/gas)	Political field of action	Smart environment	Local authorities	Municipalità / quartieri	qualitativo	Edificio	Asset management	flexibility of switching between energy providers based on price, consumption	/	profile indicator	Proposing a Smart City Energy Assessment Framework linking local vision with data sets
6	Funds devoted for renewable energy sources & energy efficiency	Political field of action	Smart Environment	Local authorities	Municipalità / quartieri	quantitativo	Città	Asset management	funds to be given to energy efficiency and renewables investments	€ / capita	profile indicator	Proposing a Smart City Energy Assessment Framework linking local vision with data sets
7	Energy consumption reduction in municipal buildings per capita	Energy and Environental profile	Smart Living	Local authorities	Municipalità / quartieri	quantitativo	Distretto o Città	Energy consumption intensity	kWh saved (compared to the last energy consumption records) per number of	kWh / capita		Proposing a Smart City Energy Assessment Framework linking local vision with data sets
8	% reduction of fossil fuels in energy mix	Energy and Environental profile	Smart Environment	Local authorities	Municipalità / quartieri	quantitativo	Città	Energy consumption intensity	% reduction of previous fossil fuel energy consumption	%		Proposing a Smart City Energy Assessment Framework linking local vision with data sets
9	% of electricity in energy mix	Energy and Environental profile	Smart Environment	Local authorities	Municipalità / quartieri	quantitativo	Città	Energy consumption intensity	% of electricity in total energy consumption mix	%		Proposing a Smart City Energy Assessment Framework linking local vision with data sets
10	RES production intensity	Energy and Environental profile	Smart Environment	Local authorities	Municipalità / quartieri	quantitativo	Città	Energy production via renewable technology	Energy produced by renewables / area	kWh / m2		Proposing a Smart City Energy Assessment Framework linking local vision with data sets
11	Ability of storing energy produced (thermal or electrucal storage)	Energy and Environental profile	Smart Environment	Local authorities	Municipalità / quartieri	quantitativo	Distretto o Città	Energy conservation features	% of stored energy compared to total energy production	%		Proposing a Smart City Energy Assessment Framework linking local vision with data sets
12	Cogenerating Heat and Power	Energy and Environental profile	Smart Environment	Local authorities	Municipalità / quartieri	quantitativo	Città	Energy conservation features	% of CHP in total electricity generation	%		Proposing a Smart City Energy Assessment Framework linking local vision with data sets
13	Exploitation of weather conditions to optimize energy performance in municipal buildings	Energy and Environental profile	Smart Living	Local authorities	Municipalità / quartieri	qualitativo	Edificio o Città	Energy conservation features	installed infrastructure exploiting weather conditions for energy conservation (i.e.	/		Proposing a Smart City Energy Assessment Framework linking local vision with data sets
14	Monitoring systems and Building energy management systems (BEMS)	Related infrastructures and	Smart Living	Local authorities	Municipalità / quartieri	qualitativo	Edificio o Città	ICT solutions in Municipal Buildings	monitoring temperature, solar radiation, CO2 energy consumption in lighting	/		Proposing a Smart City Energy Assessment Framework linking local vision with data sets
15	Forecasting systems of energy consumption, energy production and temperature	Related infrastructures and	Smart Environment	Local authorities	Municipalità / quartieri	qualitativo	Città	Forecasting systems	Forecasts on energy consumption and production and on temperature	/		Proposing a Smart City Energy Assessment Framework linking local vision with data sets
16	Municipal buildings survellance strategies	Related infrastructures and	Smart Living	Local authorities	Municipalità / quartieri	qualitativo	Città	Exploitation of Social Media	campaingns and information providing through the use of social media (Facebook,	/		Proposing a Smart City Energy Assessment Framework linking local vision with data sets

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	KPI name	Focus	Reference Pillar	Data Owner	Type of Data Owner	Data Type	Perimeter of Analysis	Description	Mode of Calculation	Unit of Measure	Notes	Dataset
1	Lifecycle GHG emissions per building	GHG emissions	Smart Environment	ZEN stakeholders	Municipalità / quartieri	quantitativo	Edificio	Total GHG emission	Amount of CO2 equivalent emissions / heated floor area	KgCO2eq / m2		A Norwegian zero emission neighbourhood (ZEN) definition and a ZEN key performance indicator (KPI) tool
2	Lifecycle GHG emissions per infrastructure	GHG emissions	Smart Environment	ZEN stakeholders	Municipalità / quartieri	quantitativo	distretto	Total GHG emission	Amount of CO2 equivalent emissions / outdoor space	KgCO2eq / m2		A Norwegian zero emission neighbourhood (ZEN) definition and a ZEN key performance indicator (KPI) tool
3	Lifecycle GHG emissions per user	GHG emissions	Smart Environment	ZEN stakeholders	Municipalità / quartieri	quantitativo	distretto	Total GHG emission	Amount of CO2 equivalent emissions / # of users	KgCO2eq / capita		A Norwegian zero emission neighbourhood (ZEN) definition and a ZEN key performance indicator (KPI) tool
4	Total Lifecycle GHG emission	GHG emissions	Smart Environment	ZEN stakeholders	Municipalità / quartieri	quantitativo	distretto	Total GHG emission	tonnes of CO2 equivalent emissions	tCO2eq		A Norwegian zero emission neighbourhood (ZEN) definition and a ZEN key performance indicator (KPI) tool
5	GHG emission reduction compared to a base case	GHG emissions	Smart Environment	ZEN stakeholders	Municipalità / quartieri	quantitativo	distretto	GHG emission reduction	percentage reduction	%		A Norwegian zero emission neighbourhood (ZEN) definition and a ZEN key performance indicator (KPI) tool
6	Net energy needed in buildings	Energy	Smart Living	ZEN stakeholders	Municipalità / quartieri	quantitativo	Edificio	Energy efficiency in buildings	total energy needed / heated floor area	kWh / m2		A Norwegian zero emission neighbourhood (ZEN) definition and a ZEN key performance indicator (KPI) tool
7	Gross energy needed in buildings	Energy	Smart Living	ZEN stakeholders	Municipalità / quartieri	quantitativo	Edificio	Energy efficiency in buildings	total energy needed / heated floor area	kWh / m2		A Norwegian zero emission neighbourhood (ZEN) definition and a ZEN key performance indicator (KPI) tool
8	Total energy needed in buildings	Energy	Smart Living	ZEN stakeholders	Municipalità / quartieri	quantitativo	Edificio	Energy efficiency in buildings	total energy needed / heated floor area	kWh / m2		A Norwegian zero emission neighbourhood (ZEN) definition and a ZEN key performance indicator (KPI) tool
9	Energy use	Energy	Smart Environment	ZEN stakeholders	Municipalità / quartieri	quantitativo	distretto	Energy carriers	yearly energy used	kWh / yr		A Norwegian zero emission neighbourhood (ZEN) definition and a ZEN key performance indicator (KPI) tool
10	Energy generation	Energy	Smart Environment	ZEN stakeholders	Municipalità / quartieri	quantitativo	distretto	Energy carriers	yearly energy generation	kWh / yr		A Norwegian zero emission neighbourhood (ZEN) definition and a ZEN key performance indicator (KPI) tool
11	Delivered energy	Energy	Smart Environment	ZEN stakeholders	Municipalità / quartieri	quantitativo	distretto	Energy carriers	yearly energy delivered	kWh / yr		A Norwegian zero emission neighbourhood (ZEN) definition and a ZEN key performance indicator (KPI) tool
12	Exported energy	Energy	Smart Environment	ZEN stakeholders	Municipalità / quartieri	quantitativo	distretto	Energy carriers	yearly energy exported	kWh / yr		A Norwegian zero emission neighbourhood (ZEN) definition and a ZEN key performance indicator (KPI) tool
13	Self consumption	Energy	Smart Environment	ZEN stakeholders	Municipalità / quartieri	quantitativo	distretto	Energy carriers	/	%		A Norwegian zero emission neighbourhood (ZEN) definition and a ZEN key performance indicator (KPI) tool
14	Self generation	Energy	Smart Environment	ZEN stakeholders	Municipalità / quartieri	quantitativo	distretto	Energy carriers	/	%		A Norwegian zero emission neighbourhood (ZEN) definition and a ZEN key performance indicator (KPI) tool
15	Colour coded carpet plot	Energy	Smart Environment	ZEN stakeholders	Municipalità / quartieri	quantitativo	distretto	Energy carriers	/	kWh / yr		A Norwegian zero emission neighbourhood (ZEN) definition and a ZEN key performance indicator (KPI) tool
16	Net load yearly profile	Power/Load	Smart Environment	ZEN stakeholders	Municipalità / quartieri	quantitativo	distretto	Power / Load performance	/	kW		A Norwegian zero emission neighbourhood (ZEN) definition and a ZEN key performance indicator (KPI) tool
17	Net load duration curve	Power/Load	Smart Environment	ZEN stakeholders	Municipalità / quartieri	quantitativo	distretto	Power / Load performance	/	kW		A Norwegian zero emission neighbourhood (ZEN) definition and a ZEN key performance indicator (KPI) tool
18	Peak load	Power/Load	Smart Environment	ZEN stakeholders	Municipalità / quartieri	quantitativo	distretto	Power / Load performance	/	kW		A Norwegian zero emission neighbourhood (ZEN) definition and a ZEN key performance indicator (KPI) tool
19	Peak export	Power/Load	Smart Environment	ZEN stakeholders	Municipalità / quartieri	quantitativo	distretto	Power / Load performance	/	kW		A Norwegian zero emission neighbourhood (ZEN) definition and a ZEN key performance indicator (KPI) tool
20	Utilisation factor	Power/Load	Smart Environment	ZEN stakeholders	Municipalità / quartieri	quantitativo	distretto	Power / Load performance	/	%		A Norwegian zero emission neighbourhood (ZEN) definition and a ZEN key performance indicator (KPI) tool
21	Daily net load profile	Power/Load	Smart Environment	ZEN stakeholders	Municipalità / quartieri	quantitativo	distretto	Power / load flexibility	/	kWh		A Norwegian zero emission neighbourhood (ZEN) definition and a ZEN key performance indicator (KPI) tool
22	Mode of transport	Mobility	Smart Mobility	ZEN stakeholders	Municipalità / quartieri	quantitativo	distretto	Mode of transport	share for each transport	%		A Norwegian zero emission neighbourhood (ZEN) definition and a ZEN key performance indicator (KPI) tool
23	Public transport Proximity	Mobility	Smart Mobility	ZEN stakeholders	Municipalità / quartieri	quantitativo	distretto	Access to public transport	distance to the PT stop	metres		A Norwegian zero emission neighbourhood (ZEN) definition and a ZEN key performance indicator (KPI) tool
24	Public transport frequency	Mobility	Smart Mobility	ZEN stakeholders	Municipalità / quartieri	quantitativo	distretto	Access to public transport	# of buses / period of time	# / h		A Norwegian zero emission neighbourhood (ZEN) definition and a ZEN key performance indicator (KPI) tool
25	Life cycle costs per building	Economy	Smart Economy	ZEN stakeholders	Municipalità / quartieri	quantitativo	Edificio	Life cycle costs	NOK / heated floor area	NOK / m2	profile indicator	A Norwegian zero emission neighbourhood (ZEN) definition and a ZEN key performance indicator (KPI) tool
26	Life cycle costs per infrastructure	Economy	Smart Economy	ZEN stakeholders	Municipalità / quartieri	quantitativo	distretto	Life cycle costs	NOK / outdoor space	NOK / m2	profile indicator	A Norwegian zero emission neighbourhood (ZEN) definition and a ZEN key performance indicator (KPI) tool
27	Life cycle costs per user	Economy	Smart Economy	ZEN stakeholders	Municipalità / quartieri	quantitativo	distretto	Life cycle costs	NOK / # users	NOK / capita	profile indicator	A Norwegian zero emission neighbourhood (ZEN) definition and a ZEN key performance indicator (KPI) tool
28	Total Life cycle costs	Economy	Smart Economy	ZEN stakeholders	Municipalità / quartieri	quantitativo	distretto	Life cycle costs	NOK	NOK	profile indicator	A Norwegian zero emission neighbourhood (ZEN) definition and a ZEN key performance indicator (KPI) tool
29	Demographic needs and consultation plan	Spacial qualities	Smart People	ZEN stakeholders	Municipalità / quartieri	qualitativo	distretto	Demography	No metric	No unit		A Norwegian zero emission neighbourhood (ZEN) definition and a ZEN key performance indicator (KPI) tool
30	Delivery of amenities	Spacial qualities	Smart Living	ZEN stakeholders	Municipalità / quartieri	quantitativo	distretto	amenities	number of amenties	#		A Norwegian zero emission neighbourhood (ZEN) definition and a ZEN key performance indicator (KPI) tool
31	proximity to amenities	Spacial qualities	Smart Living	ZEN stakeholders	Municipalità / quartieri	quantitativo	distretto	amenities	distance from buiildings	meters		A Norwegian zero emission neighbourhood (ZEN) definition and a ZEN key performance indicator (KPI) tool
32	Public space	Spacial qualities	Smart Living	ZEN stakeholders	Municipalità / quartieri	qualitativo	distretto	public space	No metric	No unit	profile indicator	A Norwegian zero emission neighbourhood (ZEN) definition and a ZEN key performance indicator (KPI) tool

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	KPI name	Focus	Reference Pillar	Data Owner	Type of Data Owner	Data Type	Perimeter of Analysis	Description	Mode of Calculation	Unit of Measure	Notes	Dataset
1	Generation of solid waste per capita	Environmental	Smart Environment	Brazilian NSIS database	Governo / PA	Quantitativo	Regione e Città	Generation	Average annual amount of generated urban waste / Total population	kg / inhab. / year		Systems of indicators and conditions for large and medium-
2	Generation of waste by composition (fractions): organic, paper, plastics, metals	Environmental	Smart Environment	/	/	Quantitativo	Regione e Città	Generation	Quantity of specific MSW components / total MSW quantity x 100	%		Systems of indicators and conditions for large and medium-
3	Municipal waste generation per capita	Environmental	Smart Environment	Brazilian NSIS database	Governo / PA	Quantitativo	Regione e Città	Generation	Quantity of generated municipal households waste / total population x 100	kg / inhab. / year		Systems of indicators and conditions for large and medium-
4	Coverage of MSW collection	Environmental	Smart Environment	Brazilian NSIS database	Governo / PA	Quantitativo	Regione e Città	Collection	Number of persons (within the city) with regular collection (hab.)/ city population x 100	%		Systems of indicators and conditions for large and medium-
5	Collection of WSM per capita	Environmental	Smart Environment	Brazilian NSIS database	Governo / PA	Quantitativo	Regione e Città	Collection	Quantity of waste collected / City population x 100	t / inhab. / year		Systems of indicators and conditions for large and medium-
6	Percentage of vehicles fleet using any renewable fuel	Environmental	Smart Mobility	/	/	Quantitativo	Regione e Città	Collection	Number of vehicles in the fleet using fuel from renewable sources / total # of vehicles in the fleet x	%		Systems of indicators and conditions for large and medium-
7	Degree of segregation (collection) (organic, paper, plastics, metals,..)	Environmental	Smart Environment	/	/	Quantitativo	Regione e Città	Collection	Quantity of raw material separated / Total amount of waste collected x 100	%		Systems of indicators and conditions for large and medium-
8	Inclusion of waste pickers in the selective collection system (planning and	Environmental	Smart Environment	/	/	Quantitativo	Regione e Città	Selective Collection	Number of collectors included in the selective collection system / total # of collectors x 100	%		Systems of indicators and conditions for large and medium-
9	Coverage of the selective collection door-to-door in relation to the urban population	Environmental	Smart Environment	Brazilian NSIS database	Governo / PA	Quantitativo	Regione e Città	Selective Collection	Urban population served by door-to-door selective collection / Total urban population x 100	%		Systems of indicators and conditions for large and medium-
10	Degree of nonconformity of selective collection with the environmental regulatory	Environmental	Smart Governance	/	/	Quantitativo	Regione e Città	Selective Collection	Number of notifications of non-compliance with environmental legislation (air, water, and soil)	%		Systems of indicators and conditions for large and medium-
11	Water usage in selective collection	Environmental	Smart Environment	/	/	Quantitativo	Regione e Città	Selective Collection	Total volume of water used to clean containers, transportation and waste facilities / Quantity of	L / t		Systems of indicators and conditions for large and medium-
12	Land usage in selective collection	Environmental	Smart Environment	/	/	Quantitativo	Regione e Città	Selective Collection	Approximate area used by containers and facilities / Quantity of collected waste	m2 / t		Systems of indicators and conditions for large and medium-
13	Rate of material collected by selective collection	Environmental	Smart Environment	Brazilian NSIS database	Governo / PA	Quantitativo	Regione e Città	Selective Collection	Quantity of materials collected by selective collection (except organic material) / Total amount	%		Systems of indicators and conditions for large and medium-
14	Disposal of waste in sanitary and controlled landfills	Environmental	Smart Governance	Brazilian NSIS database	Governo / PA	Quantitativo	Regione e Città	Disposal / Landfill	Quantity of waste deposited in landfills / Quantity of generated waste x 100	%		Systems of indicators and conditions for large and medium-
15	Degree of compliance of disposal with the environmental regulatory standard	Environmental	Smart Environment	/	/	Quantitativo	Regione e Città	Disposal / Landfill	Number of notices of non-compliance with environmental legislation (air, water, soil) detected /	%		Systems of indicators and conditions for large and medium-
16	Water usage in disposal	Environmental	Smart Environment	/	/	Quantitativo	Regione e Città	Disposal / Landfill	Total volume of water used in waste disposal facilities / amount of waste entering the facilities	L / t		Systems of indicators and conditions for large and medium-
17	Land usage in disposal	Environmental	Smart Environment	/	/	Quantitativo	Regione e Città	Disposal / Landfill	Approximate area used by disposal facilities / amount of waste entering the facilities	m2 / t		Systems of indicators and conditions for large and medium-
18	Energy generation	Environmental	Smart Environment	/	/	Quantitativo	Regione e Città	Disposal / Landfill	Amount of electrical or thermal energy generated at the biogas treatment plant / amount of waste	kWh / t		Systems of indicators and conditions for large and medium-
19	Recyling rate of solid waste	Environmental	Smart Environment	Brazilian NSIS database	Governo / PA	Quantitativo	Regione e Città	Recycling	Quantity of recycled waste / Quantity of generated waste x 100	%		Systems of indicators and conditions for large and medium-
20	Degree of nonconformity of recycling with the environmental regulatory framework	Environmental	Smart Governance	/	/	Quantitativo	Regione e Città	Recycling	Number of notices of non-compliance with environmental legislation (air, water, soil) detected /	%		Systems of indicators and conditions for large and medium-
21	Water usage in recycling	Environmental	Smart Environment	/	/	Quantitativo	Regione e Città	Recycling	Total volume of water used in waste recovery and recycling facilities / Amount of waste entering the	L / t		Systems of indicators and conditions for large and medium-
22	Land usage in recycling	Environmental	Smart Environment	/	/	Quantitativo	Regione e Città	Recycling	Approximate area used by recovery and recycling facilities / Amount of waste entering the facilities	m2 / t		Systems of indicators and conditions for large and medium-
23	Energy usage in recycling	Environmental	Smart Environment	/	/	Quantitativo	Regione e Città	Recycling	Quantity of fuel used in recovery and recycling facilities / Amount of waste entering the waste	kWh / t		Systems of indicators and conditions for large and medium-
24	Quantity of treated MSW per capita	Environmental	Smart Environment	/	/	Quantitativo	Regione e Città	Treatment	Quantity of processed MSW per day / Total amount of population	t / inhab. / day		Systems of indicators and conditions for large and medium-
25	Total installed capacity for energy production from renewable sources	Environmental	Smart Environment	/	/	Quantitativo	Regione e Città	Treatment	Amount of electricity from renewable sources	MW		Systems of indicators and conditions for large and medium-
26	Total material recovery capacity (MRF) per capita (elimination or reduction of	Environmental	Smart Environment	/	/	Quantitativo	Regione e Città	Treatment	Quantity of recovered materials / Total amount of population of the city	t / inhab. / year		Systems of indicators and conditions for large and medium-

27	Total amount of MSW processed in an MRF (material recovery unit) per capita	Environmental	Smart Environment	/	/	Quantitativo	Regione e Città	Treatment	Number of processed materials in MRF / Total quantity of population of the city	t / inhab. / year		Systems of indicators and conditions for large and medium-
28	Percentage of total collected MSW that is treated at composting facilities per year	Environmental	Smart Environment	/	/	Quantitativo	Regione e Città	Treatment	Total amount of MSW treated at annual composting facilities / Total MSW collected per year x 100	%		Systems of indicators and conditions for large and medium-
29	Quantity of waste generated at composting facilities per capita	Environmental	Smart Environment	/	/	Quantitativo	Regione e Città	Treatment	Quantity of generated waste in composting facilities per year / Total population	t / inhab. / year		Systems of indicators and conditions for large and medium-
30	Quantity of sold fertilizer per capita (compost)	Environmental	Smart Environment	/	/	Quantitativo	Regione e Città	Treatment	Quantity of fertilizers (resulting from composting) sold / Total population	kg / inhab. / year	profile indicator	Systems of indicators and conditions for large and medium-
31	Total capacity of composting facilities per capita	Environmental	Smart Environment	/	/	Quantitativo	Regione e Città	Treatment	Total amount of MSW processing capacity at composting facilities / total population	t / inhab. / year		Systems of indicators and conditions for large and medium-
32	Percentage of energetically recovered waste	Environmental	Smart Environment	/	/	Quantitativo	Regione e Città	Energy recovery	Total quantity of waste entering the energy recovery facilities / Total quantity of waste generated at the	%		Systems of indicators and conditions for large and medium-
33	Degree of nonconformity of energy recovery with the environmental regulatory	Environmental	Smart Governance	/	/	Quantitativo	Regione e Città	Energy recovery	Number of notifications of non-compliance with environmental legislation (air, water, and soil)	%		Systems of indicators and conditions for large and medium-
34	Energy usage in energy recovery	Environmental	Smart Environment	/	/	Quantitativo	Regione e Città	Energy recovery	Quantity of energy (fuel) used in energy recovery facilities / Amount of waste entering the energy	kWh / t		Systems of indicators and conditions for large and medium-
35	Water usage in energy recovery	Environmental	Smart Environment	/	/	Quantitativo	Regione e Città	Energy recovery	Total volume of water used in waste energy recovery facilities / amount of waste entering the	L / t		Systems of indicators and conditions for large and medium-
36	Land usage in energy recovery	Environmental	Smart Environment	/	/	Quantitativo	Regione e Città	Energy recovery	Approximate area used by energy recovery facilities / Amount of waste entering the facilities	m2 / t		Systems of indicators and conditions for large and medium-
37	Energy generation	Environmental	Smart Environment	/	/	Quantitativo	Regione e Città	Energy recovery	Amount of electrical or thermal energy generated at energy recovery facilities / Amount of waste	kWh / t		Systems of indicators and conditions for large and medium-
38	Degree of MSWM self-financing (financial sustainability)	Economic	Smart Economy	Brazilian NSIS database	Governo / PA	Quantitativo	Regione e Città	Cost-benefit	Revenue collected with MSW management / Total municipal expenditure with MSW management x 100	%		Systems of indicators and conditions for large and medium-
39	Efficiency in collecting MSW	Economic	Smart Environment	/	/	Quantitativo	Regione e Città	Cost-benefit	Current revenues collected per year / Total operating revenues collected per year x 100	%		Systems of indicators and conditions for large and medium-
40	Expenditure on waste management per capita	Economic	Smart Environment	Brazilian NSIS database	Governo / PA	Quantitativo	Regione e Città	Cost-benefit	Expenses with MSW management / Total local population	R$ / inhab. / year	profile indicator	Systems of indicators and conditions for large and medium-
41	Total cost of the waste collection	Economic	Smart Environment	/	/	Quantitativo	Regione e Città	Cost-benefit	Total cost of operation and maintenance involved in the collection and transportation of waste /	R$ / inhab. / year		Systems of indicators and conditions for large and medium-
42	Total cost of the landfill disposal	Economic	Smart Environment	/	/	Quantitativo	Regione e Città	Cost-benefit	Total cost of operation and maintenance involved in waste disposal facilities / attended population	R$ / inhab. / year		Systems of indicators and conditions for large and medium-
43	Total cost of recycling	Economic	Smart Environment	/	/	Quantitativo	Regione e Città	Cost-benefit	Total cost of operation and maintenance involved in waste recovery and recycling facilities / attended	R$ / inhab. / year		Systems of indicators and conditions for large and medium-
44	Total cost of energy recovery	Economic	Smart Environment	/	/	Quantitativo	Regione e Città	Cost-benefit	Total cost of operation and maintenance involved in waste energy recovery facilities / attended	R$ / inhab. / year		Systems of indicators and conditions for large and medium-
45	Fertilizer sales	Economic	Smart Environment	/	/	Quantitativo	Regione e Città	Cost-benefit	Quantity of sold fertilizer / Quantity of produced fertilizer (compost) x 100	%	profile indicator	Systems of indicators and conditions for large and medium-
46	Revenue collected with fees for the provision of MSW management services	Economic	Smart Environment	Brazilian NSIS database	Governo / PA	Quantitativo	Regione e Città	Cost-benefit	Revenue collected with annual MSW management services / Total urban population	R$ / inhab. / year		Systems of indicators and conditions for large and medium-
47	Holding of municipal events with environmental themes	Social	Smart People	/	/	Quantitativo	Regione e Città	Population, culture, environment	Number of environmental awareness events per year	# / year	profile indicator	Systems of indicators and conditions for large and medium-
48	Population coverage	Social	Smart People	/	/	Quantitativo	Regione e Città	Population, culture, environment	sum of [Number of campaigns (1-k) x Population coverage (1-k)] / total # of campaigns x 100	%		Systems of indicators and conditions for large and medium-
49	Ability to respond to consumer complaints	Social	Smart Governance	/	/	Quantitativo	Regione e Città	Population, culture, environment	Total number of MSWM complaints solved in 24 h / Total number of MSWM complaints received in 24 h	%		Systems of indicators and conditions for large and medium-

Lopez-Carreiro et al. 2018

	KPI name	Focus	Reference Pillar	Data Owner	Type of Data Owner	Data Type	Perimeter of Analysis	Description	Mode of Calculation	Unit of Measure	Notes	Dataset
1	Accessibility for groups with impaired mobility	Social transportation	Smart Living	Public transport authorities webpage	Aziende Pubbliche terze	Quantitativo	Città	PT supply (accessibility)	# of PT vehicles equipped for impaired mobility / total # of PT vehicles	%		Evaluating sustainability and innovation of mobility patterns in Spanish cities. Analysis by size and urban typology
2	Public transport (PT) subsidies	Social transportation	Smart Economy	Public transport authorities webpage	Aziende Pubbliche terze	Quantitativo	Città	PT supply (cost to the user)	(% PT fare reduction for young people + PT fare reduction for seniors) / 2	%		Evaluating sustainability and innovation of mobility patterns in Spanish cities. Analysis by size and urban typology
3	Traffic fatalities per capita	Social transportation	Smart Mobility	Regional database	Governo / PA	Quantitativo	Città o regione	externalities of urban mobility	# of traffic fatalities per year and million of inhabitants	fatalities / capita		Evaluating sustainability and innovation of mobility patterns in Spanish cities. Analysis by size and urban typology
4	Private vs Public transport modes	Social transportation	Smart Mobility	Public transport authorities webpage	Aziende Pubbliche terze	Quantitativo	Città	private vehicle demand	% trips by private motorised modes / % of trips by PT modes	No unit		Evaluating sustainability and innovation of mobility patterns in Spanish cities. Analysis by size and urban typology
5	Air quality index	Environmental transportation	Smart Environment	Public transport authorities webpage	Aziende Pubbliche terze	Quantitativo	Città	externalities of urban mobility	µg of PM 2.5 per cubic metre of air	µg / m3		Evaluating sustainability and innovation of mobility patterns in Spanish cities. Analysis by size and urban typology
6	Motorization rate	Environmental transportation	Smart Mobility	Public transport authorities webpage	Aziende Pubbliche terze	Quantitativo	Città	private vehicle demand	# of private and motorised vehicles per 1000 inhabitants	vehicles / inhab.	profile indicator	Evaluating sustainability and innovation of mobility patterns in Spanish cities. Analysis by size and urban typology
7	Density of cycle paths	Environmental transportation	Smart Mobility	Public transport authorities webpage	Aziende Pubbliche terze	Quantitativo	Città	non-motorised modes supply	Length of urban cycle paths per million of inhabitants	km / inhab.	profile indicator	Evaluating sustainability and innovation of mobility patterns in Spanish cities. Analysis by size and urban typology
8	Land consumption for transport infrastructure	Environmental transportation	Smart Environment	Public transport authorities webpage	Aziende Pubbliche terze	Quantitativo	Città	externalities of urban mobility	km2 of parking space / km2 of urban area	NO unit		Evaluating sustainability and innovation of mobility patterns in Spanish cities. Analysis by size and urban typology
9	Time spent travelling per capita	Economic transportation	Smart Mobility	Public transport authorities webpage	Aziende Pubbliche terze	Quantitativo	Città	externalities of urban mobility	commuting time to work per day and person	minutes		Evaluating sustainability and innovation of mobility patterns in Spanish cities. Analysis by size and urban typology
10	Coverage ratio of Public Transport	Economic transportation	Smart Mobility	Public transport authorities webpage	Aziende Pubbliche terze	Quantitativo	Città	PT supply (efficiency cost)	(traffic revenues / O&M costs) x100	%		Evaluating sustainability and innovation of mobility patterns in Spanish cities. Analysis by size and urban typology
11	Ratio between cost of transport for user and GDP per capita	Economic transportation	Smart Mobility	Public transport authorities webpage	Aziende Pubbliche terze	Quantitativo	Città	PT supply (cost to the user)	(single PT ticket price / GDP per capita) + (price per litre of petrol / GDP per capita)	NO unit	profile indicator	Evaluating sustainability and innovation of mobility patterns in Spanish cities. Analysis by size and urban typology
12	Annual expenditure on public transport investment per	Economic transportation	Smart Mobility	Public transport authorities webpage	Aziende Pubbliche terze	Quantitativo	Città	PT supply (user investment)	Annual investment in PT (bus and metro) per resident	€ / inhab		Evaluating sustainability and innovation of mobility patterns in Spanish cities. Analysis by size and urban typology
13	OAS (operating assistance system) coverage	Technological transportation	Smart Mobility	Public transport authorities webpage	Aziende Pubbliche terze	Quantitativo	Città	PT support system	# of buses controlledby OAS / total # of buses	%		Evaluating sustainability and innovation of mobility patterns in Spanish cities. Analysis by size and urban typology
14	Real-time information system	Technological transportation	Smart Mobility	Public transport authorities webpage	Aziende Pubbliche terze	Quantitativo	Città	PT support system	# of stops equipped with real time information services / total # of stops	%		Evaluating sustainability and innovation of mobility patterns in Spanish cities. Analysis by size and urban typology
15	Electronic ticket payment system	Technological transportation	Smart Mobility	Public transport authorities webpage	Aziende Pubbliche terze	Quantitativo	Città	PT support system	[(e-ticketing buses / total # of buses) + (e-ticketing rail modes / total # of rail modes)] /2	%		Evaluating sustainability and innovation of mobility patterns in Spanish cities. Analysis by size and urban typology
16	Alternative fuels in public transport (PT)	Technological transportation	Smart Mobility	Public transport authorities webpage	Aziende Pubbliche terze	Quantitativo	Città	PT supply (fuel)	# of Euro V and electric buses / total # of buses	%	profile indicator	Evaluating sustainability and innovation of mobility patterns in Spanish cities. Analysis by size and urban typology

Pinna et al. 2017

	KPI name	Focus	Reference Pillar	Data Owner	Type of Data Owner	Data Type	Perimeter of Analysis	Description	Mode of Calculation	Unit of Measure	Notes	Dataset
1	bus network density	Public transport	Smart Mobility	analyzed cities and INS (istituto nationale di statistica)	City and Governo	quantitativo	City	/	/	km/km2		Urban policies and mobility trends in Italian smart cities
2	demand for public transport	Public transport	Smart Mobility	analyzed cities and INS (istituto nationale di statistica)	City and Governo	quantitativo	City	/	/	passengers/year		Urban policies and mobility trends in Italian smart cities
3	cycle lanes density	Cycle lanes	Smart Mobility	analyzed cities and INS (istituto nationale di statistica)	City and Governo	quantitativo	City	/	/	km/100 km2		Urban policies and mobility trends in Italian smart cities
4	cycle lanes for ten thousand inhabitants	Cycle lanes	Smart Mobility	analyzed cities and INS (istituto nationale di statistica)	City and Governo	quantitativo	City	/	/	km/10,000 inh		Urban policies and mobility trends in Italian smart cities
5	bicycle station density	Bike sharing	Smart Mobility	analyzed cities and INS (istituto nationale di statistica)	City and Governo	quantitativo	City	/	/	#stations/100 km2		Urban policies and mobility trends in Italian smart cities
6	bicycle per thousand inhabitants	Bike sharing	Smart Mobility	analyzed cities and INS (istituto nationale di statistica)	City and Governo	quantitativo	City	/	/	#bicycles/10,000 inh		Urban policies and mobility trends in Italian smart cities
7	car for ten thousand inhabitants	Car sharing	Smart Mobility	analyzed cities and INS (istituto nationale di statistica)	City and Governo	quantitativo	City	/	/	#stations/10,000 inh		Urban policies and mobility trends in Italian smart cities
8	station for ten thousand inhabitants	Car sharing	Smart Mobility	analyzed cities and INS (istituto nationale di statistica)	City and Governo	quantitativo	City	/	/	#car/10,000 inh		Urban policies and mobility trends in Italian smart cities
9	parking stalls in parking exchange		Smart Mobility	analyzed cities and INS (istituto nationale di statistica)	City and Governo	quantitativo	City	/	/	#/1000 inh		Urban policies and mobility trends in Italian smart cities
10	percentage of electric vehicles in the fleet		Smart Mobility	analyzed cities and INS (istituto nationale di statistica)	City and Governo	quantitativo	City	/	/	%		Urban policies and mobility trends in Italian smart cities

Baralas et al. 2019

	KPI name	Focus	Reference Pillar	Data Owner	Type of Data Owner	Data Type	Perimeter of Analysis	Description	Mode of Calculation	Unit of Measure	Notes	Dataset
1	primary energy use	Energy and resources	Smart Environment	local authoties targeted by CESBA MED	City	quantitativo	Building scale	/	/	kWh/m2/y		Urban sustainability audits and ratings of the built environment
2	final thermal energy use	Energy and resources	Smart Environment	local authoties targeted by CESBA MED	City	quantitativo	Building scale	/	/	kWh/m2/y		Urban sustainability audits and ratings of the built environment
3	final electrical energy use	Energy and resources	Smart Environment	local authoties targeted by CESBA MED	City	quantitativo	Building scale	/	/	kWh/m2/y		Urban sustainability audits and ratings of the built environment
4	renewables in final thermal energy use	Energy and resources	Smart Environment	local authoties targeted by CESBA MED	City	quantitativo	Building scale	/	/	%		Urban sustainability audits and ratings of the built environment
5	renewables in final electrical energy use	Energy and resources	Smart Environment	local authoties targeted by CESBA MED	City	quantitativo	Building scale	/	/	%		Urban sustainability audits and ratings of the built environment
6	embodied non-renewables primary energy	Energy and resources	Smart Environment	local authoties targeted by CESBA MED	City	quantitativo	Building scale	/	/	MJ/m2		Urban sustainability audits and ratings of the built environment
7	water consumption for indoor uses	Environment	Smart Environment	local authoties targeted by CESBA MED	City	quantitativo	Building scale	/	/	m3/occupant/y		Urban sustainability audits and ratings of the built environment
8	global warming potential	Environment	Smart Environment	local authoties targeted by CESBA MED	City	quantitativo	Building scale	/	/	kgCO2 eq/m2/y		Urban sustainability audits and ratings of the built environment
9	solid waste categories recycled	Environment	Smart Environment	local authoties targeted by CESBA MED	City	quantitativo	Building scale	/	/	%		Urban sustainability audits and ratings of the built environment
10	ventialtion rate	Environment	Smart Environment	local authoties targeted by CESBA MED	City	quantitativo	Building scale	/	/	Lt/s/m2		Urban sustainability audits and ratings of the built environment
11	thermal comfort index	Environment	Smart Environment	local authoties targeted by CESBA MED	City	quantitativo	Building scale	/	/	%		Urban sustainability audits and ratings of the built environment
12	operational energy cost	Economy	Smart Environment	local authoties targeted by CESBA MED	City	quantitativo	Building scale	/	/	€/m2/y		Urban sustainability audits and ratings of the built environment
13	operational water cost	Economy	Smart Environment	local authoties targeted by CESBA MED	City	quantitativo	Building scale	/	/	€/m2/y		Urban sustainability audits and ratings of the built environment
14	land conservation	Urban system	Smart Environment	local authoties targeted by CESBA MED	City	quantitativo	Neighbourhood scale	/	/	%		Urban sustainability audits and ratings of the built environment
15	operational energy cost for public buildings	Economy	Smart Environment	local authoties targeted by CESBA MED	City	quantitativo	Neighbourhood scale	/	/	€/m2/y		Urban sustainability audits and ratings of the built environment
16	total final thermal energy consumption for buildings	Energy	Smart Living	local authoties targeted by CESBA MED	City	quantitativo	Neighbourhood scale	/	/	kWh/m2/y		Urban sustainability audits and ratings of the built environment
17	total final electric energy consumption for buildings	Energy	Smart Living	local authoties targeted by CESBA MED	City	quantitativo	Neighbourhood scale	/	/	kWh/m2/y		Urban sustainability audits and ratings of the built environment
18	total primary energy consumption for buildings	Energy	Smart Living	local authoties targeted by CESBA MED	City	quantitativo	Neighbourhood scale	/	/	kWh/m2/y		Urban sustainability audits and ratings of the built environment
19	on-site renewables in total final thermal energy consumption	Energy	Smart Environment	local authoties targeted by CESBA MED	City	quantitativo	Neighbourhood scale	/	/	%		Urban sustainability audits and ratings of the built environment
20	on-site renewables in total final electrical energy consumption	Energy	Smart Environment	local authoties targeted by CESBA MED	City	quantitativo	Neighbourhood scale	/	/	%		Urban sustainability audits and ratings of the built environment
21	total GHG emissions from energy use in buildings	Emissions	Smart Living	local authoties targeted by CESBA MED	City	quantitativo	Neighbourhood scale	/	/	kgCO2 eq/m2/y		Urban sustainability audits and ratings of the built environment
22	water consumption in residential buildings	Natural resources	Smart Living	local authoties targeted by CESBA MED	City	quantitativo	Neighbourhood scale	/	/	m3/occupant/y		Urban sustainability audits and ratings of the built environment
23	water consumption in public buildings	Natural resources	Smart Living	local authoties targeted by CESBA MED	City	quantitativo	Neighbourhood scale	/	/	m3/m2		Urban sustainability audits and ratings of the built environment
24	recharge of groundwater through permeable paving/landscaping	Environment	Smart Environment	local authoties targeted by CESBA MED	City	quantitativo	Neighbourhood scale	/	/	%		Urban sustainability audits and ratings of the built environment
25	ambient air quality (PM10) above acceptable limtis	Environment	Smart Environment	local authoties targeted by CESBA MED	City	quantitativo	Neighbourhood scale	/	/	days/y		Urban sustainability audits and ratings of the built environment
26	proximity of residents to public transport	Social aspects	Smart Living	local authoties targeted by CESBA MED	City	quantitativo	Neighbourhood scale	/	/	%		Urban sustainability audits and ratings of the built environment
27	pedestrian & bicycle network	Social aspects	Smart Mobility	local authoties targeted by CESBA MED	City	quantitativo	Neighbourhood scale	/	/	m/100 inhabitants		Urban sustainability audits and ratings of the built environment
28	proximity of residents to key services	Social aspects	Smart Living	local authoties targeted by CESBA MED	City	quantitativo	Neighbourhood scale	/	/	%		Urban sustainability audits and ratings of the built environment
29	community involvement in urban planning	Social aspects	Smart Governance	local authoties targeted by CESBA MED	City	qualitativo	Neighbourhood scale	/	/	level (score)		Urban sustainability audits and ratings of the built environment

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	KPI name	Focus	Reference Pillar	Data Owner	Type of Data Owner	Data Type	Perimeter of Analysis	Description	Mode of Calculation	Unit of Measure	Notes	Dataset
1	greenhouse gases	Environment	Smart Living	Tested on Expo 2015	Quartiere	quantitativo	Expo Milano 2015	distribution network and lightning system	/	CO2 eq		Smartainability: A Methodology for Assessing the Sustainability of the Smart City
2	Nox acid gases	Environment	Smart Living	Tested on Expo 2015	Quartiere	quantitativo	Expo Milano 2015	distribution network and lightning system	/	t Nox		Smartainability: A Methodology for Assessing the Sustainability of the Smart City
3	SO2 acid gases	Environment	Smart Living	Tested on Expo 2015	Quartiere	quantitativo	Expo Milano 2015	distribution network and lightning system	/	t SO2		Smartainability: A Methodology for Assessing the Sustainability of the Smart City
4	PM10 particulate	Environment	Smart Living	Tested on Expo 2015	Quartiere	quantitativo	Expo Milano 2015	distribution network and lightning system	/	t PM10		Smartainability: A Methodology for Assessing the Sustainability of the Smart City
5	PM2.5 particulate	Environment	Smart Living	Tested on Expo 2015	Quartiere	quantitativo	Expo Milano 2015	distribution network and lightning system	/	t PM2.5		Smartainability: A Methodology for Assessing the Sustainability of the Smart City
6	costs	Economy	Smart Living	Tested on Expo 2015	Quartiere	quantitativo	Expo Milano 2015	distribution network and lightning system	/	€		Smartainability: A Methodology for Assessing the Sustainability of the Smart City
7	costs variation by service suspension	Economy	Smart Living	Tested on Expo 2015	Quartiere	quantitativo	Expo Milano 2015	distribution network and lightning system	/	%		Smartainability: A Methodology for Assessing the Sustainability of the Smart City
8	energy used	Energy	Smart Living	Tested on Expo 2015	Quartiere	quantitativo	Expo Milano 2015	distribution network and lightning system	/	MWh		Smartainability: A Methodology for Assessing the Sustainability of the Smart City
9	renewable energy used	Energy	Smart Living	Tested on Expo 2015	Quartiere	quantitativo	Expo Milano 2015	distribution network and lightning system	/	%		Smartainability: A Methodology for Assessing the Sustainability of the Smart City
10	service suspension number	Living	Smart Living	Tested on Expo 2015	Quartiere	quantitativo	Expo Milano 2015	distribution network and lightning system	/	%		Smartainability: A Methodology for Assessing the Sustainability of the Smart City
11	service suspension duration	Living	Smart Living	Tested on Expo 2015	Quartiere	quantitativo	Expo Milano 2015	distribution network and lightning system	/	%		Smartainability: A Methodology for Assessing the Sustainability of the Smart City
12	greenhouse gases	Environment	Smart Living	Tested on Expo 2015	Quartiere	quantitativo	Expo Milano 2015	telecommunication network and telepresence	/	CO2 eq		Smartainability: A Methodology for Assessing the Sustainability of the Smart City
13	Nox acid gases	Environment	Smart Living	Tested on Expo 2015	Quartiere	quantitativo	Expo Milano 2015	telecommunication network and telepresence	/	t Nox		Smartainability: A Methodology for Assessing the Sustainability of the Smart City
14	SO2 acid gases	Environment	Smart Living	Tested on Expo 2015	Quartiere	quantitativo	Expo Milano 2015	telecommunication network and telepresence	/	t SO2		Smartainability: A Methodology for Assessing the Sustainability of the Smart City
15	PM10 particulate	Environment	Smart Living	Tested on Expo 2015	Quartiere	quantitativo	Expo Milano 2015	telecommunication network and telepresence	/	t PM10		Smartainability: A Methodology for Assessing the Sustainability of the Smart City
16	PM2.5 particulate	Environment	Smart Living	Tested on Expo 2015	Quartiere	quantitativo	Expo Milano 2015	telecommunication network and telepresence	/	t PM2.5		Smartainability: A Methodology for Assessing the Sustainability of the Smart City
17	costs	Economy	Smart Living	Tested on Expo 2015	Quartiere	quantitativo	Expo Milano 2015	telecommunication network and telepresence	/	€		Smartainability: A Methodology for Assessing the Sustainability of the Smart City
18	energy used	Energy	Smart Living	Tested on Expo 2015	Quartiere	quantitativo	Expo Milano 2015	telecommunication network and telepresence	/	MWh		Smartainability: A Methodology for Assessing the Sustainability of the Smart City
19	saved time	Living	Smart Living	Tested on Expo 2015	Quartiere	qualitativo	Expo Milano 2015	telecommunication network and telepresence	/	Low-High		Smartainability: A Methodology for Assessing the Sustainability of the Smart City
20	information points	Living	Smart Living	Tested on Expo 2015	Quartiere	qualitativo	Expo Milano 2015	telecommunication network and telepresence	/	Low-High		Smartainability: A Methodology for Assessing the Sustainability of the Smart City
21	foiled cybernetic attaches	Living	Smart Living	Tested on Expo 2015	Quartiere	qualitativo	Expo Milano 2015	telecommunication network and telepresence	/	Low-High		Smartainability: A Methodology for Assessing the Sustainability of the Smart City
22	simultaneously connected users	Living	Smart Living	Tested on Expo 2015	Quartiere	qualitativo	Expo Milano 2015	telecommunication network and telepresence	/	Low-High		Smartainability: A Methodology for Assessing the Sustainability of the Smart City
23	services and applications availability	Living	Smart Living	Tested on Expo 2015	Quartiere	qualitativo	Expo Milano 2015	telecommunication network and telepresence	/	Low-High		Smartainability: A Methodology for Assessing the Sustainability of the Smart City
24	effectiveness decisions growth	Living	Smart Living	Tested on Expo 2015	Quartiere	quantitativo	Expo Milano 2015	telecommunication network and telepresence	/	%		Smartainability: A Methodology for Assessing the Sustainability of the Smart City

25	exposure index	Living	Smart Living	Tested on Expo 2015	Quartiere	qualitativo	Expo Milano 2015	telecommunication network and telepresence	/	Low-High		Smartainability: A Methodology for Assessing the Sustainability of the Smart City
26	greenhouse gases	Environment	Smart Mobility	Tested on Expo 2015	Quartiere	quantitativo	Expo Milano 2015	Mobility	/	CO2 eq		Smartainability: A Methodology for Assessing the Sustainability of the Smart City
27	Nox acid gases	Environment	Smart Mobility	Tested on Expo 2015	Quartiere	quantitativo	Expo Milano 2015	Mobility	/	t Nox		Smartainability: A Methodology for Assessing the Sustainability of the Smart City
28	SO2 acid gases	Environment	Smart Mobility	Tested on Expo 2015	Quartiere	quantitativo	Expo Milano 2015	Mobility	/	t SO2		Smartainability: A Methodology for Assessing the Sustainability of the Smart City
29	PM10 particulate	Environment	Smart Mobility	Tested on Expo 2015	Quartiere	quantitativo	Expo Milano 2015	Mobility	/	t PM10		Smartainability: A Methodology for Assessing the Sustainability of the Smart City
30	PM2.5 particulate	Environment	Smart Mobility	Tested on Expo 2015	Quartiere	quantitativo	Expo Milano 2015	Mobility	/	t PM2.5		Smartainability: A Methodology for Assessing the Sustainability of the Smart City
31	costs	Economy	Smart Mobility	Tested on Expo 2015	Quartiere	quantitativo	Expo Milano 2015	Mobility	/	€		Smartainability: A Methodology for Assessing the Sustainability of the Smart City
32	fossil energy used	Energy	Smart Mobility	Tested on Expo 2015	Quartiere	quantitativo	Expo Milano 2015	Mobility	/	MWh		Smartainability: A Methodology for Assessing the Sustainability of the Smart City
33	renewable energy used	Energy	Smart Mobility	Tested on Expo 2015	Quartiere	quantitativo	Expo Milano 2015	Mobility	/	%		Smartainability: A Methodology for Assessing the Sustainability of the Smart City
34	customer engagement	Living	Smart Mobility	Tested on Expo 2015	Quartiere	qualitativo	Expo Milano 2015	Mobility	/	Low-High		Smartainability: A Methodology for Assessing the Sustainability of the Smart City
35	saved time	Living	Smart Mobility	Tested on Expo 2015	Quartiere	quantitativo	Expo Milano 2015	Mobility	/	%		Smartainability: A Methodology for Assessing the Sustainability of the Smart City
36	driving stress level	Living	Smart Mobility	Tested on Expo 2015	Quartiere	qualitativo	Expo Milano 2015	Mobility	/	Low-High		Smartainability: A Methodology for Assessing the Sustainability of the Smart City

APPENDIX C: EMPIRICAL FRAMEWORKS

For reasons of space the authors could not be able to present the entire database of contributions. However, some of them are presented in order to provide the reader a full understanding of the work done.

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	KPI name	Focus	Reference Pillar	Data Owner	Type of Data Owner	Data Type	Perimeter of Analysis	Description	Mode of Calculation	Unit of Measure	Notes	Dataset
1	Access to basic health care services	People	Smart Living	Rotterdam SCP; SCI	Governo/PA, Aziende pubbliche e private terze	quantitativo	Città	Since good health is the foundation for all other aspects of life, an good access to health is essential for the general well-being and functioning of the society. Health care access — as measured by the ease and timeliness with which people obtain medical services — is a key indicator of quality of care. Basic health care service consists of a minimum degree of health care considered to be necessary to maintain adequate health and protection from disease and includes: - General practicioners - Hospitals, including emergency and chronic treatments - Baby/youth clinics - Pharmacies. Accessibility includes e.g. to physical distance (<500m), 24hrs availability, e-health services, overcoming literacy and language barriers.	(population with access to basic health care services <500m/total population)*100	% people	Share of population with access to basic health care services within 500m	CITYkeys
2	Encouraging a healthy lifestyle	People	Smart Living		Governo/PA, Aziende pubbliche e private terze	qualitativo	Città	Simply telling people to change unhealthy behaviors doesn't work. We often rely on automatic behaviors to get us through the day. People change if unhealthy behaviors become too inconvenient: making bad choices harder is actually the best way to help people get healthier. For example programming elevator doors to close really slowly actually motivates more people to climb stairs. Little changes like these reach everyone—not just the people targeted with a health message. And they get us healthier just by letting us stay on autopilot. Encouraging a healthy lifestyle includes measures like: - biking facilities in the neighbourhood - walking opportunities (network of pedestrian walkways covering the entire area, crossing arrangements) - public sports facilities - non-smoking zones - making healthier food choices the norm - support in work/life balance	Likert scale: No at all – 1 — 2 — 3 — 4 — 5 — Excellent. 1. Not at all: no measures were taken to encourage a healthy lifestyle. 2. Poor: there was little encouragement of a healthy lifestyle. 3. Somewhat: there was some encouragement of a healthy lifestyle with the implementation of some measures 4. Good: a sufficient encouragement of a healthy lifestyle was translated into several offline (biking facilities, public sports facilities) and online (i.e. app reminders) initiatives. 5. Excellent: a healthy lifestyle was extensively encouraged offline (biking facilities, public sports facilities, pedestrian networks) and online (i.e. exercise apps).	Likert	The extent to which policy efforts are undertaken to encourage a healthy lifestyle	CITYkeys
3	Traffic accidents	People	Smart Mobility	Civitas; Rotterdam SCP; European Green Capital Award study; 2Decide; CASBEE_City_2012; UNECE; ,GCIF; COMIND; URBES	Governo/PA, Aziende pubbliche e private terze	quantitativo	Città	Traffic accident rates and, specifically, fatality rates, can serve as indicators for the overall safety of the transportation system, the complexity and congestion of the roadway and transport network, the amount and effectiveness of traffic law enforcement, the quality of the transportation fleet (public and private), and the condition of the roads themselves (ISO/DIS 37120, 2013). Traffic deaths represent the most severe type of traffic safety failure, allowing cities to focus on their most urgent traffic safety needs. This indicator includes deaths due to any transportation-related proximate causes in any mode of travel (automobile, public transport, walking, bicycling, etc.): any death directly related to a transportation incident, even if death does not occur at the site of the incident, but is directly attributable to the accident. This indicator is particularly urgent in Central-Eastern European countries, where improvements in traffic infrastructures have not kept up with the rapidly growing traffic density. Transportation fatalities are used here as a proxy for all transportation injuries. Whereas many minor injuries are never reported—and thus cannot be measured— deaths are almost always reported. It is also worth noting that differences in the quality of the roadway, the quality of motorized vehicles, and the nature of law enforcement can change the relationship between injury and fatality. Cities and countries may have different definitions of causality, specifically related to the amount of time that can elapse between a traffic incident and a death.	This indicator shall be calculated as the number of fatalities related to transportation of any kind (numerator), divided by one 100 000th of the city's total population (denominator). The result shall be expressed as the number of transportation fatalities per 100 000 population. The city shall include in this indicator deaths due to any transportation-related proximate causes in any mode of travel (automobile, public transport, walking, bicycling, etc.). The city shall count any death directly related to a transportation incident within city limits, even if death does not occur at the site of the incident, but is directly attributable to the accident.	#/100.000	Number of transportation fatalities per 100 000 population	CITYkeys
4	Crime rate	People	Smart Governance	Rotterdam SCP; Smart city Wheel; European Smart Cities v1.0 (2007); SCI; City Protocol; GCIF	Governo/PA, Aziende pubbliche e private terze	quantitativo	Città	The number of violence, annoyances and crimes is a lead indicator of feelings of personal safety (ISO/DIS 37120, 2013). Violence is the intentional use of physical force or power, threatened or actual, against oneself, another person or against a group or community, that either results in or has a high likelihood of resulting in injury, death, psychological harm, maldevelopment or deprivation (e.g. murder). Crime refers to illegal acts in general (e.g. car radio theft). Annoyances are not necessarily illegal, but do cause hinder (e.g. littering).	This indicator shall be calculated as the total number of all crimes reported (numerator) divided by one 100 000th of the city's total population (denominator). The result shall be expressed as the number of crimes per 100 000 population.	#/100.000	Number of violence, annoyances and crimes per 100.000 population	CITYkeys

5	Cybersecurity	People	Smart Governance		Governo/PA, Aziende pubbliche e private terze	qualitativo	Città	Cybersecurity is defined as “the discipline of ensuring that ICT systems are protected from attacks and incidents, whether malicious or accidental, threatening the integrity of data, their availability or confidentiality, including attempts to illegally ‘exfiltrate’ sensitive data or information out of the boundaries of an organization” (ITU, 2015). Cybersecurity will certainly gain importance in the near future because of increased digitalisation and the development of the Internet of Things (IoT) and highly increasing number of cyberattacks (Symantec, 2014). Cybersecurity is important for smart cities because smart cities with ICT as key enabler mean increasing generation of data, ICT complexity and hyper-connectivity which will also mean increasing vulnerability, both to malicious attacks and unintentional incidents. By conceiving interconnected urban systems with cybersecurity and data protection in mind, city administrators will be able to ensure service continuity, safety and well-being for citizens and businesses alike. (ITU, 2015). This indicator analyses the city’s preparedness to risks of cybersecurity (use of proper security procedures) and its ability to manage and mitigate possible disturbances (e.g. cyberattacks). In addition to this indicator, cities are recommended to adopt more detailed cybersecurity indicators adapted to their risks. Such have been developed by ITU, see ITU Recommendation ITU-T X.1208 (2014) ”A cybersecurity indicator of risk to enhance confidence and security in the use of telecommunication/information and communication technologies”.	1. There has been no serious information leakage or cyberattack with significant negative impact on the organisation, its employees or citizens during the past two years. Serious means that it results in disclosure of information (e.g. confidential or sensitive personally identifiable information) or financial lost, due to illegal system access, unauthorized data storage or transmission, unauthorized hardware and software modifications or personnel’s lack of compliance with security procedures. 2. The city makes annually a risk assessment on risks of cybersecurity and has a contingency plan against the identified risks. 3. All city personnel receive basic security training when they are employed to conduct adequately to security incidents. 4. The city has recruited personnel dedicated to cybersecurity and they have signed a security pledge. 5. Employees’ devices deploy an antivirus program for mitigating malware including viruses residing in them and remote access protected, i.e. controlled with security function for intrusion prevention or intrusion detection.	Likert	The level of cybersecurity of the cities’ systems.	CITYkeys
6	Data privacy	People	Smart Governance		Governo/PA, Aziende pubbliche e private terze	qualitativo	Città	Data privacy, or information privacy, is the privacy of personal information and usually relates to personal data stored on computer systems (Technopedia). Privacy concerns exist wherever personally identifiable information or other sensitive information is collected and stored – in digital form or otherwise. If personal data is being collected, the purpose of data collection should be known and the collected data shouldn’t be used for any other purpose. The owner of the data i.e. the administrator of the register should also be defined. If the city collects private data from the citizens (e.g. on energy consumption), authorisations from the end-users need to be acquired. It is recommended that such authorisations are made in form of a written agreement that clearly specifies the data to be collected, collection interval, use purpose and that the data won’t be used for other purposes, and who will have access to the data. It is to be noted that information based on personal or private data can often be anonymised e.g. through aggregation. This indicator analyses the extent to which regulations on data protection are followed and to which proper procedures to protect personal or private data are implemented. Data protection refers to the tools and processes used to store data relevant to a certain ICT system or environment, as well as recover lost data in case of an incident – be it fraudulent, accidental or caused by a natural disaster. One critical element about data is the concept of data ownership, which refers to who is in charge of data, who can authorize or deny access to certain data, and is responsible for its accuracy and integrity, in particular personally identifiable information (PII) . (ITU, 2015)	1. City doesn’t follow national regulations/laws on protection of personal data. 2.City follows national regulations/laws on protection of personal data. 3. City follows relevant national regulations on protection of personal data and the EU Directive on the Protection of Personal Data (95/46/EG).4. City follows all the relevant national and European regulations/laws related to data privacy and protection. If personal/private data is collected from citizens, proper authorisations with written agreements are made. 5.Relevant national and European regulations on data protection and privacy are followed and written agreements are made for use of citizens’ private/personal data. All the collected personal/private data, especially sensitive personal data, is accessed only by agreed persons and is heavily protected from others (e.g. locked or database on internal server with firewalls and restricted access).	Likert	The level of data protection by the city.	CITYkeys
7	Access to public transport	People	Smart Mobility	Rotterdam SCP; Covenant of mayors; OECD; City Protocol; GCIF; 2000-Watt;	Governo/PA, Aziende pubbliche e private terze	quantitativo	Città	It is presumed that availability of alternatives to cars will lead to less car use, thereby contributing to an accessible, green and healthy neighbourhood and moreover contributes to European policy goals for sustainable mobility and transport development (EC, 2011). The quality, accessibility and reliability of transport services will also gain increasing importance in the coming years, inter alia due to the ageing of the population. While walking and cycling are alternative modes of transport for short distances, public transport connections are needed for longer trips. Providing access to public transport is an important means to promote its use. This indicator describes the percentage of population with nearby access to a public transport stop or connection, including all modes of public transport; train, tram, subway, bus, etc. (adapted to: City Protocol, 2015).	(Number of inhabitants with a transportation stop <500m/total population)*100%. NB. It can be calculated as the sum of buildings with a point of access within 500m, multiplied by its inhabitants. A point of access is defined as the location where a mode of transportation can be accessed.	% people	Share of population with access to a public transport stop within 500m	CITYkeys
8	Access to vehicle sharing solutions for city travel	People	Smart Mobility	LEED; DGNB	Governo/PA, Aziende pubbliche e private terze	quantitativo	Città	Providing opportunities for sharing vehicles like (e-)bicycles, (e-)cars and (e-)scoorters, can decrease the need for and use of private cars, thereby contributing to an accessible, green and healthy neighbourhood. Cycling is a healthy, flexible, cheap and sustainable way to get from a to b over a short distance. Many European cities therefore would like to stimulate cycling, but in countries without a cycling culture there is limited private ownership of bikes.Car-sharing is about not owning a car, but renting it from a car-sharing company or sharing the car with friends, family, neighbours or co-workers (1,2). Car-sharing is an attractive option for people who drive less than 10.000 km a year. Car-sharers are more likely to travel by bike, saving on car use and improving their health. Car-sharing also decreases the need for parking space, less vehicles are on the road and less pollution is emitted. Car sharing may furthermore improve social cohesion in the neighborhood.	Number of vehicles per 100.000	#/100.000	Number of vehicles available for sharing per 100.000 inhabitants	CITYkeys
9	Length of bike route network	People	Smart Living	FIN Indicators; Transform; OECD; UNECE; Covenant of Mayors; European Green Capital Award study; City Protocol; URBES; ISO 37120	Governo/PA, Aziende pubbliche e private terze	quantitativo	Città	A transportation system that is conducive to bicycling can reap many benefits in terms of reduced traffic congestion and improved quality of life (ISO/DIS 37120, 2013). Economic rewards both to the individual and to society are also realized through reduced health care costs and reduced dependency on auto ownership (and the resulting in insurance, maintenance and fuel costs). Bicycle lanes also require smaller infrastructure investments than other types of transportation infrastructure. This indicator provides cities with a useful measure of a diversified transportation system. Bicycle lanes shall refer to part of a carriageway designated for cycles and distinguished from the rest of the road/carriageway by longitudinal road markings (ISO/DIS 37120, 2013). Bicycle paths shall refer to independent road or part of a road designated for cycles and sign-posted as such. A cycle track is separated from other roads or other parts of the same road by structural means.	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	% in km	% of bicycle paths and lanes in relation to the length of streets (excluding motorways)	CITYkeys
10	Access to public amenities	People	Smart Living	Smart city Profiles; RFSC; FIN indicators; Eurbanlab; 2000Watt; SCI; Rotterdam SCP; City Protocol	Governo/PA, Aziende pubbliche e private terze	quantitativo	Città	It is presumed that nearby availability of amenities leads to a lively neighbourhood and less car use. Amenities in the urban environment make an area more enjoyable and contribute to its desirability. Public amenities are services/facilities which are provided by the government or town/city councils for the general public to use, with or without charge. Examples of the types of public amenities considered here are social welfare points, social meeting centers, theatres and libraries. (note: other public amenities such as green spaces, public recreation and healthcare facilities are already covered in separate indicators). Access to public amenities is an indicator which partially exposes the mix and distribution of different uses in an urban area, indicating the availability of public services in a close proximity of residential location of inhabitants	(Number of inhabitants with a public amenity <500m/total population)*100%. NB. It can be calculated as the sum of buildings with a public amenity within 500m, multiplied by its inhabitants.	% of people	Share of population with access to at least one type of public amenity within 500m	CITYkeys

11	Access to commercial amenities	People	Smart Living	Eurbanlab ,OECD, Rotterdam SCP; City Protocol	Governo/PA, Aziende pubbliche e private terze	quantitativo	Città	It is presumed that availability of amenities leads to a lively neighbourhood and less car use. Amenities in the urban environment make an area more enjoyable and contribute to its desirability.Commercial amenities are services/goods for daily use provided by private actors. Typical commercial amenities include shops for bread, fish, meat, fruits and vegetables, general food shops (i.e. supermarkets), press, and pharmaceutical products (City Protocol (2015)). Access to commercial amenities is an indicator which partially exposes the mix and distribution of different uses in an urban area, indicating the availability of commercial amenities in a close proximity of residential location of inhabitants.		% of people	Share of population with access to at least six types of commercial amenities providing goods for daily use within 500m.	CITYkeys
12	Access to high speed internet	People	Smart Living	ISO 37120; RFSC; Rotterdam SCP; Transform; UNECE; ITU; Green Digital Charter; European Green Capital Award study; City Protocol; GCIF; URBES; Smart city Wheel; Triple Helix Model; European Smart Cities v1.0 (2007);	Governo/PA, Aziende pubbliche e private terze	quantitativo	Città	The internet has proven to be an important enabler. First mainly for sharing information, but more and more for online services such as shopping, but also municipal services such as making an appointment for a new passport or report something stolen to the police. In 2010, ADL and Chalmers found, based on a survey conducted by Ericsson Consumer Labs, that broadband speed is an important factor for driving economic growth, both on micro and macro level (Chalmers, 2013). This indicator aims to ensure good city connectivity and the provision of efficient digital infrastructures and focuses on the fixed (wired)-broadband subscriptions. Fixed (wired)-broadband subscriptions refers to the number of subscriptions for high-speed access to the public Internet (a TCP/IP connection) (ITU, 2014). High-speed access is defined as downstream speeds equal to, or greater than, 256 Kbits/s. Fixed (wired) broadband includes cable modem, DSL, fiber and other fixed (wired)-broadband technologies (such as Ethernet LAN, and broadband-over-power line (BPL) communications). Subscriptions with access to data communications (including the Internet) via mobile-cellular networks are excluded.		#/100	Fixed (wired)-broadband subscriptions per 100 inhabitants .	CITYkeys
13	Access to public free WiFi	People	Smart Living	City Protocol	Governo/PA, Aziende pubbliche e private terze	quantitativo	Città	Wi-Fi* is defined as local area networks compliant with the 802.11 standards (City protocol 2015). Wi-Fi coverage is defined as the urban surface within 200m of a Wi-Fi node, be it available to the general public or restricted to city officials. Public Wi-Fi coverage has proven instrumental in improving the image of public spaces, as well as the reputation of the city itself (City protocol 2015). It also improves the city's attractiveness to potential visitors, and facilitates basic internet access to those not wealthy enough to afford their own connection, reducing the technology gap, and improving quality of life and equity of opportunities, thus strengthening social tissue. In addition, Wi-Fi coverage connects the variety of sensors, actuators, and other devices that make the smart city to the fiber optics network running through the city, providing capillarity to it. Lastly, city officials themselves can connect to this Wi-Fi area, allowing the city administration's data intake and output to reach even further. This strengthening of the communications network provides the city with increased resilience and reaction capabilities. This indicator measures the percentage of a city's public space which is covered by a public Wi-Fi network.	(sum of wifi node's coverage / total city urban surface) *100% (City protocol 2015)	% of m2	Public space Wi-Fi coverage	CITYkeys
14	Flexibility in delivery services	People	Smart Living		Governo/PA, Aziende pubbliche e private terze	qualitativo	Città	The internet has proven to be an important enabler. Not only for sharing information, but more and more for online services such as shopping. It provides the flexibility of shopping when it is convenient for the consumer, since web stores never close. However, all these online orders need to be delivered as well. This indicator analyses the improvement in providing flexibility in delivery services. Examples of improved delivery options: -Possibility to reschedule the delivery appointment to a more convenient time; -Possibility to have the package accepted by a neighbor; -Possibility to pick up the package at a distribution point near the home (such as a post office or a super market);	1.Not at all: there is no flexibility in delivery services at all. Receiving a package requires the consumer to be home during regular business hours (the default). 2. Poor: there is little flexibility in delivery services, providing one additional option to the default. 3. Somewhat: there is some flexibility in delivery services, providing two additional options to the default. 4. Good: there is sufficient flexibility in delivery services, providing three additional options to the default. 5. Excellent: there is extensive flexibility in delivery services, providing more than three additional options to the default.	Likert	The extent to which there is flexibility in delivery services.	CITYkeys
15	Access to educational resources	People	Smart People	Adapted from project definition	Governo/PA, Aziende pubbliche e private terze	qualitativo	Città	Education and training is critical to enhance human creativity and social quality and to prevent social exclusion (ITU, 2014). Next to traditional education, i.e. primary, secondary and tertiary educational facilities, this indicator also emphasizes the importance of life-long learning. 'Lifelong learning' is the "ongoing, voluntary, and self-motivated" pursuit of knowledge for either personal or professional reasons. Therefore, it not only enhances social inclusion, active citizenship, and personal development, but also self-sustainability, rather than competitiveness and employability (EC, 2006). In addition, the number of years of education is strongly associated with the health of populations in both developed and developing countries (ITU, 2014). This indicator analyses the effort made by the city to provide access for all to adequate and affordable educational services. This access includes: physical access to educational institutions, e.g. schools, universities, libraries (number and distance), and digital access (e- learning) to education resources (e.g. open, well-documented and well-indexed).	1 Not at all: There are not enough basic educational amenities (schools, universities) in the city to provide easy access to or decent quality of education for the citizens. 2.Poor: The citizens have decent access to basic education (schools, universities) but the provision of additional educational resources (e.g. libraries) for (life-long) learning is poor 3. Somewhat: The access to basic education is good and additional free educational resources are available for all through libraries and online services 4. Good: Easy access to basic education and good coverage free educational resources for all enabling life long learning 5. Excellent: Wide variety of educational resources available with easy access offline (schools, libraries, universities, museums) and online (e.g. Massive Open Online Courses) ; most of them provided freely to all with special attention to possibilities for life long learning.	Likert	The extent to which the city provides easy access (either physically or digitally) to a wide coverage of educational resources	CITYkeys
16	Environmental education	People	Smart People	SCI	Governo/PA, Aziende pubbliche e private terze	quantitativo	Città	Awareness of environmental problems is important for creating support for environmental projects and programs. Special attention should be given to children at school, as they are the next generation. This indicator, therefore, assesses the extent to which education programs about the environment and sustainability have been implemented at schools.	Calculation;(Number of schools with environmental education programs/total number of schools)*100%	% of schools	The percentage of schools with environmental education programs	CITYkeys

17	Digital literacy	People	Smart People		Governo/PA, Aziende pubbliche e private terze	quantitativo	Città	The European Commission has acknowledged digital competence as a key skill for lifelong learning and essential for participating in our increasingly digitalized society (EC, 2013). The ECDL foundation states that digital literacy is now a critical factor in supporting the overall growth of an economy and development of society (ECDL, 2009). Digital competence can be broadly defined as the confident, critical and creative use of ICT to achieve certain goals. Digital competence is a transversal key competence which, as such, enables us to acquire other key competences (e.g. language, mathematics, learning to learn, cultural awareness). However, in practice many people currently lack digital capabilities. The four main components of the digital divide are access, affordability, relevancy of content and skills (ECDL, 2009). Many national and international policies and investments focus on addressing the first 3 components, often to the detriment of a structured focus on skills. It appears very difficult to measure the actual increase in digital literacy (ECDL, 2009). Therefore, the assessment will focus on the percentage of the target group (e.g. elderly, less-educated, immigrants) reached 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 (EC, 2013).	(Number of people reached/number of people in target group)*100%	% of people	Percentage of target group reached	CITYkeys
18	Diversity of housing	People	Smart Living	LEED; UNECE; City Protocol; Eurbanlab; SCI	Governo/PA, Aziende pubbliche e private terze	quantitativo	Città	It is presumed that a mix of housing types (houses of different sizes, different forms of ownership) is beneficial for the diversity in the city and its neighbourhoods. Jane Jacobs, for example, strongly emphasized the importance of diversity and a mixture of uses as a prerequisite for urban success. She wrote the book 'The death and life of great American cities'(1961), arguing that policies, such as urban renewal and separation of uses (i.e., residential, industrial, commercial) destroy communities and innovative economies by creating isolated, unnatural urban spaces. Jacobs identified four 'generators of diversity' that "create effective economic pools of use": 1. The district must serve more than one primary use, and preferably more than two, activating streets at different times of the day 2. Most blocks must be short, allowing high pedestrian permeability 3. Buildings must be mingled in their age, condition, and required economic yield. 4. A dense concentration of people. Though her theories were very influential, they have not been verified. However, they have recently been applied to the City of Seoul, who found that they "provided important theoretical viewpoints and implications for promoting a vital urban life in contemporary Seoul" (Sung et al., 2015). This case study also translated the theories into indicators which, after further investigation, might be relevant for uptake in CITYkeys indicators at a later stage. At the moment, this indicator focuses on diversity of housing (targeting mainly Jacob's third generator). Below, two calculation methodologies are noted that focus on one aspect of diversity in buildings; housing types (Simpson Diversity Index) and ownership variety (Social housing). Nb. The indicators 'access to public and commercial amenities' partly contribute to Jacob's first generator.	Below, two options to calculate the diversity in housing types are listed and explained. Because of the direct and coherent calculation, the Simpson Diversity Index is the preferred method. However, this Index is perceived as difficult to calculate. As an alternative, this diversity in housing can be approached by assessing the variety in ownership. Score = 1-Sommatoria (n/N)^2 where n= the total number of dwelling units in a single category, and N= total number of dwelling units in all cateogories. The housing categories are defined in the table (LEED, 2014) . This variety in definitions and interpretations of social housing means that it is virtually impossible to provide strictly comparable figures on the supply of social housing in urban innovations. The indicator is therefore to be used in the context of the country specific interpretation of social housing, as well as its importance in the national housing stock. Following Dutch social housing policy, for example, 10-90% social housing as share of the total is considered acceptable. In other countries margins are very different. In the UK, more than 75% of social housing is considered too much. Note: when the country in question has a social housing share of less than 10% in the total housing stock, the assessor can opt to qualify this indicator as "not applicable".	Simpson Diversity Index/Social housing	Simpson Diversity Index of total housing stock in the city. Social housing: Percentage of social dwellings as share of total housing stock in the city	CITYkeys
19	Preservation of cultural heritage	People	Smart People	Eurbanlab; CASBEE_Urban heritage preservation of cultural development_2014	Governo/PA, Aziende pubbliche e private terze	qualitativo	Città	An important aspect in promoting the feeling of community/home is 'place-making'; the creation of place and identity.This identity can be created by building on local and regional history, culture and character. This entails integrating urban design and heritage conservation so that it enhances or connects to the existing character of the place, e.g. preservation, restoration and/or adaptive re-use of historic buildings and cultural landscapes. Keeping these locations' special identity could also bring economic as well as other benefits to the area.	The indicator provides a qualitative measure and is rated on a five-point Likert scale: 1. Not at all: no attention has been paid to existing cultural heritage in urban planning. 2. Fair: heritage places have received some attention in urban planning, but not as an important element. 3. Moderate: some attention has been given to the conservation of heritage places. 4. Much: heritage places are reflected in urban planning 5. Very much: preservation of cultural heritage and connections to existing heritage places are a key element of urban planning.	Likert	The extent to which preservation of cultural heritage of the city is considered in urban planning.	CITYkeys
20	Ground floor usage	People	Smart Living		Governo/PA, Aziende pubbliche e private terze	quantitativo	Città	Making use of ground floors for commercial and public purposes can increase the liveability and atmosphere of a neighbourhood. Also, an interesting public realm will enhance the consumer's experience and support the endeavors of small businesses and retailers thereby adding to successful retail and commerce (Arlington, 2014). One can think of a variety of uses suitable for the ground floor, dependent on the location, including retail, personal and business services, retail equivalents such as educational and conferencing facilities, and arts and cultural resources (Arlington, 2014). The potential for increasing the use for ground floor space lies mostly within residential and office buildings.	(ground floor space used commercially/publically (in m2)/total ground floor space (in m2) *100%. Depending on the city, this indicator maybe limited to certain (central) parts of the urban area.	% of m2	Percentage of ground floor surface of buildings that is used for commercial or public purposes as percentage of total ground floor surface.	CITYkeys
21	Public outdoot recreation space	People	Smart Living	OECD; Rotterdam SCP; City Protocol	Governo/PA, Aziende pubbliche e private terze	quantitativo	Città	Recreation is an important aspect of city life, contributing to the health of citizens, the vitality of the city and community participation. Recreation is a service that many cities provide through a parks and recreation department or related office (ISO/DIS 37120, 2013). Public recreation space is defined broadly to mean land and open space available to the public for recreation. Recreation space shall include only space that primarily serves a recreation purpose. Outdoor recreation space should include: a) city-owned or maintained land; b) other-recreation lands within the city not owned or operated by the city, provided they are open to the public. This category may include state or provincially owned lands, school and college grounds, as well as non-profit. If cities report only city-owned recreation space, this shall be noted. For multi-use facilities, only the portion of the land devoted to recreation shall be counted (the play areas at a school or college, for example, not the entire school site). Double counting shall be avoided. For example, do not include indoor facilities on parkland. The area of the entire outdoor recreation site shall be included (including, for example woodedareas of parks, building maintenance and utility areas) but shall exclude parking areas.	Square meters of public outdoor recreation space per capita shall be calculated as square meters of outdoor public recreation space (numerator) divided by the population of the city (denominator), and shall be expressed as the number of square meters of outdoor recreation space per capita (ISO/DIS 37120, 2013).	m2/cap	Square meters of public outdoor recreation space per capita	CITYkeys
22	Green space	People	Smart Living	UNECE; ClimateCon; 000 100.000 population OECD; SCI; European, Green Capital Award study; City Protocol; GCIF; URBES; Rotterdam SCP	Governo/PA, Aziende pubbliche e private terze	quantitativo	Città	The amount of green area, natural and semi-natural, parks and other open space is an indicator of how much green space a city has. Green areas perform important environmental functions in an urban setting (ISO/DIS 37120, 2013). They improve the urban climate, capture atmospheric pollutants and improve quality of life by providing recreation for urban inhabitants. Research has shown that green neighbourhoods improve the health of their inhabitants (Van den Berg & Van den Berg, 2015). Urban vegetation can also reduce heat in the built environment by providing shade and evaporative cooling (Steeneveld et al., 2011; Heusinkveld et al., 2014; Van Hove et al., 2015). In addition, green elements have a significant positive influence on the human perception of temperature (Klemm et al., 2013). This indicator reflects green area, publicly or privately owned, that is "publicly accessible" as opposed to whether or not the green area is protected. Note: Green area is broader than recreation space (clause 13 ISO/DIS 37120, 2013).	Green space shall be calculated as the total area (in hectares) of green in the city (numerator) divided by one 100 000th of the city's total population (denominator). The result shall be expressed in hectares of green area per 100 000 population.	hectares/100.000	Green area (hectares) per 100 000 population	CITYkeys

23	Annual final energy consumption	Planet	Smart Environment	Eurbanlab; Transform	Governo/PA, Aziende pubbliche e private terze	quantitativo	Città	Reduced and effective energy use can create substantial savings and can enhance security of the energy supply. Reducing the energy consumption also reduces greenhouse gas emissions and the ecological footprint, which contribute to combating climate change and achieve a low carbon economy. (ISO/DIS 37120, 2013). This indicator shall assess the final energy consumption of the city taking into account all forms of energy (e.g. electricity, gas, fuels) and for all functions (transport, buildings, ICT, industry, etc.). The final energy consumption is the energy actually consumed by the end-user. This in contrast with primary energy use, 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, a more common indicator for evaluating energy consumption. When moving towards a renewable energy system, however, measuring the primary energy consumption loses its value. A reduction in primary energy consumption, for example by increasing the production of renewable energy, does not directly lead to a reduction in final energy consumption.	Energy consumption shall be calculated per year as the total use of final energy (MWh) within a city (numerator) divided by the amount of residents in city (denominator). The result indicates the total energy consumption per year in megawatt hours per capita.To facilitate the calculation of the total energy consumption, the indicator can be broken down into energy consumption of various sectors: buildings, transport, industry, public services, ICT, etc.. This can, of course, be further subdivided, for example for 'buildings', in residential buildings, commercial buildings and public buildings, or for 'transport' in public and private transport. All forms of energy need to be taken into account, including electricity consumption, natural gas or thermal energy for heating and cooling and fuels. These will be given in different units of energy (kWh, GJ, m3), but they all have to be	Mwh/cap/yr	Annual final energy consumption for all uses and forms of energy	CITYkeys
24	Renewable energy generated within the city	Planet	Smart Environment	Eurbanlab; Transform; energy derived from OECD; UNECE; READY	Governo/PA, Aziende pubbliche e private terze	quantitativo	Città	The promotion of renewable energy sources is a high priority for sustainable development, for reasons such as the security and diversification of energy supply and for environmental protection (ISO/DIS 37120, 2013). This indicator is the percentage of total energy derived from the renewable systems installed in the city as a share of the city's total energy consumption (ISO/DIS 37120, 2013). Renewable energy shall include both combustible and non- combustible renewables (ISO/DIS 37120, 2013). Noncombustible renewables include geothermal, solar, wind, hydro, tide and wave energy. For geothermal energy, the energy quantity is the enthalpy of the geothermal heat entering the process. For solar, wind, hydro, tide and wave energy, the quantities entering electricity generation are equal to the electrical energy generated. The combustible renewables include biomass (fuelwood, vegetal waste, ethanol) and animal products (animal materials/waste and sulphite lyes). Municipal waste (waste produced by the residential, commercial and public service sectors that are collected by local authorities for disposal in a central location for the production of heat and/or power) and industrial waste are not considered a renewable source for energy production.	The share of renewable energy produced within the city is calculated as the total consumption of electricity generated from renewable sources (numerator) divided by total energy consumption (denominator). The result shall then be multiplied by 100 and expressed as a percentage. Consumption of renewable sources includes geothermal, solar, wind, hydro, tide and wave energy, and combustibles, such as biomass. (ISO/DIS 37120, 2013).	% of MWh	The percentage of total energy derived from renewable sources, as a share of the city's total energy consumption	CITYkeys
25	CO2 emissions	Planet	Smart Environment	ISO 37120; Smart city Wheel; SCI; FIN indicators; DESIRE; RFSC; UNECE; European Green Capital Award study; City Protocol; GCIF	Governo/PA, Aziende pubbliche e private terze	quantitativo	Città	Greenhouse gases (GHGs) are gases in the atmosphere that absorb infrared radiation that would otherwise escape to space; thereby contributing to rising surface temperatures. There are six major GHGs: carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF6) (ISI/DIS 37120, 2013). The warming potential for these gases varies from several years to decades to centuries. CO2 accounts for a major share of Green House Gas emissions in urban areas. The main sources for CO2 emissions are combustion processes related to energy generation and transport. Tons of CO2 emissions per capita can therefore considered a useful indicator to assess the contribution of urban development on climate change.	The CO2 emissions measured in tonnes per capita shall be measured as the total amount of direct CO2 emisissions in tonnes (equivalent carbon dioxide units) generated over a calendar year by all activities within the city, including indirect emissions outside city boundaries (numerator) divided by the current city population (denominator). The protocol provides accounting methodologies and step-by-step guidance on data collection, quantification, and reporting recommendations for each source of emissions. Both emissions sources and sector categorizations reflect the unique nature of cities and their primary emissions sources. These include emissions from: 1) Stationary Units, 2) Mobile Units, 3) Waste, and 4) Industrial Process and Product Use sectors. For further specifications, refer to the full GPC methodology. Local governments shall be expected to provide information (i.e., quantified emissions) for each of these emission sources.In order to address the issue of inter-city sources of emissions that transcend more than one jurisdictional body, the GPC integrates the GHG Protocol Scope definitions, as follows: 1. Scope 1 emissions: All direct emission sources from activities taking place within the community's geopolitical boundary. Scope 2 emissions: Energy-related indirect emissions that result as a consequence of consumption of grid-supplied electricity, heating and/or cooling, within the community's geopolitical boundary. 3. Scope 3 emissions: All other indirect emissions that occur as a result of activities within the community's geopolitical boundary.	t CO2/cap/yr	CO2 emissions in tonnes per capita per year	CITYkeys
26	Local freight transport fuel mix	Planet	Smart Mobility	2 DECIDE CIVITAS	Governo/PA, Aziende pubbliche e private terze	quantitativo	Città	Worldwide, the transport sector consumes more than 60 per cent of oil products, which constitute about 98 per cent of transport energy use. The structure of energy consumption by transport is directly related to the composition of pollutant emissions.Freight transport can happen by different modes, such as trains, airplanes, ships and trucks. These vehicles can be powered by fossil fuels such as diesel and natural gas, but also by biofuels, hydrogen and electricity. The use of renewable fuels such as biofuels, hydrogen and electricity can provide climate benefits as well as air quality improvements.Despite efforts at the EU level to promote alternative (electricity, natural gas, fuel cells) and renewable energy sources (bio-fuels) for transport, these still have a low penetration.In this indicator, we focus on the fuel mix for "last mile of transport", that is the transport within the city boundaries. Smart city projects may aim at reducing the environmental burden of inner city transport (mainly motor traffic, although in some cities ships can provide an alternative).For the definition of the indicator, we haven't made a distinction in fuel types or transport modes or vehicle types, however this can be supporting information.	(ton kilometres transported by renewable fuel in the city/total ton kilometers in the city)*100% . Please indicate which fuels/energy carriers have been considered. Renewable fuels include: bio-fuels, hydrogen and electricity. Other fuels include: petrol, diesel, liquefied petroleum gas, compressed natural gas, alcohol mixtures.	% in kms	The ratio of renewable fuels in the local freight transport fuel mix.	CITYkeys
27	Domestic material consumption	Planet	Smart Environment		Governo/PA, Aziende pubbliche e private terze	quantitativo	Città	The consumption of materials and resources has an impact on the environment and might contribute to depletion of resources. It is therefore beneficial to decrease the consumption as well as the consequent impacts. In this sense, the trias energetica can also be applied to materials: reduce materials consumption, use recycled materials (and make sure the materials used are recyclable again) and use renewable materials. This indicator targets the first step in this logic. The indicator 'domestic material consumption' (DMC) considers the domestic material extraction (i.e. the amount of raw material extracted from the natural environment, except for water and air), including both imports (added) and exports (deducted) through their simple product weight when crossing the city limits. This makes cross-city comparisons 'asymmetric'. A city with almost no domestic extraction and importing all necessary resources indirectly in the form of mainly finished products will have a much lower DMC compared to a resource rich city (Eurostat 2013, modified).	Domestic Material Consumption (DMC) equals Direct Material Input (DMI) minus exports. DMI measures the direct input of materials for the use in the economy. DMI equals Domestic Extraction (DE) plus imports	t/cap/year	The total amount of material directly used in the city per capita (t/cap/year)	CITYkeys
28	Water consumption	Planet	Smart Environment	Siemens Green City Index; FIN Indicators; European Green Capital Award study; UNECE; OECD; ClimateCon; Rotterdam SCP; City protocol; GCIF; COMIND	Governo/PA, Aziende pubbliche e private terze	quantitativo	Città	Water consumption must be in harmony with water resources to be sustainable (ISO/DIS 37120, 2013). This harmony may be achieved through improvements in water supply systems and changes in water consumption patterns. The main driver for water consumption indicator is the increased concern of water scarcity and decreased water quality. Water management and supply of safe drinking water have become a global issue. Due to changes in the climate, there has been an increase of either extreme dry and warm seasons in some countries or rainy seasons connected with floods in other areas. Water scarcity varies greatly between countries, even between regions inside the country. This indicator will need to be measured in terms of changes from year to year within a city within a range of rates due to the variability among cities.	The indicator shall be calculated as the total amount of the city's water consumption in litres per day (numerator) divided by the total city population (denominator). The result shall be expressed as the total water consumption per capita in litres/days.	liters/cap/year	Total water consumption per capita per day	CITYkeys

29	Grey and rain water use	Planet	Smart Environment	OECD	Governo/PA, Aziende pubbliche e private terze	quantitativo	Città	Water consumption must be in harmony with water resources to be sustainable (ISO/DIS 37120, 2013). Re-using grey water and rain water lowers the demand for tap water and improves the balance of the water system. Greywater is wastewater generated in households or office buildings from sources such as water basins, showers, baths, clothes washing machines or dish washers (streams except for the wastewater from toilets). Grey water and rain water use may be an important aid to significantly decrease the domestic water consumption. The published literatures indicate that the typical volume of grey water varies from 90 to 120 l/p/d depending on lifestyles, living standards and other issues.		% houses	Percentage of houses equipped to reuse grey and rain water	CITYkeys
30	Water exploitation index	Planet	Smart Environment	DESIRE	Governo/PA, Aziende pubbliche e private terze	quantitativo	Città	Water consumption must be in harmony with water resources to be sustainable (ISO/DIS 37120, 2013). The earth's freshwater resources are subject to increasing pressure in the form of consumptive water use and pollution. The Water Exploitation Index (WEI) compares the volumes of water consumption to available resources.	(volume of water abstraction in the geographically relevant area/volume of long term freshwater resources in the geographically relevant area)*100% (EEA)	% of m3	Annual total water abstraction as a percentage of available long-term freshwater resources in the geographically relevant area (basin) from which the city gets its water.	CITYkeys
31	Water losses	Planet	Smart Environment	Siemens Green City Index; UNECE; FIN Indicators; City Protocol; GCIF; URBES	Governo/PA, Aziende pubbliche e private terze	quantitativo	Città	Water consumption must be in harmony with water resources to be sustainable. Before reaching the users, a part of the water supplied might be lost through leakage or illegal tapping (ISO/DIS 37120, 2013). In cities with old and deteriorating water reticulation systems, a substantial proportion of piped water may be lost through cracks and flaws in pipes – for example up to 30 per cent of water is lost in this way in some countries in Eastern Europe. The percentage of water loss (unaccounted for water) represents the percentage of water that is lost from treated water entering distribution system and that is accounted for and billed by the water provider. This includes actual water losses, e.g. leaking pipes, and billing losses, e.g. delivered through informal or illegal connection.	This indicator shall be calculated as the volume of water supplied minus the volume of customer billed water (numerator) divided by the total volume of water supplied (denominator). The result shall then be multiplied by 100 and expressed as a percentage.	% of m3	Percentage of water loss of the total water consumption	CITYkeys
32	Population density	Planet	Smart People	FIN Indicators	Governo/PA, Aziende pubbliche e private terze	quantitativo	Città	Population density is an indicator usually associated with several aspects of sustainable urban development, such as the efficient operation of urban infrastructures, the share of green transport modes, street life, and soil sealing: -Efficient urban infrastructures: The higher the population density is, the easier it is to operate the public transport, but also water, communication and energy infrastructures at low cost. -There is strong statistical evidence for a positive correlation between population density and the share of green transport modes public transport, walking and biking (Newman & Kenworthy 1999, 2006) -Also, a higher urban population is sometimes associated with lively urban streets. -Also, a high population density reduces the footprint of urban development and prevents the development of farm land and natural areas	Population density is calculated as the ratio of number of inhabitants (numerator) divided by the overall area of the city (km2) (denominator).	#/km2	Number of people per km2	CITYkeys
33	Local food production	Planet	Smart Environment		Governo/PA, Aziende pubbliche e private terze	quantitativo	Città	Local food production increases self-reliant and resilient food networks, enhances local economies by connecting food producers and food consumers in the same geographic region. It can reduce the carbon footprint of the urban areas by reducing energy demand of transport, stimualte the local economy, and improve citizen participation and social cohesion in the city, and stimulate the local economy	(Food produced in 100 km radius (tons) / Total food demand within city (tons)) * 100	% of tonnes	Share of food consumption produced within a radius of 100 km	CITYkeys
34	Brownfield use	Planet	Smart Environment		Governo/PA, Aziende pubbliche e private terze	quantitativo	Città	Brownfield is a term used in urban planning to describe "land which is or was occupied by a permanent structure, including the curtilage of the developed land and any associated fixed surface infrastructure." (Department for Communities and Local Government 2012). Many brownfields are contaminated as a result of previous industrial or commercial uses. The European Environment Agency (EEA) has estimated that there are as many as three million brownfield sites across Europe, often located and well connected within urban boundaries and as such offering a competitive alternative to greenfield investments. Brownfield remediation and regeneration represents a valuable opportunity, not only to prevent the loss of pristine countryside and reduce ground sealing, but also to enhance urban spaces and remediate the sometimes contaminated soils (DG Environment 2013).	The indicator "brownfield redevelopment" is calculated as the brownfield area redeveloped in the last year [km2] (numerator) divided by the total brownfield area in the city [km2] (denominator). The result shall then be multiplied by 100 and expressed as a percentage.Nb. Database entries, SHP files can be used	% of km2	Share of brownfield area that has been redeveloped in the past period as percentage of total brownfield area	CITYkeys
35	Climate resilience strategy	Planet	Smart Environment	Eurbanlab	Governo/PA, Aziende pubbliche e private terze	qualitativo	Città	Urban areas in Europe and worldwide are increasingly experiencing the pressures arising from climate change and are projected to face aggravated climate-related impacts in the future. Cities and towns play a significant role in the adaptation to climate change in the EU, which has been recognised by the EU Strategy on adaptation to climate change. Several cities and towns across Europe are already pioneering adaptation action and many others are taking first steps to ensure that European cities remain safe, liveable and attractive centres for innovation, economic activities, culture and social life (climate-adapt.org). This indicator assesses to what extent the city has a resilience strategy and action plan.	The indicator provides a qualitative measure and is rated on a seven - point Likert scale. This Likert scale is based on the steps suggested by the "Mayors adapt" initiative for climate change adaptation in urban areas (Mayors Adapt 2015a,b). 1. No action has been taken yet 2. The ground for adaptation has been prepared (the basis for a successful adaptation process) 3. Risks and vulnerabilities have been assessed 4. Adaptation options have been identified 5. Adaptation options have been selected 6. Adaptation options are being implemented 7. Monitoring and evaluation is being carried out.	Likert	The extent to which the city has developed and implemented a climate resilience strategy.	CITYkeys

36	Urban heat island	Planet	Smart Environment		Governo/PA, Aziende pubbliche e private terze	quantitativo	Città	Urban areas in Europe and worldwide are increasingly experiencing the pressures arising from climate change and are projected to face aggravated climate-related impacts in the future. Cities and towns play a significant role in the adaptation to climate change in the EU, which has been recognised by the EU Strategy on adaptation to climate change. This indicator focuses on the urban heat island (UHI) effect, the difference in air temperature between the city and its surroundings. The UHI effect is caused by the absorption of sunlight by (stony) materials, the lack of evaporation and the emission of heat caused by human activities. The effect is at its highest point after sunset and can reach up to 9˚C in e.g. Rotterdam (Van Hove et al., 2014). Due to the UHI effect, urban areas experience more heat stress than the countryside.	Whether there is one or several measurement stations in the built environment, compare the air temperature measurements of these stations with a station outside the city which functions as a reference station, and look for the largest temperature difference (hourly average) during the summer months.	°C UHImax	Maximum difference in air temperature within the city compared to the countryside during the summer months	CITYkeys
37	Nox	Planet	Smart Environment	Siemens Green City Index; European Green Capital Award study	Governo/PA, Aziende pubbliche e private terze	quantitativo	Città	Improving the air quality in urban areas has been identified by the European Innovation Partnership on Smart Cities anc Communities (EIP SCC) as one of the main challenges in the vertical priority area of Sustainable Urban Mobility (EIP SCC 2013, 8). Nitrogen oxides (NO and NO2) are major air pollutants, which can have significant impacts on human health and the environment (ISO/DIS 37120, 2013). NO contributes to ozone layer depletion and, when exposed to oxygen, can transform into NO2. NO2 contributes to the formation of photochemical smog and at raised levels can increase the likelihood of respiratory problems. Nitrogen dioxide inflames the lining of the lungs, and it can reduce immunity to lung infections. This can cause problems such as wheezing, coughing, colds, flu and bronchitis. Increased levels of nitrogen dioxide can have significant impacts on people with asthma because it can cause more frequent and more intense attacks. NO2 chemically transforms into nitric acid and contributes to acid rain. Nitric acid can corrode metals, fade fabrics, and degrade rubber. When deposited, it can also contribute to lake acidification and can damage trees and crops, resulting in substantial losses. Nitrogen dioxide is part of the exhaust gases of motor vehicles, but also emanates from other combustion processes, related e.g to domestic heating and industrial processes.	(Nox emissions (g)/population) = g/cap of Nox	g/cap	Annual nitrogen oxide emissions (NO and NO2) per capita	CITYkeys
38	Fine particulater matter emissione (PM2.5)	Planet	Smart Environment	Siemens Green City Index; European Smart Cities v1.0 (2007); European Green Capital Award study; Civitas	Governo/PA, Aziende pubbliche e private terze	quantitativo	Città	Improving the air quality in urban areas has been identified by the European Innovation Partnership on Smart Cities and Communities (EIP SCC) as one of the main challenges in the vertical priority area of Sustainable Urban Mobility (EIP SCC 2013, 8).Fine particulate matter can cause major health problems in cities. According to the WHO, any concentration of particulate matter (PM) is harmful to human health. PM is carcinogenic and harms the circulatory system as well as the respiratory system. As with many other air pollutants, there is a connection with questions of environmental justice, since often underprivileged citizens may suffer from stronger exposure. The evidence on PM and its public health impact is consistent in showing adverse health effects at exposures that are currently experienced by urban populations in both developed and developing countries. The range of health effects is broad, but are predominantly to the respiratory and cardiovascular systems (ISO/DIS 37120, 2013).	(PM2.5 emissions (g)/population)=g/cap of PM2.5	g/cap	Annual particulate matter emissions (PM 2,5) per capita	CITYkeys
39	Air quality index	Planet	Smart Environment	RFSC; FIN Indicators; Rotterdam SCP; OECD; COMIND	Governo/PA, Aziende pubbliche e private terze	quantitativo	Città	Improving the air quality in urban areas has been identified by the European Innovation Partnership on Smart Cities and Communities (EIP SCC) as one of the main challenges in the vertical priority area of Sustainable Urban Mobility (EIP SCC 2013, 8).Air quality is expressed in 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 summersmog). The concentration levels of these pollutants together define the air quality.For the EU, the CiteAir project has defined hourly, daily and yearly indices to express in one figure air quality. (http://www.airqualitynow.eu/index.php). For this indicator we use the year average air quality index. It is a distance to target indicator that provides a relative measure of the annual average air quality in relation to the European limit values (annual air quality standards and objectives from EU directives). If the index is higher than 1: for one or more pollutants the limit values are not met. If the index is below 1: on average the limit values are met.	scheme of air quality (Pullutant; target value/limit value; Subindex calculation): NO2; year average=40 ug/m3; year average/40. PM10 uguale a NO2. PM10daily; max number of daily averages above 50 ug/m3 is 35 days; log(number of days +1)/log(36). Ozone; 25 days with an 8 hour average value >= 120 ug/m3; #days with 8 hour average >= 120/125. SO2; year average is 20 ug/m3; year average/20. Benzene; year average is 5 ug/m3; year average/5. The overall city index is the average of the sub-indices for NO2, PM10 (both year average and the number of days >=50 µg/m3 sub-index) and ozone for the city background index. For the traffic year average index the averages of the sub-indices for NO2 and PM10 (both) are being used. The other pollutants (including PM2.5) are used in the presentation of the city index if data are available, but do not enter the calculation of the city average index. They are treated as additional pollutants like in the hourly and daily indices. The main reason is that not every city is monitoring this full range of pollutants.NOTE: Potential users of the CAQI must notify the CITEAIR partners (at caqi@airqualitynow.eu) and establish a user agreement (www.airqualitynow.eu/about_copyright.php#legal_agreement). This way, users can be kept informed in case of further developments concerning the index. The use of the CAQI is free of charge for non-commercial purposes.Note: data models are described in Van den Elshout et al, 2012.	Index	Annual concentration of relevant air pollutants	CITYkeys
40	Noise pollution	Planet	Smart Environment	ISO 37120; FIN Indicators; Rotterdam SCP; OECD; ClimateCon; European Green Capital Award study; City Protocol; URBES	Governo/PA, Aziende pubbliche e private terze	quantitativo	Città	Prolonged exposure to noise can lead to significant health effects, both physical and mental (ISO/DIS 37120, 2013). This indicator assesses the number of inhabitants exposed to noise >55 dB(A) at night time.	(#inhabitants exposed to noise > 55dB(a)/total number of inhabitants)*100%=share of population affected by noise %. Noise pollution shall be calculated by mapping the noise level at night (Ln) likely to cause annoyance as given in ISO 1996-2:1987, identifying the areas of the city where Ln is greater than 55 dB(A) and estimating the population of those areas as a percentage of the total city population. The result shall be expressed as the percentage of the population affected by noise pollution. (ISO/DIS 37120, 2013)	% of people	Share of the population affected by noise >55 dB(a) at night time	CITYkeys

41	Municipal solid waste	Planet	Smart Environment	Siemens Green City Index; Smart city Profiles; Rotterdam SCP; Transform; Desire; OECD; ClimateCon; SCI; European Green Capital Award study; City Protocol	Governo/PA, Aziende pubbliche e private terze	quantitativo	Città	The proper discharge, transportation and treatment of solid waste is one of the most important components of life in a city and one of the first areas in which governments and institutions should focus. Solid waste systems contribute in many ways to public health, the local economy, the environment, and the social understanding and education about the latter. A proper solid waste system can foster recycling practices that maximize the life cycle of landfills and create recycling micro-economies; and it provides alternative sources of energy that help reduce the consumption of electricity and/or petroleum based fuels.This indicator provides a measure of how much waste a city is producing and the level of service a city is providing for its collection (ISO/DIS 37120, 2013). Municipal waste shall refer to waste collected by or on behalf of municipalities.The data shall only refer to the waste flows managed under the responsibility of the local administration including waste collected on behalf of the local authority by private companies or regional associations founded for that purpose.Municipal waste should include waste originating from: — households; — commerce and trade, small businesses, office buildings and institutions (e.g. schools, hospitals, government buildings). The definition should also include: — bulky waste (e.g. white goods, old furniture, mattresses); — garden waste, leaves, grass clippings, street sweepings, the content of litter containers, and market cleansing waste, if managed as waste; — waste from selected municipal services, i.e. waste from park and garden maintenance, waste from street cleaning services (e.g. street sweepings, the content of litter containers, market cleansing waste), if managed as waste. The definition shall exclude: — waste from municipal sewage network and treatment; — municipal construction and demolition waste.	(annual amount of generated municipal solid waste (t/yr)/capita)=(t/cap)/yr of generated municipal solid waste. The total collected municipal solid waste per capita shall be expressed as the total municipal solid waste produced in the municipality per person. This indicator shall be calculated as the total amount of solid waste (household and commercial) generated in tonnes (numerator) divided by the total city population (denominator). The result shall be expressed as total municipal solid waste collected per capita in tonnes (ISO/DIS 37120, 2013).	t/cap/yr	The amount of municipal solid waste generated per capita annually	CITYkeys
42	Recycling rate	Planet	Smart Environment	Siemens Green City Index; Smart city Profiles; Rotterdam SCP; Desire; OECD; ClimateCon; CASBEE_City_2012; SCI; City Protocol; GCIF; 2000- Watt	Governo/PA, Aziende pubbliche e private terze	quantitativo	Città	Many cities generate more solid waste than they can dispose of (ISO/DIS 37120, 2013). Even when municipal budgets are adequate for collection, the safe disposal of collected waste often remains a problem. Diverting recyclable materials from the waste stream is one strategy for addressing this municipal issue. Higher levels of municipal waste contribute to greater environmental problems and therefore levels of collection, and also methods of disposal, of municipal solid waste are an important component of municipal environmental management. Solid waste systems contribute in many ways to public health, the local economy, the environment, and the social understanding and education about the latter. A proper solid waste system can foster recycling practices that maximize the life cycle of landfills and create recycling micro- economies; and it provides alternative sources of energy that help reduce the consumption of electricity and/or petroleum based fuels.	The percentage of city's solid waste that is recycled shall be calculated as the total amount of the city's solid waste that is recycled in tonnes (numerator) divided by the total amount of solid waste produced in the city in tonnes (denominator). The result shall then be multiplied by 100 and expressed as a percentage (ISO/DIS 37120, 2013). Recycled materials shall denote those materials diverted from the waste stream, recovered, and processed into new products following local government permits and regulations (International Solid Waste Association, ISWA).Hazardous waste that is produced in the city and is recycled shall be reported separately.	% of tonnes	Percentage of city's solid waste that is recycled	CITYkeys
43	Share of green and water spaces	Planet	Smart Environment	CASBEE_City_2012	Governo/PA, Aziende pubbliche e private terze	quantitativo	Città	Green and water spaces are regarded as an index representing the degree of the nature conservation and improving the public health and quality of life as they are directly related to the natural water circulation, environmental purification and the green network. More green and blue also reduces vulnerability to extreme weather events like urban heat islands and flooding by heavy rainfall. This indicator reflects the ratio of green and water space area from total city land area.Green areas are forest and park areas that are partly or completely covered with grass, trees, shrubs, or other vegetation. Water areas here meaning lakes, ponds, rivers.	((water area (km2) + green space area (km2))/total land area (km2))*100 = share of green and blue spaces	% in km2	Share of green and water surface area as percentage of total land area	CITYkeys
44	Change in number of native species	Planet	Smart Environment	City Protocol	Governo/PA, Aziende pubbliche e private terze	quantitativo	Città	Urbanization affects biodiversity through urban sprawl/habitat fragmentation, loss of fertile agricultural lands, and spread of invasive alien species (ISO/DS 37120, 2013). A loss in biodiversity threatens food supplies, lessens opportunities for recreation and tourism, and impacts a diverse range of medicinal and practial uses, varieties of wood, and energy. It also interferes with essential ecological function, such as carbon sequestration and air filtering. The net change in the number of species in a municipality is an indication of biological diversity loss or gain. Three key taxonomic groups that are most surveyed worldwide, i.e., plants, birds and butterflies, have been selected as "core indicators". To ensure fairness and objectivity in the index, cities can select 2 other taxonomic groups that would reflect their best biodiversity, e.g. mammals, insects, bryophytes, fungi, amphibians, reptiles, freshwater fish, molluscs, dragonflies, carabid beetles, spiders, hard corals, marine fish, seagrasses, sponges, etc. A full list can be found in the User's Manual for the City Biodiversity Index.To ensure that this indicator is unbiased against any city based on its geographical location, ecological history, size, land-use, etc., a city is requested to list the number of native species* of a) vascular plants, b) birds, and c) butterflies, d) at least 2 other taxonomic groups, and e) any other taxonomic groups that it has data on. *Native species are considered to be native only if they occur naturally in an area, without the involvement of human activity or intervention. There are two types of native species: indigenous and endemic. Indigenous species are native species that are found in multiple locations, whereas endemic species are only found in a specific, unique location.	The net change in native species shall be calculated as the number of new native species within the city from the three core taxonomic groups and the city's selection of an additional two taxonomic groups (as a result of re-introduction, rediscovery, new species found, etc.) subtracted by the number of native species that have become extirpated or locally extinct within the city.	# of species	Net change in number of species	CITYkeys

45	Unemployment rate	Prosperity	Smart Economy	ISO 37120, ClimateCon; SCI; European Green Capital Award study; City Protocol; UN HABITAT CPI; GCIF; Triple Helix Model; SCI; European Green Capital Award study; COMIND; RFSC; UNECE	Governo/PA, Aziende pubbliche e private terze	quantitativo	Città	The unemployment rate is considered one of the single, most informative labour market indicators reflecting the general performance of the labour market and the health of the economy as a whole. It is used to measure a city's unutilized labour supply and track business cycles. When economic growth is strong, unemployment rates tend to be low and when the economy is stagnating or in recession, unemployment rates tend to be higher (ISO/DIS 37120, 2013). Unemployment shall refer to individuals without work, actively seeking work in a recent past period (past four weeks), and currently available for work. Persons who did not look for work but have a future labour market stake (arrangements for a future job start) are counted as unemployed (International Labour Organization). Discouraged workers or hidden unemployed shall refer to persons who are not actively seeking work because they believe the prospects of finding it are extremely poor or they have restricted labour mobility, face discrimination, and/or structural, social, and cultural barriers – are not counted as unemployed or as part of the labour force. Not actively seeking work shall refer to people who have not taken active steps to seek work (i.e. job searches, interviews, informational meetings etc.) during a specified recent period (usually the past four weeks). (ISO/DIS 37120, 2013). Labour Force shall refer to the sum of the total persons employed and unemployed who are legally eligible to work.	A city's unemployment rate shall be calculated as the number of working-age city residents who during the survey reference period were not in paid employment or self-employment, but available for work, and seeking work (numerator) divided by the total labour force (denominator). The result shall be multiplied by 100 and expressed as a percentage (ISO/DIS 37120, 2013).	% of people	Percentage of the labout force unemployed	CITYkeys
46	Youth unmployment rate	Prosperity	Smart Economy	ISO 37120; European Green Capital Award study; City Protocol	Governo/PA, Aziende pubbliche e private terze	quantitativo	Città	The youth unemployment rate is a key indicator for quantifying and analyzing the current labour market trends for young people (ISO/DIS 37120, 2013). Unemployed or underemployed youth are less able to contribute effectively to community and national development and have fewer opportunities to exercise their rights as citizens. They have less to spend as consumers, less to invest as savers and often have no "voice" to bring about change in their lives and communities. Widespread youth unemployment and underemployment also prevents companies and countries from innovating and developing competitive advantages based on human capital investment, thus undermining future prospects. Knowing the costs of non-action, many governments around the world do prioritize the issue of youth employment and attempt to develop pro-active policies and programmes. Unemployed youth shall refer to individuals above the legal working age and under 24 years of age who are without work, actively seeking work in a recent past period (past four weeks), and currently available for work. Youth who did not look for work but have a future labour market stake (arrangements for a future job start) are counted as unemployed (International Labour Organization). Discouraged workers or hidden unemployed shall not be counted as unemployed or as part of the labour force. Not actively seeking work shall refer to people who have not taken active steps to seek work (i.e. job searches, interviews, informational meetings etc.) during a specified recent period (usually the past four weeks). Youth labour force shall refer to all persons above the legal working age and under 24 years of age, who are either employed or unemployed over a specified reference period.(ISO/DIS 37120, 2013).	Youth unemployment rate shall be calculated as the total number of unemployed youth (numerator) divided by the youth labour force (denominator). The result shall be multiplied by 100 and expressed as a percentage.	% of people	Percentage of youth labour force unemployed	CITYkeys
47	Fuel poverty	Prosperity	Smart Economy	Eurbanlab; Transform	Governo/PA, Aziende pubbliche e private terze	quantitativo	Città	Fuel poverty occurs when a household is unable to afford the most basic levels of energy for adequate heating, cooking, lighting and use of appliances in the home. In absolute sense, when more than 10% of the income is spent on energy bills this is considered too much (DECC, 2013). As a large share of the European housing stock consists of buildings in desperate need of refurbishment, particularly in lower income low-energy- efficiency buildings with residents living in fuel poverty, the key to alleviate fuel poverty is to renovate the stock into more energy efficient buildings. Avoiding energy poverty has therefore become an important policy aim in many European countries, for example in the UK, in Austria and in Germany. It should be noted that there are various definitions and calculation procedures for calculating fuel poverty. Fuel poverty lines are arbitrary in some aspects. Proposed definitions differ strongly in terms of robustness to changes in energy prices, incomes and with regard to data requirements (DIW, 2014). The CITYkeys city indicator is derived from the UK definition, according to which households are considered as energy poor if their energy bill consumes 10% or more of the household income (DECC, 2013).	For simplicity the 10% variant and not the more complicated Low Income High Costs (LIHC) variant is proposed here. The fuel poverty ratio of a single household under this method is defined as= fuel poverty ratio = modelled fuel costs (i.e. modelled consumption x price)/ income. Where this ratio has a value greater than 0.1, the household is considered to be fuel poor.In the next calculation step the number of households living in fuel poverty is compared with the total number of households in the city. Note: The energy costs include all building related energy, i.e. for heating/cooling, warm water and electricity.	% of households	The percentage of households unable to afford the most basic levels of energy	CITYkeys
48	Affordability of housing	Prosperity	Smart Economy	Eurbanlab; UNECE; SCI	Governo/PA, Aziende pubbliche e private terze	quantitativo	Città	Many Europen cities face spatial segregation of social groups. Gentrification combined with an increase in housing costs, make it more difficult for low-income residents to find affordable housing. Smart cities aim to maintain or increase the diversity within neighbourhoods to ensure that also inhabitants with low incomes can remain in developing neighbourhoods and not being pushed into suburbs or outside the city. As a rule of thumb, no more than 25-40 % of income should be spend on housing in order to be considered affordable. For developed countries the upper limit is between 33-40 %. For this indicator affordable housing is defined as: less than 40% of the household income is spend on housing expenditures. This includes rents, hereditary tenure, mortgage payments, but excludes expenditures for services or utilities.	The indicator shall be calculated as the number of people living in affordable housing (numerator) divided by the city population (denominator). The result shall then be multiplied by 100 and expressed as a percentage	% of people	% of population living in affordable housing	CITYkeys
49	Share of certified companies	Prosperity	Smart Economy		Governo/PA, Aziende pubbliche e private terze	quantitativo	Città	More and more organisations have systematic attention for the environmental aspects of their business, including products and services. Often this is the consequence of increasing attention of external parties for the environmental performance of the company. These stakeholders have wishes and demands on the environmental aspects of the company, which need to be taken into account by the company to keep its "license to operate" in the longer term. The ISO 14000 series of norms for environmental management offers guidance for organisations that want to go further than compliance with rules and regulations. The norms are meant for companies that understand that implementing a systematic approach to the environmental aspects of the company and its products will pay itself back, for example through decrease of waste costs; reductions in energy, resources and materials; improving environmental image; better relationships with government; and new market opportunities. If a city hosts a high share of certified companies, it can be assumed that environmental quality, also locally, benefits.	(Number of companies with ISO 140001 certificate/total number of companies in the city)*100%	% of companies	Share of companies based in the city holding an ISO 14001 certificate	CITYkeys
50	Share of green public procurement	Prosperity	Smart Economy	FIN Indicators	Governo/PA, Aziende pubbliche e private terze	quantitativo	Città	Europe's public authorities are major consumers. By using their purchasing power to choose environmentally friendly goods, services and works, they can make an important contribution to sustainable consumption and production – what we call Green Public Procurement, or GPP. Although GPP is not mandatory, it has a key role to play in the EU's efforts to become a more resource-efficient economy. It can help stimulate a critical mass of demand for more sustainable goods and services which otherwise would be difficult to get onto the market. GPP is therefore a strong stimulus for eco-innovation. A number of European countries already have national environmental purchasing criteria for products and services per sector. Also, green labels may be helpful in identifying the extent to which environmental considerations were taken into account. The indicator leaves the flexibility to define the use of environmental criteria according to local circumstances.	(Millon EUR annual procurement using environmental criteria/Millon EUR total annual procurement of the city administration)*100	% in €	Percentage annual procurement using environmental criteria as share of total annual procurement of the city administration	CITYkeys

51	Green jobs	Prosperity	Smart Economy	Green Digital Charter; SCI; Transform	Governo/PA, Aziende pubbliche e private terze	quantitativo	Città	Greening the economy' can boost job creation in areas directly connected to the environment such as conservation, waste, water and air quality. Smart cities are expected to show a significant growth in green jobs. UNEP 2008 defines a green job as "work in environmental service activities that contribute substantially to preserving or restoring environmental quality. Specifically, but not exclusively, this includes jobs that help to protect ecosystems and biodiversity; reduce energy, materials, and water consumption through high efficiency strategies; de-carbonize the economy; and minimize or altogether avoid generation of all forms of waste and pollution." So a green job is any job that genuinely contributes to a more sustainable world(i.e. related to measuring, avoiding, reducing, limiting or removing environmental damages as well as the preservation of natural resources). The emplying company or organization can either be in a 'green' sector (e.g. solar energy), or in a conventional sector, but making genuine and substantial efforts to green its operations.	(Number of green jobs/Total number of jobs)*100	% of jobs	Share of jobs related to environmental service activities that contribute substantially to preserving or restoring environmental quality	CITYkeys
52	Freight movement	Prosperity	Smart Mobility	2 DECIDE CIVITAS	Governo/PA, Aziende pubbliche e private terze	quantitativo	Città	Freight distribution, pickups and deliveries (sometimes there is a distinction between delivery traffic and goods transport), while essential to ensure the vitality of cities, have an important contribution to high congestion levels, traffic disruptions, and, therefore increased levels of emissions, noise, and other social costs. City centres are often areas with small streets and high population densities. The performance of urban freight systems depends on a variety of factors related to vehicle types, delivery schedules, load optimisation etc. In Europe, 29% of freight vehicles on the road in 2009 was empty. From an economic as well as environmental perspective, much can be gained by bringing this number down. ICT can be an important enabler to further improve logistics management. Optimising the system should lead to less vehicle movements.	# of freight vehicle movements	# of movements	Freight movement is defined as the number of freight vehicles moving into an area (e.g. the city)	CITYkeys
53	Gross domestic product	Prosperity	Smart Economy	Triple Helix Model; Green product per capita Digital Charter; ClimateCon; City Protocol; UN Habitat CPI; GCIF; READY; UNECE	Governo/PA, Aziende pubbliche e private terze	quantitativo	Città	Gross domestic product, abbreviated as GDP, is a basic measure of a city's overall economic production. As an aggregate measure of production, GDP is equal to the sum of the gross value added of all resident institutional units (i.e. industries) engaged in production, plus any taxes, and minus any subsidies, on products not included in the value of their outputs. Gross value added is the difference between output and intermediate consumption. GDP is also equal to: -the sum of the final uses of goods and services (all uses except intermediate consumption) measured in purchasers' prices, minus the value of imports of goods and services; - the sum of primary incomes distributed by resident producer units.		€/cap	profile indicator	CITYkeys
54	New business registered	Prosperity	Smart Economy	Triple Helix Model; European Green Capital Award study; City Protocol	Governo/PA, Aziende pubbliche e private terze	quantitativo	Città	The number of businesses can inform a city's level of economic activity and economic performance. It provides one indication of the overall business climate in a jurisdiction, and attitudes towards entrepreneurship. Strong entrepreneurial activity is closely associated with a dynamic and growing economy. The number of businesses is also used to inform competitiveness of a city. (ISO/DIS 37120, 2013). This indicator assesses the number of new businesses created (including start-ups). An enterprise birth occurs when an enterprise (for example a company) starts from scratch and begins operations, amounting to the creation of a combination of production factors with the restriction that no other enterprises are involved in the event. An enterprise birth occurs when new production factors, in particular new jobs, are created. Enterprise births do not include: - dormant enterprises being reactivated within two years; - new corporate entities being created from mergers, break-ups, spin-offs/split-offs or the restructuring of enterprises or a set of enterprises; - the entry into a sub-population resulting only from a change of activity.	(Number of new companies registered/Total Population) x 100 000 inhabitants	#/100.000	Number of new businesses per 100,000 population	CITYkeys
55	Median disposable income	Prosperity	Smart Economy	ClimateCon; European household income Green Capital Award study; GCIF; COMIND; Triple Helix Model	Governo/PA, Aziende pubbliche e private terze	quantitativo	Città	While money may not buy happiness, a certain amount is an important means to achieve higher living standards and thus greater well-being. Higher economic wealth may e.g. improve access to quality education, health care and housing.Total disposable household income (according to SILC) is calculated by adding together the personal income received by all of the household members plus income received at household level diminished by regular taxes on wealth, regular inter-household cash transfer paid and tax on income and social insurance contributions (Urban Audit, 2012)). The median is the middle value, i.e. 50% of all observations are below the median value and 50% above it. Household disposable income includes income from economic activity (wages and salaries; profits of self-employed business owners), property income (dividends, interests and rents), social benefits in cash (retirement pensions, unemployment benefits, family allowances, basic income support, etc.), and social transfers in kind (goods and services such as health care,, education and housing, received either free of charge or at reduced prices) (OECD).	In general, individual data are rarely available so income classes are used. Knowing the number of households in each class, the class of the median income is known. The "exact" amount of median income can be approximated by replacing the steps (caused by the classes) in the cumulative frequency curve by a smooth curve of distribution, at least for the class in which the median is situated.	€/household	Median disposable annual household income	CITYkeys
56	Creative industry	Prosperity	Smart Economy	Triple Helix Model; creative industries European Green Capital Award study; Smart city Wheel	Governo/PA, Aziende pubbliche e private terze	quantitativo	Città	The term refers to the socio-economic potential of activities that trade with creativity, knowledge and information. Governments and creative sectors across the world are increasingly recognizing its importance as a generator of jobs, wealth and cultural engagement. At the heart of the creative economy are the cultural and creative industries that lie at the crossroads of arts, culture, business and technology. What unifies these activities is the fact that they all trade with creative assets in the form of intellectual property (IP); the framework through which creativity translates into economic value. The UK's definition of the creative industries - 'those industries that are based on individual creativity, skill and talent with the potential to create wealth and jobs through developing intellectual property' - includes thirteen sectors: advertising, architecture, the art and antiques market, crafts, design, designer fashion, film, interactive leisure software (ie. video games), music, the performing arts, publishing, software, and television and radio. Because it was the first definition offered by a government, this original UK definition has been widely adopted by other countries, with sectors adapted based on local commercial and cultural importance.	(people working in creative industries/total workforce)*100%	% of people	Share of people working in creative industries	CITYkeys

57	Innovation hubs in the city	Prosperity	Smart Economy		Governo/PA, Aziende pubbliche e private terze	quantitativo	Città	Innovation hubs imply building and increasing intelectual capital and skills. It exposes the interest in creation of value and development of knowledge. It may create links between sectors and fields of development, which previously did not exist and thus positively impact socio-economic development of an urban area. For this indicator, physical co-working spaces for knowledge institutions, business and government should be counted.		#/100.000	# of innovation hubs in the city, whether private or public, per 100.000 inhabitants	CITYkeys
58	Accessibility of open data sets	Prosperity	Smart Economy	City Protocol	Governo/PA, Aziende pubbliche e private terze	quantitativo	Città	Open data, especially open government data, is a tremendous resource that is as yet largely untapped (opendatahandbook.org). In a large number of areas, open city data is already creating value. Examples include participation, self-empowerment, innovation, improved efficiency and effectiveness of government services, etc.. While there are numerous instances of the ways in which open data is already creating both social and economic value, we don't yet know what new things will become possible. New combinations of data can create new knowledge and insights, which can lead to whole new fields of application. The ease of use of open data is an important quality because the main aim of opening data is to make it widely available to the public (City Protocol), e.g. to create new applications. Therefore, evaluating the quality of the open data from this perspective is important to promote the ease of use and the openness of city data	Total stars of all datasets/total # datasets. Each dataset has to be rated according to below scheme. All the stars of all the datasets are added up and divided by the total number of datasets. Average stars across all datasets according to the 5 star deployment scheme for Open Data defined by Tim Berners Lee (5stardata.info): . 1. Making data online available in whatever format under an open license 2. Making data available as structured data (e.g. Excel instead of image scan of a table) 3. Making data available in a non-proprietary open format (e.g. CSV) 4. Use URIs to denote things, so that people can point at your data 5. Link your data to other data to provide context	# stars	The extent to which the open city data are easy to use	CITYkeys
59	Research intensity	Prosperity	Smart Economy	Triple Helix Model; ITU; percentage of city's GDP UNECE; Smart city Wheel; European Smart Cities v1.0 (2007)	Governo/PA, Aziende pubbliche e private terze	quantitativo	Città	The OECD Frascati Manual 2002 methodology defines R&D as - "creative work undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of man, culture and society, and the use of this stock of knowledge to devise new applications" (oecd-ilibrary.org). The main aggregate used for international comparisons of R&D expenditures is gross domestic expenditure on R&D (GERD). GERD is usually broken down among four sectors of performance: business enterprise, higher education, government and private not-for-profit institutions serving households (PNP). GERD is often reported in relative terms as a percentage of GDP, to denote the R&D intensity of an economy. This indicator analyses the total expenditure on R&D by all stakeholders as a percentage of the GDP of the city.	(total expenditure on R&D/city GDP)*100	% in euros	R&D expenditure as percentage of city's GDP	CITYkeys
60	Open data	Prosperity	Smart Economy		Governo/PA, Aziende pubbliche e private terze	quantitativo	Città	Open data is data that can be freely used, re-used and redistributed by anyone - subject only, at most, to the requirement to attribute and sharealike (opendatahandbook.org; opendefinition.org). Open data, especially open government data, is a tremendous resource that is as yet largely untapped. Government is particularly significant in this respect, both because of the quantity and centrality of the data it collects, but also because most of that government data is public data by law, and therefore could be made open and made available for others to use. In a large number of areas, open government data is already creating value. Examples include participation, self-empowerment, innovation, improved efficiency and effectiveness of government services, etc. While there are numerous instances of the ways in which open data is already creating both social and economic value, we don't yet know what new things will become possible. New combinations of data can create new knowledge and insights, which can lead to whole new fields of application. Since open datasets can stimulate innovation, this indicator analyses the number of open government datasets. In addition, the format of the available datasets is collected as this is important information for the indicator 'quality of open data'.	(number of open government datasets/total population) x 100.000. Nb. List all open government datasets and the format they are published in.	#/100.000	# of open government datasets per 100.000 inhabitants	CITYkeys
61	Congestion	Prosperity	Smart Economy	IDEAS; European Green Capital Award study; City protocol; 2Decide	Governo/PA, Aziende pubbliche e private terze	quantitativo	Città	Cities and traffic have developed hand-in-hand since the earliest large human settlements (internationaltransportforum.org). The same forces that draw inhabitants to congregate in large urban areas also lead to sometimes intolerable levels of traffic congestion on urban streets and thoroughfares. It is necessary to manage congestion in such a way as to reduce its overall impact on individuals, families, communities and societies. Effective urban governance requires a careful balancing between the benefits of agglomeration and the dis-benefits of excessive congestion. Also, the Strategic Implementation Plan on Smart Cities and Communities (EIP-SCC, 2013) defines more efficient urban transport as one goal of Smart City Development.	This indicator can be calculated as indicated by tomtom (tomtom.org): ((travel times in peak hours - travel times during non-congested periods (free flow*))/travel times during non-congested periods)*100%. NB There are other was to calculate congestion, see below. We would like to hear from the cities what method they use. For the moment, therefore, the calculation method is flexible, as long as it is specified. 2 Decide -Average delay per vehicle kilometre (congestion), with unit: hour delay/vehicle-km; -Vehicle kilometres travelled in congestion, with unit: vehicle- km/time unit Travel time (average per traffic unit), with unit: hour; -Additional travel time caused by incidents, with unit: hour; -EEA Average daily km of traffic jams per 1000 inhabitants in city -City Protocol Average daily traffic jam in hours	% in hours	Increase in overall travel times when compared to free flow situation (uncongested situation)	CITYkeys
62	Public transport use	Prosperity	Smart Mobility	City Protocol; ISO 37120; GCIF	Governo/PA, Aziende pubbliche e private terze	quantitativo	Città	Transport usage is a key indicator of how easy it is to travel in the city by modes other than single occupancy vehicles (iso/dis 37120, 2013). The indicator might also provide insight into transportation policy, traffic congestion, and urban form. Cities with higher transport ridership rates tend to invest more in their transport systems and are more geographically compact. Transport usage also addresses overall travel patterns in the city, and not just the journey to work. In addition, less vehicle use contributes to an accessible, green and healthy city and moreover contributes to European policy goals for sustainable mobility and transport development. While walking and cycling are alternative modes of transport for short distances, public transport connections are needed for longer trips	This indicator shall be calculated as the total annual number of transport trips originating in the city - "ridership of public transport" - (numerator), divided by the total city population (denominator) (ISO/DIS 31720). Transport trips shall include trips via heavy rail metro or subway, commuter rail, light rail streetcars and tramways, organized bus, trolleybus, and other public transport services. Cities shall only calculate the number of transport trips with origins in the city itself. Note: Transport systems often serve entire metropolitan areas, and not just central cities. The use of number of transport trips with origins in the city itself will still capture many trips whose destination are outside the city, but will generally capture the impact that the city has on the regional transport network.	#/cap/year	Annual number of public transport trips per capita	CITYkeys

63	Net migration	Prosperity	Smart Economy	CASBEE_City_2012; due to migration per 1000 European Green Capital	Governo/PA, Aziende pubbliche e private terze	quantitativo	Città	The rate of migration is a direct indicator for the attractiveness of the city to citizens and their willingness to live there. In addition, there is a general movement of people from the countryside towards cities (urbanisation).	((Move-ins – move-outs)/total population)*1000 (CASBEE, 2012; Telos, 2015)	#/1000	Rate of population change due to migration per 1000 inhabitants	CITYkeys
64	Population dependency ratio	Prosperity	Smart Economy	GCIF	Governo/PA, Aziende pubbliche e private terze	quantitativo	Città	Dependency ratios indicate the potential effects of changes in population age structures for social and economic development, pointing out broad trends in social support needs (un.org). By relating the group of the population most likely to be economically dependent (net consumers) to the group most likely to be economically active (net producers), changes in the dependency ratio provide an indication of the potential social support requirements resulting from changes in population age structures (ibid). In addition, the ratio highlights the potential dependency burden on workers and indicates the shifts in dependency from a situation in which children are dominant to one in which older persons outnumber children as the demographic transition advances (that is, the transition from high mortality and high fertility, to low mortality and low fertility). A healthy dependency ratio contributes to an attractive and competitive city.	100 x ((Population (0-14) + Population (65+)) / Population (15-64) (un.org)	#/100	profile indicator	CITYkeys
65	International events hold	Prosperity	Smart Economy	Smart city Wheel	Governo/PA, Aziende pubbliche e private terze	quantitativo	Città	The number of international events held is an indication of the attractiveness and competitiveness of the city. International events are, for example, congresses and fairs.		#/100.000	The number of international events per 100.000 inhabitants	CITYkeys
66	Tourism intensity	Prosperity	Smart Economy	UNECE; European Green Capital Award study; Triple Helix Model	Governo/PA, Aziende pubbliche e private terze	quantitativo	Città	The number of tourists visiting the city is an indication of the attractiveness of the city to foreigners. A study by ECM shows that city tourism has experienced exponential growth compared to tourism on a national level, making cities the engine of tourism development in Europe (europeancitiesmarketing.com). In addition, tourism as an industry adds value to the local economy.		#/100.000	Number of tourist nights per year per 100.000 inhabitants	CITYkeys
67	Cross-departmental integration	Governance	Smart Governance	Transform	Governo/PA, Aziende pubbliche e private terze	qualitativo	Città	Smart city projects are multi-disciplinary projects. Therefore, they can benefit from an integrated approach and the involvement of many disciplines and departments within the city administration. This is referred to as the “mainstreaming approach”: all policy domains are conscious of the fact that smart city initiatives touch their policy domain and they see it as an added value. The level of cross-departmental integration will be estimated by analyzing the number of departments involved in smart city initiatives, whether by contributing financial, data sources or human resources.	Likert scale: 1.There is a silo-ed smart city governance structure, only one department actively contributes to smart city initiatives and decides on the strategy. 2. The local authority is poorly oriented towards cross- departmental “smart city” management: officially there is no “mainstreaming approach”, some civil servants from a ew departments work on this portfolio on the side or provide data for the initiatives, but there is no real strategy and commitment. 3. The local authority is somewhat oriented towards cross-departmental “smart city” management: there is a strategy for a “mainstreaming approach” and several departments contribute in human, data or financial resources. 4. The local authority is clearly oriented towards cross- departmental “smart city” management: there is a strategy for a “mainstreaming approach” and almost all departments provide financial, data and human resources for the smart city themes. 5. The local authority is committed towards cross- departmental “smart city” management: there is a well- anchored “mainstreaming approach” with shared performance targets and all departments are actively contributing to the smart city themes in financial, data and human resources.	Likert	The extent to which administrative departments contribute to “Smart City” initiatives and management	CITYkeys
68	Establishment within the administration	Governance	Smart Governance	Smart city Profiles	Governo/PA, Aziende pubbliche e private terze	qualitativo	Città	Although many disciplines and municipal departments are ideally involved in the execution of the smart city strategy, a clear primary responsibility lying with one department or a director is an important factor for success. Another element of strong and dedicated establishment is the labour force allocated towards smart city initiatives. This indicator estimates the combined extent to which both elements are established in the city administration.	1. Not at all: The municipal efforts regarding smart city are not at all reflected by the organizational structure and staff resources. 2.Poor: some civil servants manage this portfolio on the side but there is no real commitment to the subject. 3.Moderate: responsibility has been assigned to a director and a small team is working on the topic. 4.Much: responsibility has been assigned to a director and a large team is working on the topic. 5.Very much: the smart city strategy is a well-anchored in the administration reflected by the assigned responsiblity to a large team and the strong commitment to achieve the smart city targets.	Likert	The extent to which the smart city strategy has been assigned to one department/director and staff resources have been allocated	CITYkeys

69	Monitoring and evaluation	Governance	Smart Governance	RFSC	Governo/PA, Aziende pubbliche e private terze	qualitativo	Città	Continued monitoring of performance and compliance with the requirements is an essential stimulating factor for success and allows the presentation of the actual progress made (Fortune and White 2006). Continued monitoring and reporting refers to the control processes by which at each stage of development, key personnel report on how the smart city programme progresses with regards to the initial goals, schedule and budget. Adequate monitoring and reporting mechanisms allow for an anticipation on problems, to oversee corrective measures, and warrants that no deficits are overlooked.	liker scale: 1.No monitoring & reporting: No monitoring and reporting at all was used to verify the progress of policies/strategies/projects. 2. Little monitoring & reporting: there is a basic monitoring scheme in place: a basic set of indicators assessed at irregular time intervals. 3. Some monitoring & reporting: there is a city-wide monitoring scheme in place with an elaborate set of indicatorsmeasurement intervals, backed by well-defined (SMARTY) goals of the smart city strategy. 4. Very much monitoring & reporting: there is a city-wide monitoring scheme in place with anelaborate set of indicators and measurement intervals, the findings of which are yearly reported upon. 5. Extensive monitoring & reporting: there is a city-wide monitoring scheme in place addressing all stages of the process, the findings of which are yearly reported upon and published transparently online.	Likert	The extent to which the progress towards a smart city and compliance with requirements is being monitored and reported	CITYkeys
70	Availability of government data	Governance	Smart Governance	ITU	Governo/PA, Aziende pubbliche e private terze	qualitativo	Città	Open information flows increase transparency and prevent information asymmetry, thereby enhancing participation. This indicator investigates the ratio of unclassified government documents available to citizens, journalist, developer, communities, etc. and whether they are available online in digital form, which is better for share storage (ITU)Unclassified government documents include urban planning, operation, budget, strategy and statistics documents.	Liker scale: 1.Not at all: most of the information is not available to the public or only upon appointment with an expert 2. Poorly: most of the information is available to the public, but available in the form of a hard copy which cannot leave city hall 3. Somewhat: most of the information is available to the public, some in the form of a hard copy, some online. 4. Good: most of the information is available online, but structure is lacking 5. Excellent: all government information is available online and neatly structured.	Likert	The extent to which government information is published	CITYkeys
71	Citizen participation	Governance	Smart Governance	Transform	Governo/PA, Aziende pubbliche e private terze	quantitativo	Città	A growing body of literature is exemplifying the importance of civil society/community participation in sustainable urban planning and execution, for example by means of smart city projects, to bring together information, knowledge and skills from diverse backgrounds to articulate the often ambiguous targets of smart cities and to create a sense of ownership over the outcomes (Healy 1999, Kasioumi 2011, Pollock and Sharp 2012). Moreover, public involvement is identified to have a positive effect on the agreement over solutions and acceptance of policy interventions through the creation of awareness (Driessen, Glasbergen and Verdaas 2001, Abdalla 2012). This indicator analyses the projects that were executed with active citizen participation. Active participation is defined as minimum level 3, 'Advise', based ob the scale of Arnstein (1969): 1. Not at all: No community involvement. The project idea came from the municipality and the project was designed and implemented without the community. 2. Inform and consult: The more or less completed project is announced to the community either for information only, or for receiving community views. The consultation, however, is mainly seeking community acceptance of the project. 3. Advise: the project implementation is done by a project team		% of projects	The number of projects in which citizens actively participated as a percentage of the total projects executed	CITYkeys
72	Open public participation	Governance	Smart Governance	City Protocol	Governo/PA, Aziende pubbliche e private terze	quantitativo	Città	Public participation encompasses varied opportunities for citizens, nongovernmental organizations, businesses, and others outside the federal government to contribute to and comment on proposed rules. The city will widen public exposure to the processes of policy planning and determination and will invite the public to respond to key issues on its agenda. It promotes democratic legitimacy by strengthening the connections between government agencies and the public they serve. This indicator shows the citizens level of commitment to the politics of this city. Higher amount of public participation processes promote an increased sense of belonging to the community and a better adjustment between what the citizens want and what is decided.	Calculation: (Total amount of open public participation processes/City population)*1000	#/100.000	Number of public participation processes per 100.000 per year	CITYkeys
73	Voter participation	Governance	Smart Governance	ISO 37120; European Smart Cities v1.0 (2007); UNECE; European Green Capital Award study; City protocol; GCIF; COMIND	Governo/PA, Aziende pubbliche e private terze	quantitativo	Città	The percentage of the eligible voting population that voted in the last municipal election is an indicator of the public's level of participation and degree of interest in local government (ISO/DIS 37120, 2013). The vast majority of analysts, consider a high voter turnout to be preferable to a low turnout because it means that the government will more likely reflect the interests of a larger share of the population. Low voter turnout implies that the democratic system may not be reflecting the interests of all citizens. However, This indicator will only reveal the level of participation, not the level of satisfaction of the population. In some cases, high rates of participation will mean that the population is not satisfied with its local government's leadership and actions.	The voter participation in the last municipal election shall be calculated as the number of persons that voted in the last municipal election (numerator) divided by the city population eligible to vote (denominator). The result shall then be multiplied by 100 and expressed as a percentage: (people who voted/total voting population)*100. A result of zero shall be indicated if there have been no municipal elections in the last five years and this shall be noted in the comments. In countries where voting is mandatory, the per cent of votes (ballots) that are not blank or spoiled shall be reported. This will indicate the share of positive voter participation.There is a distinction between eligible to vote and registered to vote. In some countries people have to register (actively) in order to be allowed to vote. In all other countries, eligible and registered voters are one and the same. This should be noted.	% of people	% of people that voted in the last municipal election as share of total population eligible to vote	CITYkeys
74	Smart city policy	Governance	Smart Governance		Governo/PA, Aziende pubbliche e private terze	quantitativo	Città	In the past decades, governments have increasingly been "attempting to provide active support for the generation and adoption of environmental innovations" (Beise and Rennings 2005, 6). The creation of a supporting framework has been identified as a success factor for shaping responses at the urban level (Suzuki, et al. 2010, Romero-Lankao 2012). A framework typically includes a shared vision statement that contains a set of long-term goals. This long-term vision sets out a visualization of where future city development should go, and provides ways to relate responses to urban development aspirations (UN-Habitat 2011). Integrating goals into a long-term strategic vision for urban development thus is a critical step in support of the transition to smart cities. The existence of such comprehensive smart city visions, alongside with a strong smart city strategy, provides ways in which smart city projects can connect to larger development aims within the city, as well as benefit from supporting measures.	1. Not at all: the complete absence of a long-term smart city vision (including and absence of long-term targets & goals) from the side of the government or an opposing vision create a difficult environment for starting smart city initiatives. 2.Poor: The long-term vision of the government does, to some extent, hamper the environment for smart city initiatives. 3Neutral: The long-term vision of the government has had no significant, positive or negative, impact on the environment for smart city initiatives. 4. Somewhat supportive: The long-term vision of the government has to some extent benefitted the environment for smart city initiatives. The city has created roadmaps and actions to support vision implementation. 5. Very supportive: The comprehensive long-term vision on the future of the city stimulates the environment for smart city initiatives to a great extent.	Likert	The extent to which the city has a supportive smart city policy	CITYkeys

75	Expenditures by the municipalitiey for a transition towards a smart city	Governance	Smart Governance	Smart city Profiles	Governo/PA, Aziende pubbliche e private terze	quantitativo	Città	One of the ways in which the municipality can support the transition towards a smart city, next to a supportive framework, establishment within the administration and cross-departmental integration, is by providing financial resources. Smart city expenditures include process relevant expenditures and fundings.	(Total annual expenditures by the municipality for a transition towards a Smart City/total population)	€/capita	Annual expenditures by the municipality for a transition towards a Smart City	CITYkeys
76	Multilevel government	Governance	Smart Governance	RFSC	Governo/PA, Aziende pubbliche e private terze	quantitativo	Città	Smart city developments benefit from alignment of objectives throughout layers of government, both vertically (regional/national level) and horizontally (other cities). This makes it easier to implement projects in general and in different cities in particular. Moreover, lessons learned can be transferred. The level of cooperation with other municipalities and /or other levels of government will be evaluated by analyzing the frequency of consultation or coordination in the planning and decision-making processes and the extent to which partnerships have been established atlocal, regional level, national level, European and/or international level.	1.Not at all: there is no cooperation or coordination with other municipalities and/or other levels of government whatsoever. 2. Poorly: there is little cooperation with other authorities, but this is irregularand very dependent of the people involved. 3. Somewhat: there is some cooperation or coordination with other municipalities and/or other levels of government, which is formalized in a partnership policy. 4. Good: there is good cooperation or coordination with other municipalities and/or other levels of government, which is formalized in partnership policies and in process through regular participation in meetings. 5. Excellent: the city is a driving force in the cooperation or coordination with other municipalities and/or other levels of government, which is formalized in policy and in process through regular meetings initiated by the city.	Likert	The extent to which the city cooperates with other authorities from different levels	CITYkeys

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	KPI name	Focus	Reference Pillar	Data Owner	Type of Data Owner	Data Type	Perimeter of Analysis	Description	Mode of Calculation	Unit of Measure	Notes	Dataset
1	City's unemployment rate	Economy	Smart Economy	City departments	Città	quantitativo	Città	individuals without work	# working-age primary residents not in paid employment/ total labour force x100%	%	core indicator	Sustainable cities and communities — Indicators for city services and quality of life (ISO 37120)
2	Assessed value of commercial and industrial properties as a percentage of total assessed value of all properties	Economy	Smart Economy	City departments	Città	quantitativo	Distretto o Città	mix of assessed values of properties	total assessed value of commercial and industrial properties / total assessed value of all properties x100%	%	supporting indicator	Sustainable cities and communities — Indicators for city services and quality of life (ISO 37120)
3	% of persons in full-time employment	Economy	Smart Economy	City departments	Città	quantitativo	Distretto o Città	economic health of the city	# of persons in full-time employment / total labour force x100%	%	supporting indicator	Sustainable cities and communities — Indicators for city services and quality of life (ISO 37120)
4	Youth unemployment rate	Economy	Smart Economy	Municipal departments	Municipalità /quartieri	quantitativo	Distretto o Città	under 24 without work, seeking for it	# unemployed youth / youth labur force x100%	%	supporting indicator	Sustainable cities and communities — Indicators for city services and quality of life (ISO 37120)
5	Number of businesses per 100 000 population	Economy	Smart Economy	Business registry	Città	quantitativo	Città	city's level of economic activity and performance	total # businesses x 100000 / total population	#	supporting indicator	Sustainable cities and communities — Indicators for city services and quality of life (ISO 37120)
6	Number of new patents per 100 000 population per year	Economy	Smart Economy	Government patent offices	Governo/PA	quantitativo	Città	commercial and technological innovation	total # patents x 100000 / total population	# / year	supporting indicator	Sustainable cities and communities — Indicators for city services and quality of life (ISO 37120)
7	Annual # of visitors stays (overnight) per 100 000 population	Economy	Smart Economy	Hotels, lodging, tourism boards	Aziende private terze	quantitativo	Città	importance of tourism to the local economy	sum of overnight visitors x 100 000 / city total population	# / year	supporting indicator	Sustainable cities and communities — Indicators for city services and quality of life (ISO 37120)
8	commercial air connectivity	Economy	Smart Economy	Commercial airport operators, planners, agencies	Aziende private terze	quantitativo	Città	city's connectivity to the rest of the nation and world	sum of non-stop commercial flights departing from all airports serving the city	#	supporting indicator	Sustainable cities and communities — Indicators for city services and quality of life (ISO 37120)
9	Average household income	Economy	Smart Economy	Singolo cittadino	Singolo cittadino	quantitativo	Edificio o Distretto o Città	monetary well-being of residents	sum of total yearly income of all households / total # households	USD	profile indicator	Sustainable cities and communities — Indicators for city services and quality of life (ISO 37120)
10	Annual inflation rate based on avg past five years	Economy	Smart Economy	City departments	Città	quantitativo	Città		sum of rate of inflation of the preceding 5 years / 5	%	profile indicator	Sustainable cities and communities — Indicators for city services and quality of life (ISO 37120)
11	City product per capita	Economy	Smart Economy	Government Agencies	Governo/PA	quantitativo	Città	economic development	national product in each city sector x differential wage rate at city level for each sector	USD	profile indicator	Sustainable cities and communities — Indicators for city services and quality of life (ISO 37120)
12	% female school aged populatiom enrolled in schools	Education	Smart People	Local school boards	Governo/PA	quantitativo	Città	Human development	# of female school-aged population at primay and secondary levels / total female school-aged population	%	core indicator	Sustainable cities and communities — Indicators for city services and quality of life (ISO 37120)
13	survival rate	Education	Smart People	Local school boards	Governo/PA	quantitativo	Distretto o Città	holding power and internal efficiency of an education system	% students completing primary education (both private and public)	%	core indicator	Sustainable cities and communities — Indicators for city services and quality of life (ISO 37120)
14	survival rate (2)	Education	Smart People	Local school boards	Governo/PA	quantitativo	Distretto o Città	holding power and internal efficiency of an education system	% students completing secondary education (both private and public)	%	core indicator	Sustainable cities and communities — Indicators for city services and quality of life (ISO 37120)
15	Primary education student- teacher ratio	Education	Smart People	Local school boards	Governo/PA	quantitativo	Distretto o Città		# enrolled students / Full-time equivalent teachers	#	core indicator	Sustainable cities and communities — Indicators for city services and quality of life (ISO 37120)
16	% of school-aged population enrolled in schools	Education	Smart People	Local school boards	Governo/PA	quantitativo	Distretto o Città	Human development	total primary and secondary students / total school-aged population	%	supporting indicator	Sustainable cities and communities — Indicators for city services and quality of life (ISO 37120)
17	Number of higher education degrees per 100 000 population	Education	Smart People	Census and household surveys	Singolo cittadino	quantitativo	Città		# people with higher education degrees x 100000 / city total population	#	supporting indicator	Sustainable cities and communities — Indicators for city services and quality of life (ISO 37120)
18	total end-use energy consumption per capita	Energy	Smart Environment	Electricity and fuel distributors	DSO/TSO	quantitativo	Edificio o Distretto o Città		total end-use energy consumed by a city / total population of the city	GJ / year	core indicator	Sustainable cities and communities — Indicators for city services and quality of life (ISO 37120)
19	% of total end-use energy derived from renewable sources	Energy	Smart Environment	Local utility providers	Aziende private terze	quantitativo	Città	Both combustible and non-combustible renewables	total consumption of end-use energy generated from RES / total end-use energy consumption	%	core indicator	Sustainable cities and communities — Indicators for city services and quality of life (ISO 37120)
20	% of city population with authorized electrical service	Energy	Smart Living	Local utility providers	Aziende private terze	quantitativo	Edificio o Distretto o Città		# of people with authorized electrical service / population of the city	%	core indicator	Sustainable cities and communities — Indicators for city services and quality of life (ISO 37120)

21	# gas distribution service connections per 100 000 population	Energy	Smart Living	Electricity and fuel distributors	DSO/TSO	quantitativo	Città		# people with connection to gas services x 100000 / city total population	#	core indicator	Sustainable cities and communities — Indicators for city services and quality of life (ISO 37120)
22	final energy consumption of public buildings per year	Energy	Smart Living	Electricity and fuel distributors	DSO/TSO	quantitativo	Edificio	both thermal and electrical energy consumption	total end use of energy in public buidings within a city / total floor space of these buildings	GJ / m2	core indicator	Sustainable cities and communities — Indicators for city services and quality of life (ISO 37120)
23	electricity consumption of public street lighting per km of lighted street	Energy	Smart Living	Electricity and fuel distributors	DSO/TSO	quantitativo	Distretto o Città		Total electricity consumption of public street lighting / total distance of streets where lights are present	kWh / Km per year	supporting indicator	Sustainable cities and communities — Indicators for city services and quality of life (ISO 37120)
24	Avg annual hours of electrical service interruptions per household	Energy	Smart Living	Electricity and fuel distributors	DSO/TSO	quantitativo	Edificio o Distretto o Città		sum of hours of interruption x househoulds impacted / total number of houselds	h	supporting indicator	Sustainable cities and communities — Indicators for city services and quality of life (ISO 37120)
25	Heating degree days	Energy	Smart Living	Electricity and fuel distributors	DSO/TSO	quantitativo	Città		sum of daily difference of (standard baseline air temperature - mean daily temperature) x days	# / year	profile indicator	Sustainable cities and communities — Indicators for city services and quality of life (ISO 37120)
26	cooling degree days	Energy	Smart Living	Electricity and fuel distributors	DSO/TSO	quantitativo	Città		sum of daily difference of (standard baseline air temperature - mean daily temperature) x days	# / year	profile indicator	Sustainable cities and communities — Indicators for city services and quality of life (ISO 37120)
27	Fine particulate matter (PM2.5) concentration	Environment and climate change	Smart Environment	City departments	Città	quantitativo	Distretto o Città		total mass / volume of air sapled	µg / m3	core indicator	Sustainable cities and communities — Indicators for city services and quality of life (ISO 37120)
28	Particulate matter (PM10) concentration	Environment and climate change	Smart Environment	City departments	Città	quantitativo	Distretto o Città		total mass / volume of air sapled	µg / m3	core indicator	Sustainable cities and communities — Indicators for city services and quality of life (ISO 37120)
29	GHG emissions measured in tonnes per capita	Environment and climate change	Smart Environment	City departments	Città	quantitativo	Distretto o Città		tonnes of GHG in a year / city population	Tonnes	core indicator	Sustainable cities and communities — Indicators for city services and quality of life (ISO 37120)
30	% areas designated for natural protection	Environment and climate change	Smart Environment	City departments	Città	quantitativo	Distretto o Città		total land area of designated natural protection and/or biodiversity / total land area of the city	%	supporting indicator	Sustainable cities and communities — Indicators for city services and quality of life (ISO 37120)
31	NO2 concentration	Environment and climate change	Smart Environment	City departments	Città	quantitativo	Distretto o Città		avg daily concentration in a year	µg / m3	supporting indicator	Sustainable cities and communities — Indicators for city services and quality of life (ISO 37120)
32	SO2 concentration	Environment and climate change	Smart Environment	City departments	Città	quantitativo	Distretto o Città		avg daily concentration in a year	µg / m3	supporting indicator	Sustainable cities and communities — Indicators for city services and quality of life (ISO 37120)
33	O3 (Ozone) concentration	Environment and climate change	Smart Environment	City departments	Città	quantitativo	Distretto o Città		avg daily concentration in a year	µg / m3	supporting indicator	Sustainable cities and communities — Indicators for city services and quality of life (ISO 37120)
34	Noise pollution	Environment and climate change	Smart Environment	City departments	Città	quantitativo	Distretto o Città		population exposed to noise pollution / total city population	%	supporting indicator	Sustainable cities and communities — Indicators for city services and quality of life (ISO 37120)
35	Percentage change in number of native species	Environment and climate change	Smart Environment	Government agencies	Governo/PA	quantitativo	Distretto o Città		total net change in species / total # of species from the 5 taxonomic groups from most recent survey	%	supporting indicator	Sustainable cities and communities — Indicators for city services and quality of life (ISO 37120)
36	Debt service ratio	Finance	Smart Economy	City departments	Città	quantitativo	Città	amount of financial resorces available for day-to-day operations	debt service expenditure / city's own-source revenue	%	core indicator	Sustainable cities and communities — Indicators for city services and quality of life (ISO 37120)
37	Capital spending as percentage of total expenditures	Finance	Smart Economy	City's audited financial statements	Città	quantitativo	Città		total expenditure in fixed assets in the preceding year / total expenditure by the city in the same period	%	core indicator	Sustainable cities and communities — Indicators for city services and quality of life (ISO 37120)
38	Own-source revenue as a percentage of total revenues	Finance	Smart Economy	City departments	Città	quantitativo	Città		total funds collected for city services or purposes / operationg or reoccuring revenues transferred to the city	%	supporting indicator	Sustainable cities and communities — Indicators for city services and quality of life (ISO 37120)
39	tax collected as a percentage of tax billed	Finance	Smart Economy	City departments	Città	quantitativo	Città		total reveneues by tax collection / taxes billed	%	supporting indicator	Sustainable cities and communities — Indicators for city services and quality of life (ISO 37120)
40	Gross operating budget per capita	Finance	Smart Economy	Government Agencies	Governo/PA	quantitativo	Città		gross operating budget / city population	USD	profile indicator	Sustainable cities and communities — Indicators for city services and quality of life (ISO 37120)

41	gross capital budget per capita	Finance	Smart Economy	Government Agencies	Governo/PA	quantitativo	Città		gross capital budget / city population	USD	profile indicator	Sustainable cities and communities — Indicators for city services and quality of life (ISO 37120)
42	wowen as a percentage of total elected to city-level office	Governance	Smart People	City departments	Città	quantitativo	Città		total # of elected city-level positions held by women / total number og elected city-level positions	%	core indicator	Sustainable cities and communities — Indicators for city services and quality of life (ISO 37120)
43	Number of convictions for corruption and/or bribery by city officials per 100 000 population	Governance	Smart Governance	City departments	Città	quantitativo	Distretto o Città	officials shall refer to elected or employed representatives of the city	# convictions x 100000 / city total population	#	supporting indicator	Sustainable cities and communities — Indicators for city services and quality of life (ISO 37120)
44	Number of registered voters as a percentage of the voting age population	Governance	Smart Governance	City departments	Città	quantitativo	Città		total number of registered voters / voting age population	%	supporting indicator	Sustainable cities and communities — Indicators for city services and quality of life (ISO 37120)
45	Voter partecipation in last municipal election	Governance	Smart Governance	Local authorities	Città	quantitativo	Città		# persons who voted in the last municipal election / total # registered voters	%	supporting indicator	Sustainable cities and communities — Indicators for city services and quality of life (ISO 37120)
46	Average life expenctancy	Health	Smart People	National sources	Governo/PA	quantitativo	Città		avg number of years if health and living conditions remained the same throughout their lives	#	core indicator	Sustainable cities and communities — Indicators for city services and quality of life (ISO 37120)
47	Number of in-patent hospital beds per 100 000 population	Health	Smart People	Public and private in-patient facilities	Aziende private/ publiche terze	quantitativo	Città		# beds x 100000 / city total population	#	core indicator	Sustainable cities and communities — Indicators for city services and quality of life (ISO 37120)
48	Number of physicians per 100 000 population	Health	Smart People	City departments	Città	quantitativo	Città		# specialist physicians with workplace in the city x 100000 / city total population	#	core indicator	Sustainable cities and communities — Indicators for city services and quality of life (ISO 37120)
49	Under age five mortality per 1 000 live births	Health	Smart People	Sample surveys	Città	quantitativo	Città		probability of a child born in a specified year dying before the age of 5	#	core indicator	Sustainable cities and communities — Indicators for city services and quality of life (ISO 37120)
50	Number of nursing and midwifery personnel per 100 000 polulation	Health	Smart People	City departments	Città	quantitativo	Città		number x 100000 /city total population	#	supporting indicator	Sustainable cities and communities — Indicators for city services and quality of life (ISO 37120)
51	suicide rate per 100 000 population	Health	Smart people	coroner's office	Città	quantitativo	Città		# dealth per suicide x 100000 / city total population	#	supporting indicator	Sustainable cities and communities — Indicators for city services and quality of life (ISO 37120)
52	% of city population living in a inadequate housing	Housing	Smart People	Census and surveys	Città	quantitativo	Città	Housing not in good repair, or without sufficient living area, or without adequate access to affordable services	# of people living in inadequate housing / city population	%	core indicator	Sustainable cities and communities — Indicators for city services and quality of life (ISO 37120)
53	% of population living in affordable housing	Housing	Smart People	Census and surveys	Città	quantitativo	Città		total # of households that do not surpass regulations on housing affodability / total # of households	%	core indicator	Sustainable cities and communities — Indicators for city services and quality of life (ISO 37120)
54	Number of homeless per 100 000 population	Housing	Smart People	Census and surveys	Città	quantitativo	Città		number x 100000 /city total population	#	supporting indicator	Sustainable cities and communities — Indicators for city services and quality of life (ISO 37120)
55	% of households that exist without registered legal titles	Housing	Smart Living	Census and surveys	Città	quantitativo	Città	unregistered legal title: unregistered lease or leaseholds, rental, ownership title, occupancy right and use right	# of households that exist without registered legal entities / total # of households	%	supporting indicator	Sustainable cities and communities — Indicators for city services and quality of life (ISO 37120)
56	Total number of households	Housing	Smart Living	City departments	Città	quantitativo	Distretto o Città	measure of the housing demand and attractiveness	total households within city boundaries	#	profile indicator	Sustainable cities and communities — Indicators for city services and quality of life (ISO 37120)
57	Persons per unit	Housing	Smart Living	City departments	Città	quantitativo	Distretto o Città		total number of people living in a city / total number of dwelling units in the city	# / unit	profile indicator	Sustainable cities and communities — Indicators for city services and quality of life (ISO 37120)
58	Vacancy rate	Housing	Smart Living	City departments	Città	quantitativo	Città	vacant dwelling : for sale or rent, already attributed to a buyer or a tenant, pending succession settlements, kept by an employer for future use by one of their employees, kept vacant	# unoccupied dwellings / total # of dwellings in the city	%	profile indicator	Sustainable cities and communities — Indicators for city services and quality of life (ISO 37120)
59	Living space per person	Housing	Smart Living	City departments	Città	quantitativo	Edificio		totoal area of all dwellings units in a city / total number of persons living in the units	m2 / person	profile indicator	Sustainable cities and communities — Indicators for city services and quality of life (ISO 37120)
60	Secondary residence rate	Housing	Smart Living	City departments	Città	quantitativo	Edificio		# of secondary dwelling units / total # of dwelling units in the city	%	profile indicator	Sustainable cities and communities — Indicators for city services and quality of life (ISO 37120)

61	Residential rental dwelling units as a percentage of total dwelling units	Housing	Smart Living	City departments	Città	quantitativo	Città		# of residential rental dwelling units in the city / total # of dwelling units in the city	%	profile indicator	Sustainable cities and communities — Indicators for city services and quality of life (ISO 37120)
62	% of city population living below the internatonal poverty line	Population and social conditions	Smart Economy	City departments	Città	quantitativo	Città		extreme poverty threshold is set by the United Nations	%	core indicator	Sustainable cities and communities — Indicators for city services and quality of life (ISO 37120)
63	% of city population living below the natonal poverty line	Population and social conditions	Smart Economy	City departments	Città	quantitativo	Città		the poverty threshold is set at country level	%	supporting indicator	Sustainable cities and communities — Indicators for city services and quality of life (ISO 37120)
64	Gini coefficient of inequality	Population and social conditions	Smart Economy	Census and surveys	Città	quantitativo	Città	measure of statistical dispersion that quantifies inequality among incomes or levels of consumption	(area between Lorentz curve and uniform distribution line) / area under the uniform distribution line	%	supporting indicator	Sustainable cities and communities — Indicators for city services and quality of life (ISO 37120)
65	annual population change	Population and social conditions	Smart People	City departments	Città	quantitativo	Città		(city's current population - city's previous annual population) / city's previous annual population	%	profile indicator	Sustainable cities and communities — Indicators for city services and quality of life (ISO 37120)
66	% of population that are foreign born	Population and social conditions	Smart People	City departments	Città	quantitativo	Città		total # of people born abroad / total city population	%	profile indicator	Sustainable cities and communities — Indicators for city services and quality of life (ISO 37120)
67	Population demographics	Population and social conditions	Smart People	City departments	Città	quantitativo	Città		% of population per each age category and gender	%	profile indicator	Sustainable cities and communities — Indicators for city services and quality of life (ISO 37120)
68	% of population that are new immigrants	Population and social conditions	Smart People	City departments	Città	quantitativo	Città	people been in the city's counttry for less than 5 years	total population of new city immigrants / total city population	%	profile indicator	Sustainable cities and communities — Indicators for city services and quality of life (ISO 37120)
69	% of population that are non-citizens	Population and social conditions	Smart People	City departments	Città	quantitativo	Città	people that live in another city and study or work in the city	total city non-citizen population / total city population	%	profile indicator	Sustainable cities and communities — Indicators for city services and quality of life (ISO 37120)
70	Number of university students per 100 000 population	Population and social conditions	Smart People	City departments	Città	quantitativo	Città		number of students x 100000 / city's population	#	profile indicator	Sustainable cities and communities — Indicators for city services and quality of life (ISO 37120)
71	m 2 of public indoor recreation space per capita	Recreation	Smart Living	City planning department	Città	quantitativo	Città		surface area / city population	m2 / person	supporting indicator	Sustainable cities and communities — Indicators for city services and quality of life (ISO 37120)
72	m 2 of public outdoor recreation space per capita	Recreation	Smart Living	City planning department	Città	quantitativo	Città		surface area / city population	m2 / person	supporting indicator	Sustainable cities and communities — Indicators for city services and quality of life (ISO 37120)
73	# of fireflighters per 100 000 populattion	Safety	Smart People	City departments	Città	quantitativo	Città		# Full time equivalent fireflighters x 100000 /city population	#	core indicator	Sustainable cities and communities — Indicators for city services and quality of life (ISO 37120)
74	Number of fire-related deaths per 100 000 population	Safety	Smart People	Insurance companies	Aziende Private terze	quantitativo	Città		# of citizen fire-related deaths in a year / city's total population	#	core indicator	Sustainable cities and communities — Indicators for city services and quality of life (ISO 37120)
75	Number of natural-hazard-related deaths per 100 000 population	Safety	Smart People	Insurance companies	Aziende Private terze	quantitativo	Città		# of hazard-related deaths in a year / city's total population	# / year	core indicator	Sustainable cities and communities — Indicators for city services and quality of life (ISO 37120)
76	# of police officiers per 100 000 population	Safety	Smart People	Police personnel information	Città	quantitativo	Città		# Full time equivalent police officiers x 100000 /city population	#	core indicator	Sustainable cities and communities — Indicators for city services and quality of life (ISO 37120)
77	Number of homicides per 100 000 population	Safety	Smart People	Police department	Città	quantitativo	Città		number of homicides x 100000 / city's population	#	core indicator	Sustainable cities and communities — Indicators for city services and quality of life (ISO 37120)
78	Number of volunteer and part-time firefighters per 100 000 population	Safety	Smart People	City departments	Città	quantitativo	Città		number x 100000 / city's population	#	supporting indicator	Sustainable cities and communities — Indicators for city services and quality of life (ISO 37120)
79	Response time for emergency response services from initial call	Safety	Smart People	City departments	Città	quantitativo	Distretto o Città		sum of time elapsed / # of emergency responses in a year	minutes	supporting indicator	Sustainable cities and communities — Indicators for city services and quality of life (ISO 37120)
80	Crimes against property per 100 000 population	Safety	Smart People	City departments	Città	quantitativo	Città		number of crimes x 100000 / city's population	#	supporting indicator	Sustainable cities and communities — Indicators for city services and quality of life (ISO 37120)

81	Number of deaths caused by industrial accidents per 100 000 population	Safety	Smart People	City departments	Città	quantitativo	Città		number x 100000 / city's population (in a year)	#	supporting indicator	Sustainable cities and communities — Indicators for city services and quality of life (ISO 37120)
82	Number of violent crimes against women per 100 000 population	Safety	Smart People	Loal public safety or police services	Città	quantitativo	Città	Violence against women could include honour killings, rape, coercion or arbitrary deprivation of liberty, whether	number x 100000 / city's population	#	supporting indicator	Sustainable cities and communities — Indicators for city services and quality of life (ISO 37120)
83	% of city population with regular solid waste collection (residential)	Solid Waste	Smart Environment	Local operators	Aziende private terze	quantitativo	Città	occurring in public or private life.	# of people served by regualr solid waste collection / total city population	%	core indicator	Sustainable cities and communities — Indicators for city services and quality of life (ISO 37120)
84	Total collected municipal solid waste per capita	Solid Waste	Smart Environment	City departments	Città	quantitativo	Città		tonnes of solid waste / total city population	tonnes / person	core indicator	Sustainable cities and communities — Indicators for city services and quality of life (ISO 37120)
85	% of city's solid waste that is recycled	Solid Waste	Smart Environment	Municipal bodies and public services	Aziende pubbliche terze	quantitativo	Città		tonnes of recycled solid waste / total tonnes of city solid waste	%	core indicator	Sustainable cities and communities — Indicators for city services and quality of life (ISO 37120)
86	% of the city's solid waste that is disposed of in a sanitary landfill	Solid Waste	Smart Environment	Municipal bodies and public services	Aziende pubbliche terze	quantitativo	Città		tonnes of solid waste disposed in a sanitary landfill / tonnes of solid waste produced in a city	%	core indicator	Sustainable cities and communities — Indicators for city services and quality of life (ISO 37120)
87	% of city's solid waste that is treated in energy-from-waste plants	Solid Waste	Smart Environment	Municipal bodies and public services	Aziende pubbliche terze	quantitativo	Città		tonnes of solid waste disposed in energy-from-waste plants / total tonnes of city solid waste	%	core indicator	Sustainable cities and communities — Indicators for city services and quality of life (ISO 37120)
88	% of the city's solid waste that is biologically treated and used as compost of biogas	Solid Waste	Smart Environment	Municipal bodies and public services	Aziende pubbliche terze	quantitativo	Città		tonnes of solid waste biologically treated and used as compost of biogas / total tonnes of city solid waste	%	supporting indicator	Sustainable cities and communities — Indicators for city services and quality of life (ISO 37120)
89	% of the city's solid waste that is disposed of in an open dump	Solid Waste	Smart Environment	Municipal bodies and public services	Aziende pubbliche terze	quantitativo	Città	uncovered space or hole where solid waste is disposed of without further treatment	tonnes of solid waste that is disposed of in an open dump / total tonnes of city solid waste	%	supporting indicator	Sustainable cities and communities — Indicators for city services and quality of life (ISO 37120)
90	% of the city's solid waste that is disposed of by other means	Solid Waste	Smart Environment	Municipal bodies and public services	Aziende pubbliche terze	quantitativo	Città		tonnes of solid waste that is disposed of by other means / total tonnes of city solid waste	%	supporting indicator	Sustainable cities and communities — Indicators for city services and quality of life (ISO 37120)
91	Hazardous waste generation per capita	Solid Waste	Smart Environment	Municipal landfills	Città	quantitativo	Città		tonnes of hazardous waste / city population	tonnes / person	supporting indicator	Sustainable cities and communities — Indicators for city services and quality of life (ISO 37120)
92	% of the city's hazardous waste that is recycled	Solid Waste	Smart Environment	Municipal landfills	Città	quantitativo	Città		hazardous waste that is recycled / total hazardous waste	%	supporting indicator	Sustainable cities and communities — Indicators for city services and quality of life (ISO 37120)
93	# of cultural institutions and sporting facilities per 100 000 population	Sport and Culture	Smart Governance	City departments	Città	quantitativo	Città	split cultural institutions and sporting facilities	number x 100000 / city's population	#	core indicator	Sustainable cities and communities — Indicators for city services and quality of life (ISO 37120)
94	% of municipal budget allocated to cultural and sporting facilities	Sport and Culture	Smart Governance	City departments	Città	quantitativo	Città		total expenditure for cultural and sporting facilities / total gross operating budget	%	supporting indicator	Sustainable cities and communities — Indicators for city services and quality of life (ISO 37120)
95	Annual number of cultural events per 100 000 population	Sport and Culture	Smart Governance	City departments	Città	quantitativo	Città		number x 100000 / city's population	#	supporting indicator	Sustainable cities and communities — Indicators for city services and quality of life (ISO 37120)
96	Number of internet connection per 100 000 population	Telecommunication	Smart Living	Internet service and telecommunications providers	Aziende private terze	quantitativo	Città		number of internet connection x 100000 / city's population	#	supporting indicator	Sustainable cities and communities — Indicators for city services and quality of life (ISO 37120)
97	Number of mobile phones connection per 100 000 population	Telecommunication	Smart Living	telecommunication providers	Aziende private terze	quantitativo	Città		number of mobile phones connection x 100000 / city's population	#	supporting indicator	Sustainable cities and communities — Indicators for city services and quality of life (ISO 37120)
98	Kilometres of public transport system per 100 000 population	Transportation	Smart Mobility	Municipal transport offices	Città	quantitativo	Città		total Km of public transportation systems within the city x 100 000 / city population	Km	core indicator	Sustainable cities and communities — Indicators for city services and quality of life (ISO 37120)
99	Annual number of public transport trips per capita	Transportation	Smart Mobility	Municipal transport offices	Città	quantitativo	Città		number of trips / city population	# / person	core indicator	Sustainable cities and communities — Indicators for city services and quality of life (ISO 37120)
100	% of commuters using a travel mode to work other than a personal vehicle	Transportation	Smart Mobility	Surveys	Città	quantitativo	Città		# of commuters working in the city who use a mode of transportation other than a private single occupancy vehicle (SOV) as their primary way / all trips to work, regardless of mode	%	supporting indicator	Sustainable cities and communities — Indicators for city services and quality of life (ISO 37120)

101	Kilometres of bicycle paths and lanes per 100 000 population	Transportation	Smart Mobility	City departments	Città	quantitativo	Città		paths distance x 100000 / city population	Km	supporting indicator	Sustainable cities and communities — Indicators for city services and quality of life (ISO 37120)
102	Transportation deaths per 100 000 population	Transportation	Smart Mobility	City departments	Città	quantitativo	Città		number of deaths related to transportation x 100000 / city population	#	supporting indicator	Sustainable cities and communities — Indicators for city services and quality of life (ISO 37120)
103	% of population living in affordable housing within 0,5 Km of public transit running at least every 20 min during peak periods	Transportation	Smart Living	Public transit departments	Città	quantitativo	Città		population living in affordable housing within 0,5 Km of public transit running at least every 20 min during peak periods / total population	%	supporting indicator	Sustainable cities and communities — Indicators for city services and quality of life (ISO 37120)
104	Avg commute time	Transportation	Smart Mobility	City departments	Città	quantitativo	Città	one-way commute (not round trip) and include only travel from home to work	Avg time that it takes a person to travel from home to place of employment	hours or minutes	supporting indicator	Sustainable cities and communities — Indicators for city services and quality of life (ISO 37120)
105	Number of personal automobilies per capita	Transportation	Smart Mobility	City departments	Città	quantitativo	Città		# of registered automobiles in a city / city population	# / person	profile indicator	Sustainable cities and communities — Indicators for city services and quality of life (ISO 37120)
106	Number of two-wheeled motorized vehicles per capita	Transportation	Smart Mobility	City departments	Città	quantitativo	Città		# of registered two-wheeled motorized vehicles in a city / city population	# / person	profile indicator	Sustainable cities and communities — Indicators for city services and quality of life (ISO 37120)
107	Total urban agricultural area per 100 000 population	Urban/local agricultural and food security	Smart Environment	City departments	Città	quantitativo	Città		total area x 100000 / city population	Km	core indicator	Sustainable cities and communities — Indicators for city services and quality of life (ISO 37120)
108	Amount of food produced locally as a percentage of total food supplied to the city	Urban/local agricultural and food security	Smart Economy	City departments	Città	quantitativo	Città		tonnes of food locally produced and supplied to the city / tonnes of total food supplied to the city	%	supporting indicator	Sustainable cities and communities — Indicators for city services and quality of life (ISO 37120)
109	% of city population undernourished	Urban/local agricultural and food security	Smart People	WHO statistics on nutrition	Aziende Private terze	quantitativo	Città	Undernourishment includes stunting (low height for age), wasting (low weight for height), underweight (lowweight for age) and micronutrient deficiencies or insufficiencies (a	population undernourished / total population	%	supporting indicator	Sustainable cities and communities — Indicators for city services and quality of life (ISO 37120)
110	% of city population that is overweight or obese - Body Mass Index (BMI)	Urban/local agricultural and food security	Smart People	City departments	Città	quantitativo	Città	BMI in the overweight or obese categories defined by WHO	population obese or overweight / total population	%	supporting indicator	Sustainable cities and communities — Indicators for city services and quality of life (ISO 37120)
111	Green area per 100 000 population	Urban Planning	Smart Environment	municipal epartments	Città	quantitativo	Città	amount of vegetated and/or natural surface cover in the city.	hectares x 100000 / city population	hectares	core indicator	Sustainable cities and communities — Indicators for city services and quality of life (ISO 37120)
112	Areal size of informal settlements as a percentage of city area	Urban Planning	Smart Living	City planning department	Città	quantitativo	Città	slums are included	informal settlements area / city area	%	supporting indicator	Sustainable cities and communities — Indicators for city services and quality of life (ISO 37120)
113	Jobs - housing ratio	Urban Planning	Smart Living	City departments	Città	quantitativo	Città		# jobs / # dwelling units	# / unit	supporting indicator	Sustainable cities and communities — Indicators for city services and quality of life (ISO 37120)
114	basic service proximity	Urban Planning	Smart Living	City departments	Città	quantitativo	Città		# inhabitants living near at least one basic service / city population	%	supporting indicator	Sustainable cities and communities — Indicators for city services and quality of life (ISO 37120)
115	Population density	Urban Planning	Smart Living	City departments	Città	quantitativo	Città		city population / city's land area (Km2)	# / Km2	profile indicator	Sustainable cities and communities — Indicators for city services and quality of life (ISO 37120)
116	Number of trees per 100 000 population	Urban Planning	Smart Living	Municipal government records	Città	quantitativo	Città		total number of trees in the city x 100000 / city population	#	profile indicator	Sustainable cities and communities — Indicators for city services and quality of life (ISO 37120)
117	Build- up density	Urban Planning	Smart Living	City departments	Città	quantitativo	Città		m2 of floor area for all buildings / (total city area - green space area)	m2 / m2	profile indicator	Sustainable cities and communities — Indicators for city services and quality of life (ISO 37120)
118	% of city population served by wastewater collection	Wastewater	Smart Environment	Local operators	Aziende private terze	quantitativo	Città		# of people served by wastewater collection / city population	%	core indicator	Sustainable cities and communities — Indicators for city services and quality of life (ISO 37120)

119	% of city's wastewater receinving centralized treatment	Wastewater	Smart Environment	Water supply companies	Azinde private terze	quantitativo	Città		# of people receinving centralized treatment / city population	%	core indicator	Sustainable cities and communities — Indicators for city services and quality of life (ISO 37120)
120	% of population wirh access to improved sanitation	Wastewater	Smart People	City departments	Città	quantitativo	Città		# of people with access to improved sanitation / city population	%	core indicator	Sustainable cities and communities — Indicators for city services and quality of life (ISO 37120)
121	Compliance rate of wastewater treatment	Wastewater	Smart Environment	City departments	Città	quantitativo	Città		# of compliant tests required by local regulation multiplied by 100 / # of tests performed as required by local regulation	%	supporting indicator	Sustainable cities and communities — Indicators for city services and quality of life (ISO 37120)
122	% of city population with potable water supply service	Water	Smart People	Water utilities	Aziende private terze	quantitativo	Città		# of people with potable water suplly service / city population	%	core indicator	Sustainable cities and communities — Indicators for city services and quality of life (ISO 37120)
123	% of city population with sustainable access to an improved water source	Water	Smart People	Water utilities	Aziende private terze	quantitativo	Città		# of people with sustainable access to an improved water source / city population	%	core indicator	Sustainable cities and communities — Indicators for city services and quality of life (ISO 37120)
124	Total domestic water consumption per capita	Water	Smart Environment	Water supply companies	Aziende private terze	quantitativo	Città		amount of city's water consumption for domestic use / city population	Litres per person / day	core indicator	Sustainable cities and communities — Indicators for city services and quality of life (ISO 37120)
125	Compliance rate of drinking water quality	Water	Smart Environment	Water utilities	Aziende private terze	quantitativo	Città		sum of # compliant test x 100 / # of treated water quality tests	%	core indicator	Sustainable cities and communities — Indicators for city services and quality of life (ISO 37120)
126	Total water consumption per capita	Water	Smart Environment	Water utilities	Aziende private terze	quantitativo	Città		amount of city's water consumption / city population	Litres per person/ day	supporting indicator	Sustainable cities and communities — Indicators for city services and quality of life (ISO 37120)
127	Avg annual hours of water service interruptions per household	Water	Smart Living	Water utilities	Aziende private terze	quantitativo	Città		sum of hours of interruption x househoulds impacted / total number of households	hours	supporting indicator	Sustainable cities and communities — Indicators for city services and quality of life (ISO 37120)
128	% of water loss (unaccounted for water)	Water	Smart Environment	Water utilities	Aziende private terze	quantitativo	Città		(volume of water supplied - volume of utilized water) / volume of water suplied	%	supporting indicator	Sustainable cities and communities — Indicators for city services and quality of life (ISO 37120)

Smiciklas 2019

	KPI name	Focus	Reference Pillar	Data Owner	Type of Data Owner	Data Type	Perimeter of Analysis	Description	Mode of Calculation	Unit of Measure	Notes	Dataset
1	household internet access	ICT infrastructure	Smart Living	Local/ national statistics department	Città	quantitativo	Città	Percentage of households with Internet access	Number of households with internet access / total number of households	%	core	Collection methodology for Key Performance Indicators for Smart Sustainable Cities
2	fixed broadband subscriptions	ICT infrastructure	Smart Living	Local/ national statistics department	Città	quantitativo	Città	Percentage of households with fixed (wired) broadband	Number of fixed (wired) broadband subscriptions / total number of households	%	core	Collection methodology for Key Performance Indicators for Smart Sustainable Cities
3	wireless broadband subscriptions	ICT infrastructure	Smart Living	Local/ national statistics department	Città	quantitativo	Città	Wireless broadband subscriptions per 100,000 inhabitants	Number of wireless broadband subscriptions x 100000 / city's population	# / 100 000 inhab	core	Collection methodology for Key Performance Indicators for Smart Sustainable Cities
4	wireless broadband coverage -3G	ICT infrastructure	Smart Living	local mobile service providers	Aziende private terze	quantitativo	Città	Percentage of the city served by wireless broadband (by technology)	Area of city covered by mobile services 3G (km2) / total area of the city (km2)	%	core	Collection methodology for Key Performance Indicators for Smart Sustainable Cities
5	wireless broadband coverage -4G	ICT infrastructure	Smart Living	local mobile service providers	Aziende private terze	quantitativo	Città	Percentage of the city served by wireless broadband (by technology)	Area of city covered by mobile services 4G (km2) / total area of the city (km2)	%	core	Collection methodology for Key Performance Indicators for Smart Sustainable Cities
6	smart water meters	Water and Sanitation	Smart Living	Local water utilities	Aziende private terze	quantitativo	Città	Percentage implementation of smart water meters	number of smart water meters installed / total number of water meters installed	%	core	Collection methodology for Key Performance Indicators for Smart Sustainable Cities
7	smart electricity meters	Electricity supply	Smart Living	Local electrical utility	DSO / TSO	quantitativo	Città	Percentage implementation of smart electricity meters	Number of smart electricity meters installed / total number of electricity meters installed	%	corre	Collection methodology for Key Performance Indicators for Smart Sustainable Cities
8	dynamic public transport information	Transport	Smart Mobility	transportation agencies	Aziende pubbliche terze	quantitativo	Città	% of urban PT stops for which traveller inforation is dynamically available to the public in real time	Number of stops and stations with dynamic information available / total number of stops and stations	%	core	Collection methodology for Key Performance Indicators for Smart Sustainable Cities
9	traffic monitoring	Transport	Smart Mobility	municipal, regional transportation and road	Città	quantitativo	Città	percentage of major streets monitored by ICT	Length of major streets monitored by ICT (km) / total length of major streets	%	core	Collection methodology for Key Performance Indicators for Smart Sustainable Cities
10	availability of wifi in public areas	ICT infrastructure	Smart Living	ICT ministry	Città	quantitativo	Città	Number of (public) WIFi hotspots in the city	total number of wifi hotspots provided by the city administration (excluding commercial entities)	#	advanced	Collection methodology for Key Performance Indicators for Smart Sustainable Cities
11	water supply ICT monitoring	Water and Sanitation	Smart Living	Local water utilities	Aziende private terze	quantitativo	Città	Percentage of the water distribution system monitored by ICT	Length of system monitored by ICT (km) / total length of total system (km)	%	advanced	Collection methodology for Key Performance Indicators for Smart Sustainable Cities
12	drainage / storm water system ICT monitoring	Drainage	Smart Living	local authorities	Città	quantitativo	Città	Percentage of drainage / storm water system monitored by ICT	Length of system monitored by ICT (km) / total length of total system (km)	%	advanced	Collection methodology for Key Performance Indicators for Smart Sustainable Cities
13	electricity supply ICT monitoring	Electricity supply	Smart Living	Local electrical utility	DSO / TSO	quantitativo	Città	Percentage of electricity supply system monitored by ICT	Length of system monitored by ICT (km) / total length of total system (km)	%	advanced	Collection methodology for Key Performance Indicators for Smart Sustainable Cities
14	demand response penetration	Electricity supply	Smart Living	Local electrical utility	DSO / TSO	quantitativo	Città	Percentage of electricity customers with demand response capabilities	Number of demand response enabled electricty customers / total number of electricity customers	%	advanced	Collection methodology for Key Performance Indicators for Smart Sustainable Cities
15	intersection control	Transport	Smart Mobility	Local national traffic authorities	Città	quantitativo	Città	percentage of road intersection with adaptive traffic control or prioritization measures	Number of intersectios with adaptive traffic control / total number of signal controlled intersections	%	advanced	Collection methodology for Key Performance Indicators for Smart Sustainable Cities
16	open data	Public sector	Smart Living	municipal ICT departments	Governo / PA	quantitativo	Città	% and number of inventoried open datasets that are published	total number of open data sets published / total number of data sets	% and #	advanced	Collection methodology for Key Performance Indicators for Smart Sustainable Cities
17	e-government	Public sector	Smart Governance	survey of municipal departments	Governo / PA	quantitativo	Città	number of public services delivered through electr means	Number of public services available through online service	#	advanced	Collection methodology for Key Performance Indicators for Smart Sustainable Cities
18	public sector e-procurement	Public sector	Smart Governance	IT city departmets	Città	quantitativo	Città	% of public sector procurement activities that are conducted electronically	number of public sector procurement activities conducted online / total number of public sector procurement activities	%	advanced	Collection methodology for Key Performance Indicators for Smart Sustainable Cities
19	basic water supply	Water and Sanitation	Smart Living	Local water utilities	Aziende private terze	quantitativo	Città	Percentage of city households with access to basic water supply	Number of city households with access to basic water sources / total number of city households	%	core	Collection methodology for Key Performance Indicators for Smart Sustainable Cities
20	potable water supply	Water and Sanitation	Smart Living	Local water utilities	Aziende private terze	quantitativo	Città	Percentage of households with a safely managed drinking water service	Number of city households with a safely managed drinking water service / total number of city households	%	core	Collection methodology for Key Performance Indicators for Smart Sustainable Cities
21	water supply loss	Water and Sanitation	Smart Living	Local water utilities	Aziende private terze	quantitativo	Città	Percentage of water loss in the water distribution system	Volume of water supplied minus the volume of utilized water (l / year) / total volume of water supply (l / year)	%	core	Collection methodology for Key Performance Indicators for Smart Sustainable Cities

22	wastewater collection	Water and Sanitation	Smart Living	wastewater local utilities	Aziende private terze	quantitativo	Città	% of households served by wastewater collection	Number of households served by wastewater collection / total number of households	%	core	Collection methodology for Key Performance Indicators for Smart Sustainable Cities
23	household sanitation	Water and Sanitation	Smart Living	Who-Unicef joint programme	Singolo cittadino	quantitativo	Città	% of city households with access to basic sanitation facilities	Total number of city households with access to basic sanitation and facilities / total number of city households	%	core	Collection methodology for Key Performance Indicators for Smart Sustainable Cities
24	solid waste collection	Waste	Smart Living	Municipal bodies	Municipalità / quartiere	quantitativo	Città	Percentage of city households with regular solid waste collection	Number of city households that are served by solid waste collection / total number of city households	%	core	Collection methodology for Key Performance Indicators for Smart Sustainable Cities
25	electricity system outage frequency	Electricity Supply	Smart Living	Local electrical utility	DSO / TSO	quantitativo	Città	Average number of electrical interruptions per customer per year	sum of customers interrupted / total number of customers served	# of customers	core	Collection methodology for Key Performance Indicators for Smart Sustainable Cities
26	electricity system outage time	Electricity Supply	Smart Living	Local electrical utility	DSO / TSO	quantitativo	Città	Average length of electrical interruptions	sum of all customer interruption times (mins) / total number of customer interruptions	minutes	core	Collection methodology for Key Performance Indicators for Smart Sustainable Cities
27	access to electricity	Electricity Supply	Smart Living	Local electrical utility	DSO / TSO	quantitativo	Città	Percentage of households with authorized access to electricity	number of city households with an authorized connection to the electrical system	%	core	Collection methodology for Key Performance Indicators for Smart Sustainable Cities
28	public transport network	Transport	Smart Mobility	local public transportation operator	Aziende pubbliche terze	quantitativo	Città	Length of public transport network per 100,000 inhabitants	length of public transport lines within city boundaries (km) (one way length) x 100000 / city's population	km /100 000 inhab	core	Collection methodology for Key Performance Indicators for Smart Sustainable Cities
29	bicycle network	Transport	Smart Mobility	municipal transportation authorities	Città	quantitativo	Città	length of bycicle paths and lanes per 100 000 population	km of bicycle paths or lanes x 100000 / city's population	km /100 000 inhab	core	Collection methodology for Key Performance Indicators for Smart Sustainable Cities
30	public transport network convenience	Transport	Smart Mobility	local public transportation operator	Aziende publiche terze	quantitativo	Città	Percentage of the city population that has convenient access (within 0.5 km) to public transport	Total number of city inhabitants living within 0.5km of a PT stop / total city inhabitants	%	advanced	Collection methodology for Key Performance Indicators for Smart Sustainable Cities
31	transportation mode share - private vehicles	Transport	Smart Mobility	tranportation surveys	Singolo cittadino	quantitativo	Città	The percentage of people using various forms of transportation to travel to work	Number of travellers using private vehicles / total number of travellers	%	advanced	Collection methodology for Key Performance Indicators for Smart Sustainable Cities
32	transportation mode share - public transport	Transport	Smart Mobility	tranportation surveys	Singolo cittadino	quantitativo	Città	The percentage of people using various forms of transportation to travel to work	Number of travellers using public transportation / total number of travellers	%	advanced	Collection methodology for Key Performance Indicators for Smart Sustainable Cities
33	transportation mode share - walking	Transport	Smart Mobility	tranportation surveys	Singolo cittadino	quantitativo	Città	The percentage of people using various forms of transportation to travel to work	Number of travellers walking / total number of travellers	%	advanced	Collection methodology for Key Performance Indicators for Smart Sustainable Cities
34	transportation mode share - paratransit	Transport	Smart Mobility	tranportation surveys	Singolo cittadino	quantitativo	Città	The percentage of people using various forms of transportation to travel to work	Number of travellers using paratransit / total number of travellers	%	advanced	Collection methodology for Key Performance Indicators for Smart Sustainable Cities
35	travel time index	Transport	Smart Mobility	transportation authorities	Città	quantitativo	Città	Ratio of travel time during peak periods to travel time at free flow periods	travel time during peak periods (mins) / travel time at free flow periods (mins)	ratio	advanced	Collection methodology for Key Performance Indicators for Smart Sustainable Cities
36	shared bicycles	Transport	Smart Mobility	bicycle sharing operators	Aziende private terze	quantitativo	Città	Number of shared bicycles per 100,000 inhabitants	Number of shared bicycles available x 100000 / city's population	# / 100 000 inhab	advanced	Collection methodology for Key Performance Indicators for Smart Sustainable Cities
37	shared vehicles	Transport	Smart Mobility	car sharing providers	Aziende private terze	quantitativo	Città	Number of shared vehicles per 100,000 inhabitants	Number of shared vehicles available x 100000 / city's population	# / 100 000 inhab	advanced	Collection methodology for Key Performance Indicators for Smart Sustainable Cities
38	low-carbon emission passenger vehicles	Transport	Smart Mobility	government agencies	Città	quantitativo	Città	Percentage of low-carbon emission passenger vehicles	Number of low emission vehicles registered (PHEV & EV) / number of total vehicles	%	advanced	Collection methodology for Key Performance Indicators for Smart Sustainable Cities
39	public building sustainability	Buildings	Smart Living	facilities group within the city	Città	quantitativo	Città	% area of public buildings with recognized sustain certifications for ongoing operations	Area of public buildings with certification to a recognized standard for ongoing building operations (m2) / total area of public buildings	%	advanced	Collection methodology for Key Performance Indicators for Smart Sustainable Cities
40	integrated building management systems in public buildings	Buildings	Smart Governance	buildings registry of the city	Città	quantitativo	Città	% of public buildings using integrated ICT systems to automate building management	Floor Area of public buildings using ICT-based systems for integrated management of the city (m2) / total floor number of public buildings in	%	advanced	Collection methodology for Key Performance Indicators for Smart Sustainable Cities
41	pedestrian infrastructure	Urban Planning	Smart Mobility	geographical information systems (GIS)	Città	quantitativo	Città	% of the city designated as a pedestrian / car free zone	Total area of pedestrian or car free zones / total city area	%	advanced	Collection methodology for Key Performance Indicators for Smart Sustainable Cities
42	urban development and spatial planning - compact development	Urban Planning	Smart Living	Urban planning websites	Città	qualitativo	Città	Strategic city planning documents promoting compact development	Existence of urban development and spatial planning strategies or documents at the city level	yes / no	advanced	Collection methodology for Key Performance Indicators for Smart Sustainable Cities
43	urban development and spatial planning - connectivity	Urban Planning	Smart Living	Urban planning websites	Città	qualitativo	Città	Strategic city planning documents promoting connectivity	Existence of urban development and spatial planning strategies or documents at the city level	yes / no	advanced	Collection methodology for Key Performance Indicators for Smart Sustainable Cities

44	urban development and spatial planning - integration & mixed urban land use	Urban Planning	Smart Living	Urban planning websites	Città	qualitativo	Città	Strategic city planning documents promoting integration &mixed urban land use	Existence of urban development and spatial planning strategies or documents at the city level	yes / no	advanced	Collection methodology for Key Performance Indicators for Smart Sustainable Cities
45	urban development and spatial planning - social inclusion	Urban Planning	Smart Living	Urban planning websites	Città	qualitativo	Città	Strategic city planning documents promoting social inclusion	Existence of urban development and spatial planning strategies or documents at the city level	yes / no	advanced	Collection methodology for Key Performance Indicators for Smart Sustainable Cities
46	urban development and spatial planning - resilience to climate change	Urban Planning	Smart Living	Urban planning websites	Città	qualitativo	Città	Strategic city planning documents resilience to climate change	Existence of urban development and spatial planning strategies or documents at the city level	yes / no	advanced	Collection methodology for Key Performance Indicators for Smart Sustainable Cities
47	R&D expenditure	Innovation	Smart Economy	economics departments	Città	quantitativo	Città	Research and development expenditure as % of city GDP	R&D expenditure (US$) / city GDP (US$)	%	core	Collection methodology for Key Performance Indicators for Smart Sustainable Cities
48	patents	Innovation	Smart Economy	regional or national patent offices	Governo / PA	quantitativo	Città	# new patents granted per 100 000 inhabitants per year	Total number of new patents issued to residents and organizations of the city x 100000 / city's population	# /100 000 inhab / year	core	Collection methodology for Key Performance Indicators for Smart Sustainable Cities
49	unemployment rate	Employment	Smart Economy	labour force survey	Singolo cittadino	quantitativo	Città	% of the total city labour force that is unemployed	Total number of city-related unemployed youth / total city-related youth labour force	%	core	Collection methodology for Key Performance Indicators for Smart Sustainable Cities
50	youth unemployment rate	Employment	Smart Economy	government statistical agencies	Città	quantitativo	Città	% of the city youth labour force that is unemployed	Total number of city-related unemployed / total city-related labour force	%	core	Collection methodology for Key Performance Indicators for Smart Sustainable Cities
51	small and medium-sized enterprises	Innovation	Smart Economy	business registration data	Governo / PA	quantitativo	Città	% of SMEs	Number of SMEs / total number of enterprises	%	advanced	Collection methodology for Key Performance Indicators for Smart Sustainable Cities
52	tourism sector employment	Employment	Smart Economy	government tourism departments	Città	quantitativo	Città	% of the city-related labour force working in the tourism industry	Number of city-related employees - tourism sector / total city-related labour force	%	advanced	Collection methodology for Key Performance Indicators for Smart Sustainable Cities
53	ICT sector employment	Employment	Smart Economy	national account tables	Città	quantitativo	Città	Percentage of employees involved with ICT	Number of employees ICT sector / Number total city labour force	%	additional	Collection methodology for Key Performance Indicators for Smart Sustainable Cities
54	air pollution - PM2.5	Air Quality	Smart Environment	WHO air quality guidelines	Città	quantitativo	Città	annual mean concentration for each pollutant	mass of pollutant collected (µg) / volume of air sampled (m3)	µg / m3	core	Collection methodology for Key Performance Indicators for Smart Sustainable Cities
55	air pollution - PM10	Air Quality	Smart Environment	WHO air quality guidelines	Città	quantitativo	Città	annual mean concentration for each pollutant	mass of pollutant collected (µg) / volume of air sampled (m3)	µg / m3	core	Collection methodology for Key Performance Indicators for Smart Sustainable Cities
56	air pollution - NO2	Air Quality	Smart Environment	WHO air quality guidelines	Città	quantitativo	Città	annual mean concentration for each pollutant	mass of pollutant collected (µg) / volume of air sampled (m3)	µg / m3	core	Collection methodology for Key Performance Indicators for Smart Sustainable Cities
57	air pollution - SO2	Air Quality	Smart Environment	WHO air quality guidelines	Città	quantitativo	Città	annual mean concentration for each pollutant	mass of pollutant collected (µg) / volume of air sampled (m3)	µg / m3	core	Collection methodology for Key Performance Indicators for Smart Sustainable Cities
58	air pollution - O3	Air Quality	Smart Environment	WHO air quality guidelines	Città	quantitativo	Città	annual mean concentration for each pollutant	mass of pollutant collected (µg) / volume of air sampled (m3)	µg / m3	core	Collection methodology for Key Performance Indicators for Smart Sustainable Cities
59	GHG emissions	Air Quality	Smart Environment	United Nations GHG inventory data	Città	quantitativo	Città	Greenhouse gas (GHG) emissions per capita	Total GHG emissions (Tonnes eCO2) / total number of city inhabitants	eCO2 / capita	core	Collection methodology for Key Performance Indicators for Smart Sustainable Cities
60	drinking water quality	Water and Sanitation	Smart Environment	WHO guidelines on drinking water quality	Città	quantitativo	Città	% of households covered by an audited Water Safety Plan	Number of compliant samples to WHO Guidelines / total number of samples	%	core	Collection methodology for Key Performance Indicators for Smart Sustainable Cities
61	water consumption	Water and Sanitation	Smart Environment	water supply utilities	Aziende private terze	quantitativo	Città	Total water consumption per capita	Total amount of water consumption in cities (ℓ /day) / total number of city inhabitants	l / day / capita	core	Collection methodology for Key Performance Indicators for Smart Sustainable Cities
62	freshwater consumption	Water and Sanitation	Smart Environment	water supply utilities	Aziende private terze	quantitativo	Città	Percentage of water consumed from freshwater sources	Volume of fresh water consumed / total volume of water supply	%	core	Collection methodology for Key Performance Indicators for Smart Sustainable Cities
63	wastewater treatment - primary	Water and Sanitation	Smart Environment	water supply and treatment companies	Aziende private terze	quantitativo	Città	% of wastewater receiving treatment	Total amount of wastewater that has undergone primary treatment (l) / total amount of wastewater collected (l)	%	core	Collection methodology for Key Performance Indicators for Smart Sustainable Cities
64	wastewater treatment - secondary	Water and Sanitation	Smart Environment	water supply and treatment companies	Aziende private terze	quantitativo	Città	% of wastewater receiving treatment	Total amount of wastewater that has undergone secondary treatment (l) / total amount of wastewater collected (l)	%	core	Collection methodology for Key Performance Indicators for Smart Sustainable Cities
65	wastewater treatment - tertiary	Water and Sanitation	Smart Environment	water supply and treatment companies	Aziende private terze	quantitativo	Città	% of wastewater receiving treatment	Total amount of wastewater that has undergone tertiary treatment (l) / total amount of wastewater collected (l)	%	core	Collection methodology for Key Performance Indicators for Smart Sustainable Cities
66	solid waste treatment - disposed to sanitary landfills	Environment	Smart Environment	waste collection and disposal contractors	Aziende pubbliche terze	quantitativo	Città	The percentage of solid waste dealt with the specific treatment	Total amount of solid waste that is disposed to sanitary landfills (tonnes) / total amount of solid waste produced (tonnes)	%	core	Collection methodology for Key Performance Indicators for Smart Sustainable Cities

67	solid waste treatment - burnt in an open area	Environment	Smart Environment	waste collection and disposal contractors	Aziende pubbliche terze	quantitativo	Città	The percentage of solid waste dealt with the specific treatment	Total amount of solid waste that is burnt in an open area (tonnes) / total amount of solid waste produced (tonnes)	%	core	Collection methodology for Key Performance Indicators for Smart Sustainable Cities
68	solid waste treatment - incinerated	Environment	Smart Environment	waste collection and disposal contractors	Aziende pubbliche terze	quantitativo	Città	The percentage of solid waste dealt with the specific treatment	Total amount of solid waste that is incinerated (tonnes) / total amount of solid waste produced (tonnes)	%	core	Collection methodology for Key Performance Indicators for Smart Sustainable Cities
69	solid waste treatment - disposed to an open dump	Environment	Smart Environment	waste collection and disposal contractors	Aziende pubbliche terze	quantitativo	Città	The percentage of solid waste dealt with the specific treatment	Total amount of solid waste that is disposed in an open dump (tonnes) / total amount of solid waste produced (tonnes)	%	core	Collection methodology for Key Performance Indicators for Smart Sustainable Cities
70	solid waste treatment - recycled	Environment	Smart Environment	waste collection and disposal contractors	Aziende pubbliche terze	quantitativo	Città	The percentage of solid waste dealt with the specific treatment	Total amount of solid waste that is recycled (tonnes) / total amount of solid waste produced (tonnes)	%	core	Collection methodology for Key Performance Indicators for Smart Sustainable Cities
71	solid waste treatment - other (with regard to total amount of solid waste produced)	Environment	Smart Environment	waste collection and disposal contractors	Aziende pubbliche terze	quantitativo	Città	The percentage of solid waste dealt with the specific treatment	Total amount of solid waste that is not treated in the previous ways (tonnes) / total amount of solid waste produced (tonnes)	%	core	Collection methodology for Key Performance Indicators for Smart Sustainable Cities
72	EMF exposure	Environmental quality	Smart Living	ITU EMF Guide	Città	quantitativo	Città	% of mobile network antenna sites in compliance with WHO endorsed ElectroMagnetic Fields exposure guidelines	Number of sites complying with WHO guidelines / total number of sites	%	core	Collection methodology for Key Performance Indicators for Smart Sustainable Cities
73	Noise Exposure	Environmental quality	Smart Living	municipal / national environmental departments	Municipalità / quartiere	quantitativo	Città	Percentage of city inhabitants exposed to excessive noise levels	Number of city inhabitants exposed to noise levels [LDEN (day-evening-night)] over 55 dB (A) / total city inhabitants	%	advanced	Collection methodology for Key Performance Indicators for Smart Sustainable Cities
74	green areas	Public Spaces & Nature	Smart Living	municipal parks and recreation departments	Municipalità / quartiere	quantitativo	Città	Green area per 100,000 inhabitants	Total area of green space in the city (hectares) (public and private) x 100000 / city's population	heactares /100 000 inhab	core	Collection methodology for Key Performance Indicators for Smart Sustainable Cities
75	green area accessibility	Public Spaces & Nature	Smart Living	municipal parks and recreation departments	Municipalità / quartiere	quantitativo	Città	Percentage of inhabitants with accessibility to green areas	Number of inhabitants living with 300m of a publicly accessible green space of at least 0.5 ha / number of city inhabitants	%	advanced	Collection methodology for Key Performance Indicators for Smart Sustainable Cities
76	Protected natural areas	Public Spaces & Nature	Smart Governance	municipal parks and recreation departments	Municipalità / quartiere	quantitativo	Città	Percentage of city area protected as natural sites	Area of protected natural areas preserved by law or other effective means (heactares) / total city area (hectares)	%	advanced	Collection methodology for Key Performance Indicators for Smart Sustainable Cities
77	Reacreation facilities	Public Spaces & Nature	Smart Living	municipal recreations, planning and sports	Municipalità / quartiere	quantitativo	Città	Area of total public recreational facilities per 100,000 inhabitants	Total area of indoor and outdoor facilities (m2) x 100000 / city's population	m2 / 100 000 inhab	advanced	Collection methodology for Key Performance Indicators for Smart Sustainable Cities
78	renewable energy consumption	Energy	Smart Environment	Local utility providers	Aziende private terze	quantitativo	Città	Percentage of renewable energy consumed in the city	Total consumption of electricity from renewable sources (kWh/ yr) / total city electricity consumption (kWh/ yr)	%	core	Collection methodology for Key Performance Indicators for Smart Sustainable Cities
79	electricity consumption	Energy	Smart Environment	Local electricity utilities	DSO / TSO	quantitativo	Città	Electricity consumption per capita	Total consumption of electricity (kWh / year) / total number of city inhabitants	kWh / year / capita	core	Collection methodology for Key Performance Indicators for Smart Sustainable Cities
80	residential thermal energy consumption	Energy	Smart Environment	local utilities	DSO / TSO	quantitativo	Città	Residential thermal energy consumption per capita	Total consumption of thermal energy (GJ / year) / total number of city inhabitants	Gj / year / capita	advanced	Collection methodology for Key Performance Indicators for Smart Sustainable Cities
81	public building energy consumption	Energy	Smart Environment	local utilities	DSO / TSO	quantitativo	Città	Annual energy consumption of public buildings	Total energy consumption by public buildings (ekWh/yr) / total floor space of public buildings (m2)	ekWh / m2 / year	core	Collection methodology for Key Performance Indicators for Smart Sustainable Cities
82	student ICT access	Education	Smart People	local school boards / education departments	Governo / PA	quantitativo	Città	Percentage of students with classroom access to ICT facilities	Students with classroom access to ICT facilities / total number of students enrolled in schools	%	core	Collection methodology for Key Performance Indicators for Smart Sustainable Cities
83	school enrolment	Education	Smart People	local school boards / education departments	Governo / PA	quantitativo	Città	Percentage of school-aged population enrolled in schools	Number of students in primary and secondary levels in public and private schools / total number of the school aged population	%	core	Collection methodology for Key Performance Indicators for Smart Sustainable Cities
84	higher education degrees	Education	Smart People	education departments / national census data	Singolo cittadino	quantitativo	Città	Higher level education degrees per 100,000 inhabitants	Number of city inhabitants holding at least one higher level education degree x 100000 / city's population	# degrees /100 000 inhab	core	Collection methodology for Key Performance Indicators for Smart Sustainable Cities
85	adult literacy	Education	Smart People	education or labour force departments	Singolo cittadino	quantitativo	Città	Adult literacy rate	number of adult city inhabitants who are deemed to be literate / total number of city inhabitants	%	core	Collection methodology for Key Performance Indicators for Smart Sustainable Cities
86	life expectancy	Health	Smart Living	health departments	Città	quantitativo	Città	Average life expectancy	Average number of years that a newborn is expected to live if current mortality rates continue to apply	years	core	Collection methodology for Key Performance Indicators for Smart Sustainable Cities
87	maternal mortality rate	Health	Smart Living	households surveys, census	Città	quantitativo	Città	Maternal deaths per 100,000 live births	Number of materal deaths in a year x 100000 / live births in a year	deaths /100 000 births	core	Collection methodology for Key Performance Indicators for Smart Sustainable Cities
88	physicians	Health	Smart Living	local health authorities / hospitals / surveys	Città	quantitativo	Città	Number of physicians per 100,000 inhabitants	Number of general or specialized physicians working in the city (FTE) x 100000 / city's population	# /100 000 inhab	core	Collection methodology for Key Performance Indicators for Smart Sustainable Cities

89	cultural expenditure	Culture	Smart Governance	municipal financial reports	Città	quantitativo	Città	Percentage expenditure on city cultural heritage	Municipal expenditure on preservation, protection and conservation of all cultural and natural heritage (USD) / total city operating budget	%	core	Collection methodology for Key Performance Indicators for Smart Sustainable Cities
90	electronic health records	Health	Smart Living	health departments	città	quantitativo	Città	The percentage of city inhabitants with complete health records electronically accessible to all health providers	Number of city inhabitants with electronic health records / total number of city inhabitants	%	advanced	Collection methodology for Key Performance Indicators for Smart Sustainable Cities
91	in-patient hospital beds	Health	Smart Living	local health authorities / hospitals / surveys	Città	quantitativo	Città	Number of in-patient public hospital beds per 100,000 inhabitants	Total number of in-patient hospital beds (public and private) x 100000 / city's population	# / 100 000 inhab	advanced	Collection methodology for Key Performance Indicators for Smart Sustainable Cities
92	health insurance/public health coverage	Health	Smart Living	health departments	Città	quantitativo	Città	Percentage of city inhabitants covered by basic health insurance program or a public heath system	Number of inhabitants covered by health insurance or a public health system / city's population	%	advanced	Collection methodology for Key Performance Indicators for Smart Sustainable Cities
93	cultural infrastructure	Culture	Smart Living	cultural and arts departments	Città	quantitativo	Città	Number of the cultural institutions per 100,000 inhabitants	Number of cultural institutions x 100000 /city's population	# / 100 000 inhab	advanced	Collection methodology for Key Performance Indicators for Smart Sustainable Cities
94	informal settlements	Housing	Smart Living	municipal planning and housing departments	Municipalità / quartiere	quantitativo	Città	% of city inhabitants living in slums, informal settlements or inadequate housing	Number of people living in slums, informal settlements or inadequate housing / total city inhabitans	%	core	Collection methodology for Key Performance Indicators for Smart Sustainable Cities
95	gender income equality	Social inclusion	Smart Economy	labour market surveys	Singolo cittadino	quantitativo	Città	Ratio of average hourly earnings of female to male workers	avg hourly earnings of female employees (USD) /avg hourly earnings of male employees (USD)	ratio	core	Collection methodology for Key Performance Indicators for Smart Sustainable Cities
96	gini coefficient	Social inclusion	Smart Economy	World Bank, OECD: Income distribution database	Città	quantitativo	Città	Income distribution in accordance with Gini coefficient: it assesses whether income is distributed equally among the population	Area between 45 degree line and Lorenz curve / entire area below 45 degree line. 1= one person having access to all income. 0= perfectly equal distribution of income	0 < c <1	core	Collection methodology for Key Performance Indicators for Smart Sustainable Cities
97	poverty share	Social inclusion	Smart Economy	World bank website	Città	quantitativo	Città	% of city inhabitants living in income poverty	Number of city inhabitants living below the poverty line / total number of city inhabitants	%	core	Collection methodology for Key Performance Indicators for Smart Sustainable Cities
98	voter participation	Citizen participation	Smart Governance	local statistics	Città	quantitativo	Città	% of the eligible population that voted during the last municipal election	Number of people who voted in the previous administrative city elections / people eligible to vote	%	core	Collection methodology for Key Performance Indicators for Smart Sustainable Cities
99	natural disaster related deaths	Safety	Smart Living	municipal emergency services and hospitals	Città	quantitativo	Città	Number of natural disaster related deaths per 100,000 inhabitants	Number of annual natural disaster related deaths x 100000 / city's population	# /100 000 inhab	core	Collection methodology for Key Performance Indicators for Smart Sustainable Cities
100	disaster related economic losses	Safety	Smart Economy	governmental statistics and insurance statistics	Città	quantitativo	Città	Economic losses (related to natural disasters) as a percentage of the city's GDP	Total economic losses (last annual reporting period) related to disasters / GDP of the city	%	core	Collection methodology for Key Performance Indicators for Smart Sustainable Cities
101	police service	Safety	Smart Governance	police service personnel records	Città	quantitativo	Città	number of police officers per 100 000 inhabitants	Number of full time police officers (expressed as FTE) x 100000 / city's population	# / 100 000 inhab	core	Collection methodology for Key Performance Indicators for Smart Sustainable Cities
102	fire service	Safety	Smart Governance	fire service personnel records	Città	quantitativo	Città	number of firefighters per 100 000 inhabitants	Number of full time firefighters (expressed as FTE) x 100000 / city's population	# / 100 000 inhab	core	Collection methodology for Key Performance Indicators for Smart Sustainable Cities
103	violent crime rate	Safety	Smart Governance	local police departments	Città	quantitativo	Città	Violent crime rate per 100 000 inhabitants	Number of violent crimes committed x 100000 / city's population	# / 100 000 inhab	core	Collection methodology for Key Performance Indicators for Smart Sustainable Cities
104	traffic fatalities	Safety	Smart Mobility	local transportation and emergency departments	Città	quantitativo	Città	Traffic fatalities per 100,000 inhabitants	Number of traffic fatalities x 100000 / city's population	# / 100 000 inhab	core	Collection methodology for Key Performance Indicators for Smart Sustainable Cities
105	expenditure on housing	Housing	Smart Living	national statistics office	Singolo cittadino	quantitativo	Città	Percentage share of income expenditure for housing	Expenditure on housing (USD) / total household income (USD)	%	advanced	Collection methodology for Key Performance Indicators for Smart Sustainable Cities
106	child care availability	Social inclusion	Smart Governance	Eurostat, OECD family database	Città	quantitativo	Città	% of pre-school age children (0-3) covered by public and private day-care centres	Number of day-care spots available for pre-school children/ total number of pre-school age children	%	advanced	Collection methodology for Key Performance Indicators for Smart Sustainable Cities
107	resilience plans	Safety	Smart Governance	Città	Città	qualitativo	Città	implementation risk and vulnerability assessments and actions	presence (and adequacy) of risk reduction strategies in line with Sendai Framework for Disaster Risk Reduction (DRR)	yes / no	advanced	Collection methodology for Key Performance Indicators for Smart Sustainable Cities
108	population living in disaster prone areas	Safety	Smart Living	Città	Città	quantitativo	Città	Percentage of inhabitants living in natural hazards prone areas	Number of city inhabitants living in natural hazard prone areas / total number of city inhabitants	%	advanced	Collection methodology for Key Performance Indicators for Smart Sustainable Cities
109	emergency services response time	Safety	Smart Governance	local emergency services	Città	quantitativo	Città	Average response time for Emergency Services	Sum of all the minutes from an initial call to the on-site arrival of the emergency service in the year (minutes) / Number of emergency responses in the same year	minutes	advanced	Collection methodology for Key Performance Indicators for Smart Sustainable Cities
110	local food production	Food security	Smart Economy	departments related to agriculture and trade	Città	quantitativo	Città	% of local food supplied from within 100 km of the urban area	Amount of local food supplied within 100 km (tonnes) / Amount of total food supplied in tonnes	%	core	Collection methodology for Key Performance Indicators for Smart Sustainable Cities