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Monitoring cities' environmental sustainability: Lisbon's case study

A dashboard to measure sustainability KPIs and metrics

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Project Work proposal presented as partial requirement for obtaining the Master's degree in Information Management with a specialization in Marketing Intelligence

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MONITORING CITIES' ENVIRONMENTL SUSTAINABILITY: LISBON'S CASE STUDY

by

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DEDICATION

To my parents and family. Throughout all time, across the entire universe, I had the joy of being with you.

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First, to Catarina and Guilherme. The unaccountable hours of companionship, the unmeasurable size of your friendship, the nights spent on your couch.

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ABSTRACT

Lisbon's position as the capital and largest city of Portugal provides a clear need for a way to track the city's sustainability efforts to not only deliver insights into its initiatives and transparency for its government, but also to present data that powers strong and informed decisions. In a world of increasing urbanization and where climate change is a growing concern, data presents itself as way to measure the established efforts and forecast future needs and policies as Lisbon finds means to solve some of the major problems that come with being a large city such as air quality and pollution, waste management, mobility and overall quality of life for its residents. As such, this project developed a dashboard in a BI visualization tool comprised of metrics and indicators based on a tailored framework from the city derived from pre-existing frameworks and conversations with Lisbon's city experts. The final result is a prototypical dashboard that can be built upon in the future, once the city invests in a stronger ICT infrastructure that allows for the collection of data to support a project of this nature, something that, currently, is lacking.

KEYWORDS

Lisbon, sustainability, dashboard, data-driven decisions, data

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LIST OF ABBREVIATIONS AND ACRONYMS

BI	Business Intelligence
CCV	Compromisso Crescimento Verde
CEN	European Committee for Standardization
CENELEC	European Committee for Electrotechnical Standardization
CML	Câmara Municipal de Lisboa
CO2	Carbon Dioxide
EGCA	European Green Capital Award
EGD	European Green Deal
ETSI	European Telecommunications Standards Institute
EU	European Union
GDP	Gross Domestic Product
GVA	Gross Value Added
ICT	Information and Communication Technology
ISO	International Standardization Organization
ITU	International Telecommunication Union
KPIs	Key Performance Indicators
Mt	Metric Tons
PNAC	Plano Nacional para as Alterações Climáticas 2020/2030
PNEC	Plano Nacional Energia e Clima 2030
QEPiC	Quadro Estratégico para a Política Climática
RNC	Roteiro para a Neutralidade Carbónica 2050
SDGs	Sustainable Development Goals
TOE	Ton of Oil Equivalent
UN	United Nations
UNECE	United Nations Economic Commission for Europe
UNFCC	United Nations Framework Convention on Climate Change

USA	United States of America
WCCD	World Council on City Data
YoY	Year-over-Year

1. INTRODUCTION

1.1. BACKGROUND AND PROBLEM IDENTIFICATION

Since the 20th century, governments and global institutions alike have been focusing on sustainable development as a primary focus for the future following the understanding that a global ecological crisis might be imminent (Du Pisani, 2006). The Brundtland Report (1987), devised by the World Commission on Environment and Development (WCED) first defined the concept of "sustainable development" as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs". In recent years, plans such as the "2030 Agenda for Sustainable Development" conceived by the United Nations (UN), the "Paris Agreement" by the United Nations Framework Convention on Climate Change (UNFCC) and the "European Green Deal" by the European Union (EU) have delineated and concentrated efforts from international institutions and governments to further implement sustainable development frameworks (United Nations, 2017).

These frameworks have focused on different pillars considered paramount for sustainability such as the 17 Sustainable Development Goals (SDGs) inscribed in the "2030 Agenda for Sustainable Development" adopted by all UN member states. Of these, 6 focus on environmental concerns and one is specifically aimed at cities and their intersection with sustainability ("Sustainable Cities and Communities") (United Nations, 2015a). This is not surprising, considering that, as of 2007, more than 50% of the global population lives in urban areas which are, in turn, responsible for 70% of carbon emissions and 60% of resource consumption while occupying only 3% of the world's landmass (*Cities – United Nations Sustainable Development*, n.d.).

It is within this context that the following research is presented: given the growing efforts for sustainable development, with special emphasis on environmental challenges, and the relevant role urban areas play in these areas, it is important to delineate and develop a framework that measures cities' environmental sustainability. This problem is particularly relevant when cities look towards benchmarks and goals (such as the SDGs) as a way to measure their own performance: this measurement is done through data collecting and processing, bringing into question the quality of the data and respective reporting (Barns, 2020). Data is abundant, but its full potential towards solving major problems (such as global warming or urban development) is not yet completely recognized (Pentland, 2013). Through the development of a data-driven framework developed alongside city officials, we hope to bridge this gap between the needs of cities to survey their environmental sustainability and the existing data and its inherent quality.

1.2. RESEARCH QUESTION AND OBJECTIVES

Within the given background, the research question is thus: *what are the necessary metrics and indicators to develop a relevant framework to measure cities' environmental sustainability?*

A few objectives can be determined to ultimately help answer the research question:

1. Identify the existing sustainability frameworks and assess their relevancy towards environmental sustainability.

2. Analyse the needs of city officials and the information they need to make data-driven decisions regarding the city's environmental sustainability.

3. Determine the relevant metrics and key performance indicators (KPIs) as well as the raw data necessary to measure them.

4. Design a data-architecture and respective dashboard to convey the information.

1.3. STUDY DESIGN

The first objective will be achieved by looking at the existing literature, analysing different frameworks and projects that have already delineated KPIs and measures related to sustainability. Through this initial understanding of the current state of the art, a prototype of the environmental sustainability framework will be developed.

This first version of the framework will then be tested with city officials through semi-formal guided interviews where the prototype will be presented, and questions will be asked regarding its relevancy to understand whether it provides the necessary information to make data-driven decisions. This will fulfil the second objective.

Afterwards, the qualitative data will be analysed and compared with the reviewed literature to improve the framework's prototype and develop a newer version. Alongside this step, the necessary data to calculate the metrics and KPIs will also be described, thus accomplishing the third objective.

Lastly, with a final version of the framework and its necessary data, a dashboard prototype will be designed with the aim of materializing the previous research, concluding the final objective and answering the research question.

2. LITERATURE REVIEW

The following literature review is presented as an attempt to study the current state of the art regarding the several subtopics related to the main research question. As mentioned in the study design, its goal is to analyse and study the current frameworks related to environmental sustainability and, eventually, provide preliminary insights that will allow for the construction of a prototype of a new framework focused solely on this topic.

Therefore, it is important to first breakdown the research question into its several components and identify the study areas of interest that might help us further understand the topic. This is exemplified by the diagram in Figure 1. The identified research topics are as follows:

1. **Sustainability and environmental sustainability:** as the primary focus of the research question, this is the first subtopic. Through this literature review, we hope to better understand what sustainability is and how it relates with the environment as well as outline why it is important and relevant in today's context.

2. **Cities, Smart Cities and their context within environmental sustainability:** this research will shine a light on the importance of cities for the environment and why they're key players in the fight for environmental sustainability. There is a lot of overlap between this topic and Smart Cities and, so, the latter will also be researched to bring relevant information to the discussion.

3. **Policies/Deals/Agreements related to environmental sustainability:** given the previous understanding of environmental sustainability, it is now important to explore what is being done by governments, institutions and other key players in regards to this matter. This will help explain why it is relevant to quantify the progress being made through metrics and KPIs and why cities are looking for ways to get this information.

4. **Existing frameworks:** with the previous theoretical background, it is now possible to look at the existing frameworks and provide a critical discussion about their relevancy within environmental sustainability as well as study the KPIs, metrics and dimensions they aim to measure and conclude which ones should be included in the first prototype of the new framework.

5. **Open Data and Dashboards for a better Government-Citizen relationship:** once the framework is designed, the data that will effectively quantify the information will come from open data portals and be visualised through a BI tool. It is, thus, relevant to explore what open data and open data portals are and why they are being used to feed the project and how can dashboards affect the relationship between the government and its citizens.

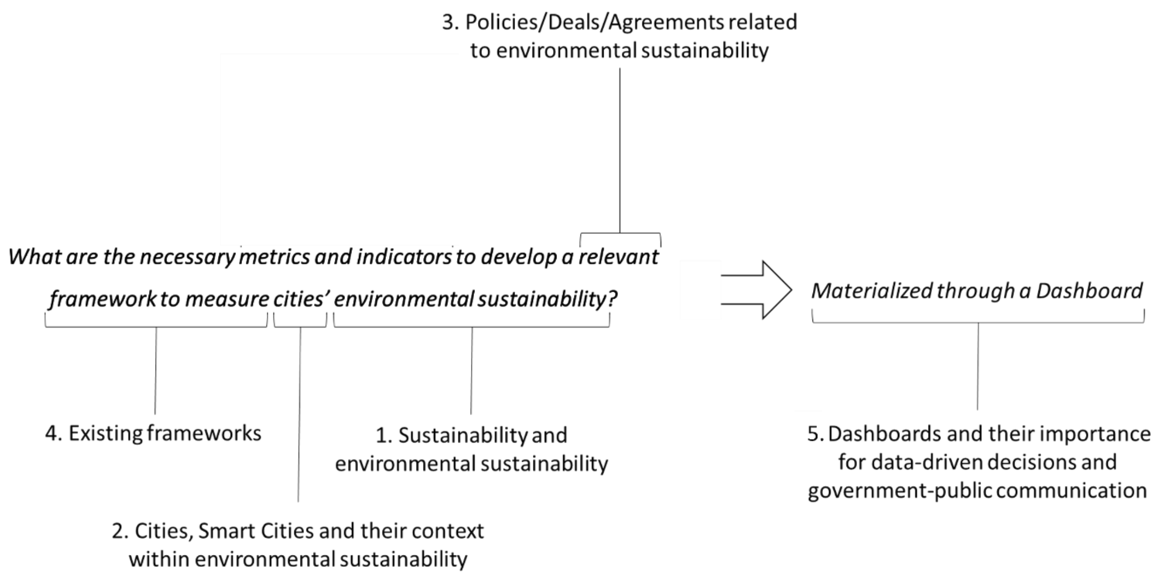

Figure 1 – Breakdown of the research question into its research components

Thus, this thesis follows an integrative literature review (Dudovsky, 2018) as it focuses mostly on critiquing secondary data related to the main research topic and does not have quantitative data collection while aiming to provide a new, holistic approach to the subject matter.

2.1. SUSTAINABILITY AND ENVIRONMENTAL SUSTAINABILITY

Table 1 – Documents used throughout chapter 2.1.

Year	Author(s)	Publication	Title	Keywords	DOI
2006	Du Pisani, J. A.	Environmental Sciences	Sustainable development – historical roots of the concept	Sustainable development, sustainability, history, development, progress, economic growth, conservation	https://doi.org/10.1080/15693430600688831
2007	Johnston, P; Everard, M; Santillo, D; Robèrt, K	Environmental Science and Pollution Research	Reclaiming the Definition of Sustainability	Ecosystems; ethical standards; over-exploitation; pollution; public policy; resources; sustainability; sustainable development; uncertainty	http://dx.doi.org/10.1065/espr2007.01.375
2008	Vos, R	Journal of Chemical Technology and Biotechnology	Defining sustainability: a conceptual orientation	Sustainable development; theories of sustainability; limits to growth	https://doi.org/10.1002/jctb.1675
2011	Morelli, J.	Journal of Environmental Sustainability	Environmental Sustainability: A Definition for Environmental Professionals	Defining sustainability; ecological services; environmental sustainability; goals of the	https://doi.org/10.14448/jes.01.0002
2015	Ramsey, J. L.	Journal of Agricultural and Environmental Ethics	On Not Defining Sustainability	Sustainability; definitions, Wittgenstein, normativity	https://doi.org/10.1007/s10806-015-9578-3
2017	Howes, M; Wortley, L; Potts, R; Dedekorkut-Howes, A; Serrao-Neumann, S; Davidson, J; Smith, T; Nunn, P	Sustainability (Switzerland)	Environmental sustainability: A case of policy implementation failure?	Environmental policy; sustainable development; environment; environmental governance; environmental outcomes	https://doi.org/10.3390/su9020165

Before delving deeper into the specificities of the literature regarding the research question, it is important to lay the conceptual foundation that will guide said review. To that end, this initial chapter is dedicated to better understanding the concept of sustainability, how it came to be, how it is defined and what other concepts can be related to it. This chapter was conducted with an explorative and broad approach, with the aim of setting the first steps towards a more specific and narrow research. Thus, two major databases were used – Google Scholar (scholar.google.com) and ScienceDirect (sciencedirect.com) – with the terms "sustainability", "sustainable development", "defining sustainability" and "environmental sustainability". The resources used can be found on table 1.

In summary, the term "sustainability" is complex and hard to define, with no definition being universally accepted. The one provided by the "Brundtland Report" regarding "sustainable development" is, to this day, the closest we've come to a universal definition of the term. Despite that, these terms, due to their normative subject, require definitions to guide policy and actions and, more importantly, to identify KPIs and metrics to measure the effectiveness of said policies and determine whether we're on the right path towards a more sustainable future – whatever that might encompass.

Throughout the years, there have been many attempts at clearly defining "sustainability" or "sustainable development". In fact, it is estimated that, across the multidisciplinary areas related to sustainability, there are around three hundred definitions of the concept (Johnston et al., 2007). The term finds its origins in relation to the environment and resource consumption, with many ancient civilizations already questioning the rate at which they could extract resources from nature – such as wood from forests and food from agriculture – without compromising their availability in the future (Du Pisani, 2006). The concept was then adopted by biologists and ecologists as they studied the progress of ecosystems and the depletion of their resources through extraction or pollution damage while maintaining the underlying integrity of the system (Vos, 2008).

As society moved past the idea of unbridled and unlimited progress, the concept of "sustainable development" appeared. Following the world wars of the 20th century and their respective devastating consequences, as well as a series of economic recessions, people realized the fragility of economic growth and that it was, in fact, limited and dependent on the availability of natural resources. As these concepts became more widely accepted and environmental concerns became more popular, ideologies focused on ecologism and green movements surged. It was within this context, and with the hopes of outlining ways of distributing wealth and resources to developing countries to ensure a better quality of live for everyone, that the WCED submitted "The Brundtland Report" wherein the first definition of "sustainable development" was written and which can be found in the introduction of this research project. This definition, which combines, for the first time, ideas of sustainability and economic growth, is still the most widely accepted description of the concept (Du Pisani, 2006).

However, in the following decades, hundreds of new definitions were proposed, and this proliferation of the concept diluted its original meaning and allowed it to be interpreted in different ways by different people. As Johnston (2007) puts it, this becomes especially problematic considering the widespread use of "sustainable development" as a synonym for "sustainability", weakening the latter term even further. Differing ideas as to what "sustainability" and "sustainable development" are and what dimensions should be considered when talking about one or the other can, on the other hand, be beneficial when one considers the complexity of a dynamic system such as the environment, opening the door to broader arguments and discussions (Vos, 2008). Even the Brudntland definition is brought into question when one ponders what needs must be met, what the idea of "development" entails and how far into the future should resources be maintained. Still, definitions, especially of normative terms such as "sustainability", are still important for operational purposes such as setting policies, making business decisions, and determining what is or isn't sustainable.

It is against this confusing background of definitions and doubts about what is or isn't sustainable that some authors champion the idea of *not* defining sustainability. As a normative term, sustainability has an underlying call to action; but *what is* this action? As mentioned, most definitions leave ample space for questions regarding the terms that they use: what natural resources must be sustained? Only biological resources? Or should it also include non-biological elements such as water features? Should sustainability include social action? Or focus solely on an economic dimension?

As Ramsey (2015) explains, based on Wittgentstein's 1958 use theory of meanings, attempts at defining "sustainability" before there being any sustainable practices and a common, social understanding of the word, will always fail. Ramsey gives the example of trying to define "sustainability" without the normative backdrop that allows for it to be truly understood as akin to giving people in an absolute monarchical society a definition of "voting": one can tell them what the act of voting is and how it's done, but without the practice of democracy already established, a vote to them will always just be a mark on a piece of paper. Therefore, definitions of "sustainability" should come from practice-oriented attempts that start with the systems already in place, through the implementation of metrics and KPIs of progress, and through practice of sustainability itself. Only then will the term be truly understood (Ramsey, 2015; Vos, 2008).

However, these practices and systems must start somewhere and, despite the abundant definitions of the word, some common themes are apparent as they focus mostly on three topics, often called the "three-legged stool" approach: economy, environment and society (Vos, 2008). It is, therefore, impossible to decouple "sustainability" from the more specific topic of "environmental sustainability". In fact, by analysing this triad of pillars essential to sustainability, one can clearly see that, for a society and an economy to exist sustainable, a sustainable environment is required: a society is dependent on the availability of natural resources and an economy necessitates both a society and natural resources to thrive. It is apparent, then, that, of the three, only the environment can stand by itself and, by taking actions to promote a sustainable environment one is also fostering a sustainable society and economy (Morelli, 2011). Beyond this, another core concept of "sustainability" is that of intergenerational equity, or the handing over of the current state of these three components to the next generation, putting an emphasis on larger time scales and the evolution of these pillars throughout them (Vos, 2008). As a result, there's a focus on the change of the state of these elements that presupposes a need for measuring the progression of their condition.

It is unsurprising that sustainability and, more specifically, environmental sustainability, have been the focus of many policies throughout the last several decades. Nonetheless, much like the attempts at defining the concept, these policies have, for the most part, failed (Howes et al., 2017). Definitions, as stated, are necessary to generate and guide policymaking and, more importantly, to kickstart the actions and plans that will bring forth a sustainably developed world. Moreover, the previously mentioned need to measure the progression of sustainability efforts requires a definition of what must be measured in the first place. Still, the lack of a definition notwithstanding, policies have been drafted and actions have been taken and their effectiveness can be measured by changes in the environment between its state before and after the implementation of said policies (Howes et al., 2017).

Thus, the need for frameworks containing performance indicators to measure the progress towards sustainability emerges. To, in fact, determine what "sustainability" truly is through actions and to define what is or isn't sustainable, we must first determine which actions actually pushes us towards a sustainable future. To that end, indicators and KPIs are needed to measure the difference between the starting point (baseline) and the current state and establish whether progress has been made or not. Additionally, as is explored in chapter 2.3, there are politically established targets that must be met and, to determine whether those have been reached, measurements are also necessary.

Sustainability implies the dimension of time; it encompasses, by most definitions, an idea of progress and preservation. We must measure sustainability to determine what sustainability is.

2.2. CITIES, SMART CITIES AND THEIR CONTEXT WITHIN ENVIRONMENTAL SUSTAINABILITY

Table 2 – Documents used throughout chapter 2.2.

Year	Author(s)	Publication	Title	Keywords	DOI
2005	Bulkeley, H.; Betsill, M.	Environmental Politics	Rethinking sustainable cities: Multilevel governance and the 'urban' politics of climate change	n/a	https://doi.org/10.1080/ 0964401042000310178
2006	Egger, S.	Environmental Modelling and Software	Determining a sustainable city model	Adaptive change; Cities; City-regions; Sustainability; Sustainability indicators; Sustainability models	http://doi.org/10.1016/ j.envsoft.2005.04.012
2007	Giffinger, R.; Fertner, C.; Kramar, H.; Meijers, E.	Centre of Regional Science, Vienna UT	City-ranking of European medium-sized cities	n/a	n/a
2008	Hollands, R.	City	Will the real smart city please stand up? Intelligent, progressive or entrepreneurial?	n/a	http://doi.org/10.1080/ 13604810802479126
2011	Hilty, L. Lohmann W., Huang, E.	Notizie di Politeia	Sustainability and ICT – An overview of the field	Environmental informatics; Green information technology; Resource decoupling.; Sustainable development; Sustainable human-computer interaction	https://doi.org/10.5167/ uzh-55640 Journal
2011	Caragliu, A.; del Bo, C.; Nijkamp, P.	Journal of Urban Technology	Smart cities in Europe	n/a	http://doi.org/10.1080/ 10630732.2011.601117
2012	OECD	n/a	OECD: Environmental Outlook to 2050	n/a	https://doi.org/10.1787/ 9789264122246-en
2014	Wheeler, S. Beatley, T.	n/a	Sustainable Urban Development Reader	n/a	n/a
2014	Kramers, A.; Höjer, M.; Lövehagen, N.; Wangel, J.	Environmental Modelling and Software	Smart sustainable cities - Exploring ICT solutions for reduced energy use in cities	Energy use; Household; ICT; Smart cities; Smart sustainable cities	http://doi.org/10.1016/ j.envsoft.2013.12.019
2015	United Nations	n/a	World Urbanization Prospects The 2014 Revision	n/a	n/a
2015	Agelidou, M.	Cities	Smart cities: A conjuncture of four forces	History; Knowledge economy; Market; Policy; Smart city; Technology	http://doi.org/10.1016/ j.cities.2015.05.004
2017	Bibri, S.; Krogstie, J.	Sustainable Cities and Society	Smart sustainable cities of the future: An extensive interdisciplinary literature review	Big data analytics; Computing; ICT; Planning; Smart cities; Smart sustainable cities; Sustainable cities; Sustainable development goals; Sustainable urban forms; Urban sustainability	http://doi.org/10.1016/ j.scs.2017.02.016
2017	Ahvenniemi, H.; Huovila, A.; Pinto-Seppä, I.; Airaksinen, M.	Cities	What are the differences between sustainable and smart cities?	Assessment framework; Indicator; Performance measurement; Smart city; Sustainable city	http://doi.org/10.1016/ j.cities.2016.09.009

When looking at current efforts being drafted to tackle the problem of sustainability, several trends emerge. There's a clear focus of environmental sustainability, as is evident by the policies and agreements explored on chapter 2.3 which, for the most part, deal with environmental problems such as air pollution, global warming, greenhouse gas emissions, etc. However, these environmental problems are complex and require different approaches to reach a solution. As is apparent by the literature presented in this chapter, one of the major axes upon which the fight towards sustainability rests is urban areas.

This chapter explores the role cities play in the concept of sustainability and what can be done to transition them into a more sustainable future. In essence, cities play a vital role in today's economy and social fabric, but their impact on the environment is clear. Hence, major organizations have issued guidelines and action plans to bring relevance to the problem and propose solutions that show that cities can contribute to a more sustainable development. The resources used for this chapter can be found on Table 2 and were sourced using Google Scholar (scholar.google.com) and ScienceDirect (sciencedirect.com) using key words such as "smart cities", "smart sustainable cities", "cities and sustainability" and "big data in cities".

The link between cities and the environment is one that has made global institutions such as the Organisation for Economic Co-operation and Development (OECD) and the UN worried about the future. By 2050, it is expected that the world's population will grow from 7 to 9 billion people, an almost 30% increase that will be completely absorbed by cities and urban areas. This growth will have severe impacts on air pollution, transportation, waste and water management, etc. (OECD, 2012). Other environmental impacts are to be expected as cities grow: their spatial growth threatens habitats and biodiversity as it also contributes to carbon emissions, deforestation and land usage; their inhabitants' consumption is also higher than those from rural areas; and they are also responsible for almost 70% of energy usage (United Nations, 2015b). In fact, this concern regarding cities and sustainability stems from the Brundtland Report, and its acknowledgment has made cities a focal point of policies (Bulkeley & Betsill, 2005).

It is, thus, not surprising to see the term "sustainability" applied to cities and urban areas. Indeed, concerns regarding the expansion and growth of cities date back to the early 19th century as major cities such as London and Boston became hubs of industrialization, attracting people from the countryside and paving the way for future megalopolises as they not only expanded and embraced new technologies but were also riddled with problems regarding air pollution, sanitation, overcrowding and deteriorating infrastructure. As cities grew, so did the distance between people and nature, and early city-planners sought to bridge the gap by attempting to balance the two, a theme that has passed on to modern sustainability practices. Additionally, problems with housing and work conditions from this era also brought the topic of equity into focus as many economists of the time also questioned the trend of endless economic growth. Thus, the three pillars of sustainable development – environment, economy and society (equity), first mentioned in the previous chapter – were realized within the context of urban areas (Wheeler & Beatley, 2014). Cities are, then, at the forefront of the path towards sustainability (Egger, 2006).

One of the most commonly touted terms when one is looking at sustainability within urban areas is that of "smart cities" or, more specifically, "smart sustainable cities" (Bibri & Krogstie, 2017). Much like the term "sustainability", "smart cities" has been the victim of a series of attempts at defining it and, to this day, there still isn't any clear-cut, universally accepted clarification of the concept (Ahvenniemi et al., 2017; Angelidou, 2015; Bibri & Krogstie, 2017; Hollands, 2008). Nonetheless, one of the most widely accepted definitions of the term is offered by Caragliu et al. (2011): "A city [is] smart when investment 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." (Bibri & Krogstie, 2017). This ideation of the concept is based on a classification framework divided in six dimensions such as the one used by Giffinger et al. (2007), the "European Smart Cities Ranking". These dimensions are: smart mobility, smart environment, smart living, smart people, smart economy, and smart governance (Bibri & Krogstie, 2017; Giffinger et al., 2007). Each of these dimensions is then broken down into a number of factors, each with indicators that analyse a city's performance (Giffinger et al., 2007). A small description of each dimension and their respective factors can be found on Tables 3 and 4, respectively. However, this framework doesn't highlight which dimensions should be prioritized to achieve sustainability, and, in fact, the definition of "smart cities" does not require the subject of sustainability, even though smart initiatives can be useful in this aspect (Bibri & Krogstie, 2017).

Table 3 – The six dimensions of smart cities and their respective descriptions (Giffinger et al., 2007)

Dimension	**Description**
Smart Mobility	A city with new transport systems which improve urban traffic and citizens' mobility
Smart Environment	A city that is green, efficient, and sustainable and relies mostly on green and sustainable energy
Smart Living	A city that uses modern technology such as, but not limited to, ICT in its everyday urban life
Smart People	A city with educated citizens (higher educational grades)
Smart Economy	A city with a "smart" industry, i.e., industries using ICT in their production processes
Smart Governance	A city with good governance, whose administration relies on new channels of communication for the citizens

Table 4 – The six dimensions of smart cities and their respective evaluation factors (Giffinger et al., 2007)

Dimension	**Factors**
Smart Mobility	• Local accessibility • Inter-(national) accessibility • Availability of ICT infrastructure • Sustainable, innovative, and safe transport systems
Smart Environment	• Attractivity of natural conditions • Pollution • Environmental protection • Sustainable resource management
Smart Living	• Cultural facilities

	• Health conditions • Individual safety • Housing quality • Education facilities • Touristic attractivity • Social cohesion
Smart People	• Level of qualification • Affinity to lifelong learning • Social and ethnic plurality • Flexibility • Creativity • Cosmopolitanism/Open-mindedness • Participation in public life
Smart Economy	• Innovative spirit • Entrepreneurship • Economic image and trademarks • Productivity • Flexibility of labor market • International embeddedness • Ability to transform
Smart Governance	• Participation in decision-making • Public and social services • Transparent governance • Political strategies and perspectives

Regardless, one shared element across all definitions, strategies and approaches towards the concept of "smart cities" is that of Information and Communication Technologies, or ICT (Bibri & Krogstie, 2017). Hilty et al. (2011) show how ICT can be used towards a more sustainable future through several applications aimed at monitoring and analysing the environment (databases, research, planning, modelling, etc.) which can, in turn, lead to strategies and policies that emerge out of the shared data. By supplying and using open data to track urban sustainable development progress, open data for smart cities play a crucial role in monitoring city sustainability (Neves et al., 2020). Additionally, ICT can be used to substitute, improve, and optimize processes through technological improvements. Hence why, even though "smart cities" do not necessarily require sustainability, through the usage of ICT – which *is* a requirement – they can help the cause of sustainability. Therefore, cities aiming to become environmentally sustainable must turn towards ICT as a supporting – and essential – framework that underlies the complex urban systems so as to provide a better quality of life for its citizens while improving the environment (Bibri & Krogstie, 2017; Kramers et al., 2014).

Both Bibri & Krogstie (2017) and Hilty et al. (2011), however, warn of the dangers of ICT and smart cities in the context of environmental sustainability since these technological infrastructures require a lot of energy to operate and could cause increases in energy consumption across other sectors. This is, in part, explained by the rebound effect in which increases in efficiency of the input resources results in an increase in their consumption rather than a decrease. For example: as energy efficiency improved in computing, so did the overall availability of computation (through the proliferation of personal computers, smartphones, etc.). So, even though computing has required less energy throughout the years, the wide availability of computation has led to increases in energy consumption. The ICT sector itself could fall victim to this paradox: as we find ways of improving energy efficiency through ICT, we could also be paving the way to an over usage of ICT which will, in turn, consume more energy (and, therefore, have a bigger environmental impact) (Hilty et al., 2011). This, of course, without mentioning the other possible environmental impacts of ICT: resource extraction for production of the materials, inefficiency in recycling the technology, fast-paced sector making technology quickly obsolete, etc.

To summarize, cities pose environmental and sustainable problems in the way they are built today. Current models for smart cities do not incorporate solutions to rectify these problems; however, new frameworks have shown that the ICT infrastructure subjacent to smart cities models can, in fact, be used towards sustainability and, thus, propose new models for smart, sustainable cities. An essential part of the potential of said ICT infrastructure is that it can gather data for analysis to calculate metrics and indicators that help guide the progress towards said sustainability.

2.3. POLICIES, DEALS AND AGREEMENTS RELATED TO ENVIRONMENTAL SUSTAINABILITY

Table 5 – Documents used throughout chapter 2.3.

Year	Author(s)	Publication	Title	Keywords	DOI
1992	United Nations	-	Agenda 21	-	10.4135/9781412971867.n128
2014	República Portuguesa	-	Compromisso para o Crescimento Verde	-	-
2015	United Nations	-	The 2030 Agenda for Sustainable Development	-	-
2016	Shishlov, Igor; Morel, Romain; Bellassen, Valentin	Climate Policy	Compliance of the Parties to the Kyoto Protocol in the first commitment period	Carbon accounting; GHG emissions; Kyoto Protocol; carbon emissions trading; compliance	10.1080/14693062.2016.1164658
2016	Grunewald, Nicole; Martinez-Zarzoso, Inmaculada	Environment and Development Economics	Did the Kyoto Protocol fail? An evaluation of the effect of the Kyoto Protocol on CO2 emissions	-	10.1017/S1355770X15000091
2017	Almer, Christian; Winkler, Ralph	Journal of Environmental Economics and Management	Analyzing the Effectiveness of International Environmental Policies: The Case of the Kyoto Protocol	Climate policy; International environmental agreements; Kyoto Protocol; Synthetic control method	10.1016/j.jeem.2016.11.003
2018	Governo Português	-	Roteiro para a Neutralidade Carbónica 2050	-	-
2019	Maamoun, Nada	Journal of Environmental Economics and Management	The Kyoto protocol: Empirical evidence of a hidden success	Air pollution; Generalized synthetic controls; Global warming; International public goods; Kyoto	10.1016/j.jeem.2019.04.001

				protocol; Treatment effects	
2019	Ulucak, Recep; Yücel, Ali Gökhan; Koçak, Emrah	Environmental Kuznets Curve	The Process of Sustainability: From Past To Present	-	10.1016/b978-0-12-816797-7.00005-9

Following the assessment regarding the importance of measuring the progress towards sustainability through metrics and KPIs calculated using data provided by ICT in cities, it becomes relevant to understand which metrics and KPIs should be calculated. This relevancy is deferred to the policies and agreements already set in place to deal with environmental sustainability such as the Paris Agreement or the 17 Sustainable Development Goals (SDGs). These documents contain targets and goals devised to help the world transition into a more sustainable future and, given the institutions that issued them and their wide international reach, can, therefore, be considered of most relevance.

Due to the nature of this chapter, most information within it was collected through institutional or governmental websites and documents. The latter can be found on table 5. Some scientific papers were also used and procured using the databases Google Scholar (scholar.google.com) and ScienceDirect (sciencedirect.com) using keywords such as "environmental policy", "Kyoto Protocol", "Paris Agreement", "efficiency of environmental policy" and so on.

To summarize, there are, currently, several targets aiming at developing a more environmentally sustainable future. In the specific case of Portugal, these are mostly set by international agreements (such as the Paris Agreement), the EU (such as the European Green Deal and other European policies), the UN (such as the SDGs) and the Portuguese government (through agendas aiming to comply with the previous examples or to set new targets altogether). These targets will be taken into consideration when developing a new framework to measure cities' sustainability in Portugal.

As discussed in the chapter 2.1., one of the primary reasons for the unrelenting attempts at defining the terms "sustainability" and "sustainable development" is to properly guide policymaking. To outline comprehensive policies that provide a clear understanding of what actions are sustainable and which ones aren't, which ones are ethically correct and which ones are "greenwashing", is even more necessary in normative terms such as these (Ramsey, 2015). Following the first attempts at defining "sustainable development" by the Brundtland Report in 1987, already extensively covered in this project, and the subsequent proliferation of interpretations of the term, it wasn't long before the first policies, conventions and agreements appeared. One of the first major sets of international policies and plans came with the Rio Summit in 1992, also known as the Earth Summit, from which two major documents were produced: the "Agenda 21" – signed by more than 178 governments, outlining an action plan to tackle human impact on the environment – and the "United Nations Convention on Climate Change" (UNFCCC) – an agreement on climate change convention signed by 154 nations (Ulucak et al., 2019; United Nations, n.d.).

The "Agenda 21" was so called because it outlined a set of actions to achieve global sustainability by the beginning of the 21st century. It was not legally binding, instead encouraging local, national, regional and international governments to adopt their own "Agenda 21", and it did not contain specific targets or goals, instead delineating general objectives that should be taken into consideration and achieved, with a special focus on the environment and its protection, as it contained a specific section dedicated to conservation and management of resources (United Nations, 1992). It was also determined that subsequent summits would evaluate the adoption and impact of the “Agenda 21” and, through those summits, it was acknowledged that progress towards sustainability was lacking (Howes et al., 2017).

As for the UNFCCC, it was originally signed by 154 nations, with that number changing to 197 by 2020, of which 50 have ratified the treaty. It is a non-legally binding treaty with the goal of stabilizing greenhouse gas (GHG) emissions to prevent anthropogenic influences in the climate within a reasonable period that would allow for ecosystems to adapt to climate change. Seven GHGs were outlined in the UNFCCC: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), perfluorocarbons (PFCs), hydrofluorocarbons (HFCs), sulphur hexafluoride (SF_6) and nitrogen trifluoride (NF_3) (UNFCCC, 2020). Despite also not containing specific targets, the UNFCCC set out a series of commitments and objectives that paved the path to future protocols and agreements, with the signatory parties convening every year to assess the progress being made (National Atmospheric Emissions Inventory, n.d.; Ulucak et al., 2019; UNFCCC, 2018b).

In fact, the UNFCCC set the precedent for the Kyoto Protocol, one of the most important documents in international climate change awareness and action. The Kyoto Protocol, signed in 1997 in Kyoto, Japan, entered into force in 2005 and is an internationally legally binding document regarding the reduction of GHG emissions. Thus, the Protocol sets clear targets, divided in two time periods: from 2005 to 2012, which aimed to reduce GHG 5% below 1990 levels; and from 2013 to 2020 (the Doha Amendment), which aimed to reduce GHG 18% below 1990 levels (European Commission, 2014; Ulucak et al., 2019; United Nations, 2019).

The implementation and success – or lack thereof - of the Kyoto Protocol are widely controversial and criticized (Almer & Winkler, 2017; Le Page, 2016). To begin with, only 38 countries signed the deal; of those, the United States of America (USA) never ratified the treaty and Canada eventually withdrew. The remaining 36 countries, at first glance, seem to have complied to the proposed targets, with the data showing an overaccomplishment as the countries reduced their emissions by 24% compared to base-year emissions (Shishlov et al., 2016). However, many have attributed this reduction to the collapse of the Soviet Bloc, which resulted in an economic contraction which led to a decrease of GHG emissions; this emissions deficit occurred between the base-year (for most countries, 1990) and the adoption of the Kyoto Protocol, which means that global emissions were already below the base-year emissions when the deal was signed. Others invoke the economic crisis of 2008/2009 as an explanation for the reduction in GHG emissions and, finally, some claim that, without the withdrawal of Canada and the USA, the targets would’ve never been achieved. Some papers claim that the Kyoto Protocol *did* impact CO_2 emissions of the ratified countries (Grunewald & Martinez-Zarzoso, 2016; Maamoun, 2019), while others show the opposite (Almer & Winkler, 2017). In an *ex post* analysis, Shishlov et al., 2016 show that, had the aforementioned events not happened, the ratifying countries would’ve still achieved their targets. Additionally, some critics show that, throughout the protocol’s period, global emissions still increased due to major polluters (such as China, India, and the USA) not being part of the deal and some of the reductions might be explained by carbon leakage (the shifting of emissions to developing countries).

Regardless, one of the major successes of the Kyoto Protocol is, indeed, the international cooperation to tackle the climate change issue, as well as the focus it attributed to the problem. Whether it did, in fact, contribute to the reduction of GHG emissions or whether it was significant in the fight against global warming, it still helped set the stage for the next major agreement in this area: the Paris Agreement.

As per the UNFCCC (2018a), “the Paris Agreement is a legally binding international treaty on climate change. It was adopted by 196 Parties at COP 21 in Paris, on 12 December 2015 and entered into force on 4 November 2016. Its goal is to limit global warming to well below 2, preferably to 1.5 degrees Celsius, compared to pre-industrial levels” (para. 1-2). However, unlike the Kyoto Protocol, the Paris Agreement does not have specific targets beyond the proposed global warming limit. Instead, each country is responsible for presenting a set of measures and policies in 5 year cycles that should be more ambitious with each cycle (UNFCCC, 2018a).

The Portuguese commitment to the Agreement comes through a series of policies and targets set by the Portuguese Government and by the European Union. For the most part, under the “Quadro Estratégico para a Política Climática” (QEPiC), which includes the “Plano Nacional para as Alterações Climáticas 2020/2030” (PNAC 2020/20230 or just PNAC) with 3 main goals for 2030 (Agência Portuguesa do Ambiente, n.d.-a, n.d.-b):

- Decarbonize the economy.
- Reduce GHG emissions between -18% and -23% by 2020 and between -30% and -40% by 2030 compared to 2005 levels.
- Promote these goals across several economic sectors.

Other targets are observed under the EU’s “2030 climate & energy framework” with 3 key goals for 2030 which will be updated in 2021 to incorporate new and more ambitious targets (European Commission, 2018a):

- 40% less GHG emissions compared with 1990.
- 32% share of renewable energy.
- 32.5% improvement in energy efficiency.

Additionally, the Portuguese Government also approved the “Compromisso para o Crescimento Verde” (CCV) with 14 other targets to be attained between 2020 and 2030 (Republica Portuguesa, 2014) and the “Roteiro para a Neutralidade Carbónica 2050” (RNC) which aims to attain full decarbonization of the economy by 2050 (Governo Português, 2018) and goes in line with the EU’s target of achieving a net-zero GHG emissions economy by the same year (European Commission, 2018b). The “European Green Deal” is the EU’s response to the Paris Agreement, a set of policies aiming at achieving the goals set out by the Agreement and also expanding them to more ambitious targets and longer time periods (European Commission, 2019). This set of policies is too wide reaching and broad and aims to transform the entire European continent. Thus, it will be taken into consideration as a general guideline as to the relevancy of the metrics and KPIs for the framework.

Following the implementation of Agenda 21, the United Nations organized another summit in the year 2000, called “The Millennium Summit”, where the Millennium Development Goals were outlined. These 8 goals were designed to ensure better living conditions for people in developing countries by the year 2015 and included a specific goal regarding environmental sustainability with 4 major targets (United Nations, 2012b; World Bank, 2015):

- Integrate principles of sustainable development into country policies.
- Reduce biodiversity loss.
- Halve the proportion of population without access to safe drinking water and basic sanitation.
- Achieve significant improvement in the lives of, at least, 100 million slum-dwellers.

These goals were replaced in 2015 by the Sustainable Development Goals following the Rio+20 (or Earth Summit 2012) conference with the aim of building upon the Millennium Development Goals and achieving a more sustainable world by 2030 (United Nations, 2012a, 2013). Of these 17 goals, 6 are related to the environment and environmental sustainability: Goal 6 - Clean Water and Sanitation; Goal 7 – Affordable and Clean Energy; Goal 11 – Sustainable Cities and Communities; Goal 13 – Climate Action; Goal 14 – Life Below Water; Goal 15 – Life on Land. Each of these goals has targets; however, most of these are too broad and general to be tackled by individual cities (as they are more targeted towards global, international action) (United Nations, 2015a). As such, these goals will be taken into consideration when developing a new framework only as general guidelines and support to ensure the relevancy of the chosen metrics. The exception is Goal 11, which has specific indicators for cities.

A summary of some – the ones relating to environmental sustainability – of the quantifiable targets and goals for Portugal can be found on table 6.

It is clear, then, that the importance of sustainability and sustainable development are undeniable in today's context. Since the first definition of the concepts in 1987, there have been a slew of policies, agreements and protocols all aiming to strive for a more sustainable future. For the most part, these have focused – in full or partially – on environmental sustainability, further sustaining the importance of measuring the progress towards the achievement – or not – of the proposed goals. However, most of these policies, due to their international and broad nature, contain only general guidelines instead of individual, quantifiable targets. These guidelines will help develop a new framework as they will aid in determining which indicators and metrics are relevant, and which ones are not.

Table 6 – Quantifiable targets and respective policies affecting Portugal.
*Target year for this target is 2027.

		Target Years		
Goals	**Policy**	**2030**	**2040**	**2050**
Reduce GHG emissions	PNAC	30% to 40% compared to 2005 levels		
	2030 climate & energy framework	40% compared to 1990 levels		
	RNC		65% to 75% compared to 2005 levels	85% to 90% compared to 2005 levels
	CCV	Cap CO2 emissions between 52.7-61.5 Mt		
Energy efficiency	PNEC	35% improvement in energy efficiency		
	2030 climate & energy framework	32.5% improvement in energy efficiency		
	CCV	101 toe/€m GDP		
Renewable energy	PNEC	47% share of renewable energy		
	2030 climate & energy framework	32% share of renewable energy		
	CCV	40% share of renewable energy		
	PNEC	20% share of renewable energy in transportation		
Urban Areas	CCV	23% urban renewal in total construction		
		15.296 million public transport passengers		
	SDG – Goal 11	100% proportion of population with access to public transport		
		Increase proportion of solid and water waste collected and properly discharged		
Air and Water	CCV	Reduce to 20% water loss in the network		
		100% bodies of water with “Good or Better” rating*		
		Average of 2 days with Air Quality Index “poor” or “bad”		
	SDG – Goal 11	Decrease annual mean levels of fine particulate matter		

2.4. EXISTING FRAMEWORKS

Table 7 - Documents used throughout chapter 2.4.

Year	Author(s)	Publication	Title	Keywords	DOI
2006	Reed, Mark S.; Fraser, Evan D.G.; Dougill, Andre J	Ecological Economics, 59	An adaptive learning process for developing and applying sustainability indicators with local communities	Sustainability indicators; Community empowerment; Stakeholders; Local; Participation	10.1016/j.ecolecon.2005.11.008
2014	Pires, Sara Moreno; Fidélis, Teresa; Ramos, Tomás B.	Cities	Measuring and comparing local sustainable development through common indicators: Constraints and achievements in practice	Sustainable development; Local indicators; Indicator systems; Comparison; Benchmark; Local government	10.1016/j.cities.2014.02.003
2015	Verma, Pramit; Raghubanshi, A. S.	Ecological Indicators	Urban sustainability indicators: Challenges and opportunities	Indicator application; Indicator evaluation; Indicator framework; Sustainability target; Urban sustainability	10.1016/j.ecolind.2018.05.007
2015	Albino, Vito; Berardi, Umberto; Dangelico, Rosa Maria	Journal of Urban Technology	Smart cities: Definitions, dimensions, performance, and initiatives	Indicators; Smart city; Sustainability; Urban development	10.1080/10630732.2014.942092
2016	Costanza, Robert; Daly, Lew; Fioramonti, Lorenzo; Giovannini, Enrico; Kubiszewski, Ida; Mortensen, Lars Fogh; Pickett, Kate E.; Ragnarsdottir, Kristin Vala; De Vogli, Roberto; Wilkinson, Richard	Ecological Economics	Modelling and measuring sustainable wellbeing in connection with the UN Sustainable Development Goals	Ecosystem services; GPI; Natural capital; Social capital; Wellbeing	10.1016/j.ecolecon.2016.07.009
2019	Huovila, Aapo; Bosch, Peter; Airaksinen, Miimu	Cities	Comparative analysis of standardized indicators for Smart sustainable cities: What indicators and standards to use and when?	Decision making; Monitoring; Smart sustainable cities; Standardization; Sustainable	10.1016/j.cities.2019.01.029

				Development Goals; Urban indicator	
2020	European Telecommunications Standards Institute	-	Access, Terminals, Transmission and Multiplexing (ATTM); Sustainable Digital Multiservice Communities; Key Performance Indicators for Sustainable Digital Multiservice Areas; Part 1: Description of Key Performance Indicators	KPI; smart grid; smart meter; sustainability	-

As mentioned in section 2.2. regarding cities and their place within the sustainability context, the concept of smart cities has appeared, in recent years, as a possible solution to the problem. However, it isn't as clear-cut as applying smart solutions to cities: as Bibri & Krogstie (2017) explain, the concept of smart cities does not require the idea of sustainability, but some smart cities tenets *can* contribute to sustainability within urban areas; additionally, new frameworks for developing smart *sustainable* cities have been discussed.

Additionally, as explained, the very concept of sustainability beseeches the need for measurement and tracking as it requires a comparison between a base state and changed state to determine whether positive or negative developments towards sustainability were made. At the intersection of these concepts – sustainability, smart cities, and measurement –, we can find a plethora of frameworks aiming at judging if cities are, in fact, implementing smart solutions and whether those are contributing towards solving the problems facing urban areas today – sustainability just one among them.

One such examples of frameworks designed to measure the effects of smart cities concepts and respective implementations can be found in Giffinger et al.'s (2007) European Smart Cities Ranking, which includes a specific section dedicated to "Smart Environment" and is the most widely recognized ranking in the field (Bibri & Krogstie, 2017). This "Smart Environment" is measured through 10 indicators separated by 4 domains: environmental conditions, air quality (no pollution), ecological awareness, and sustainable resource management (VUT, 2014). However, neither the official website of the ranking nor Giffinger et al.'s 2007 paper specify what these 10 indicators are.

However, other frameworks designed to measure sustainability within smart cities have been developed and are summarized in Huovila et al.'s (2019) study where they analysed seven standardized indicator frameworks and developed a taxonomy to organize them and help city managers determine which indicators to use and when. This study will guide most of this section.

Many indicators and measurement frameworks have been proposed throughout the years since the development of the concept of smart cities. Albino et al. (2015) provide a quick summary of some of the assessment tools, from the already discussed European Smart Cities Ranking to other, more sophisticated frameworks. For the most part, these serve to measure and compare a city's smartness against other smart cities to assess progress and determine what can be improved and, therefore, often combine a series of indicators to calculate one or more composed indexes. The problem with this process, however, is how to determine which indicators to use and what weights to attribute to each (Albino et al., 2015; Costanza et al., 2016).

In Huovila et al.'s 2019 study, 7 standardized frameworks issued by international agencies (the International Organization for Standardization [ISO], the International Telecommunication Union

[ITU], the European Committee for Electrotechnical Standardization [CENELEC], the European Committee for Standardization [CEN] and the European Telecommunications Standards Institute [ETSI]) are evaluated. Some of these frameworks focus on sustainability, others on smartness, others on city services and quality of life. Connecting them, however, is the fact that they all take the concept of sustainability as a foundational support.

The ISO issued three standards regarding the measurement of cities' data: ISO 37120, ISO 37122, and ISO 37123. These were developed alongside the World Council on City Data (WCCD) and are implemented by this organization through the WCCD ISO 37120 series with the goal of improving the available data on cities and supporting data driven planning (*Data Portal — World Council on City Data*, n.d.). The ITU standards have slightly different focuses, but the ITU 4903 was used to develop a manual linked to the SDGs in conjunction with the UN and the United Nations Economic Commission for Europe (UNECE) through the initiative "United Nations 4 Smart sustainable cities" (Huovila et al., 2019; International Telecommunications Union, 2016). The ETSI standard, ETSI TS 103 463/2020, was developed with CEN and CENELEC and is based on 43 previous frameworks and as a continuation of the CITYkeys initiative, a project funded by the European Union HORIZON 2020 program with the aim of measuring and monitoring smart city solutions with and across European cities (CITYKeys, 2017; European Telecommunications Standards Institute, 2020). Finally, the study also takes into consideration the UN's standard for measuring the progress towards the SDG 11, "Make cities and human settlements inclusive, safe, resilient and sustainable". The European Statistical Office (EUROSTAT), measures these indicators for European cities (EUROSTAT, n.d.).

The study then analyses the indicators proposed by the frameworks and classifies them according to 3 categories (City Sector, Indicator Type and Urban Focus) which then subdivide into more specific categories. The City Sector category subdivides into 10 sectors such as "Economy", "Health, well-being and safety", and "ICT"; the Indicator Type category subdivides into 5 types with the aim of providing insight as to what the indicator is measuring such as "Input", "Output", and "Impact", etc. Finally, the Urban Focus category subdivides into "Sustainability" and "Smartness" which, in turn, subdivide into "People", Planet" and "Prosperity", and "Hard" or "Soft", respectively.

This taxonomy and its respective indicators will serve as the basis for indicator selection in this project. However, constructing a framework of urban sustainability is not without its problems and challenges, chief among them the difficulty of choosing universally applicable and relevant indicators that can be used in any city (Huovila et al., 2019; Moreno Pires et al., 2014; Verma & Raghubanshi, 2018). On the one hand, standardized frameworks allow data comparison and consolidation of complex problems which help guide policy and decision-making; on the other, standardized indicators might miss important and contextual-dependent problems, misguide debate and are presented as a universal solution when, in fact, such thing is not possible (Moreno Pires et al., 2014). Therefore, many authors argue in favour of specific and adapted frameworks with indicators adapted to each city's needs.

Using the aforementioned standardized frameworks as a starting point, this is what this project hopes to achieve.

2.5. OPEN DATA AND DASHBOARDS FOR A BETTER GOVERNMENT-CITIZEN RELATIONSHIP

Table 8 - Documents used throughout chapter 2.5.

Year	Author(s)	Publication	Title	Keywords	DOI
2010	Bertot, John C.; Jaeger, Paul T.; Grimes, Justin M.	Government Information Quarterly	Using ICTs to create a culture of transparency: E-government and social media as openness and anti-corruption tools for societies	E-government; ICT; Social media; Transparency	10.1016/j.giq.2010.03.001
2012	Janssen, Marijn; Charalabidis, Yannis; Zuiderwijk, Anneke	Information Systems Management	Benefits, Adoption Barriers and Myths of Open Data and Open Government	Adoption; Diffusion; Governance; Institutional theory; Open data; Open government; Systems theory; Transformation	10.1080/10580530.2012.716740
2011	Zurada, Jozef; Karwowski, Waldemar	Information Systems Management	Knowledge discovery through experiential learning from business and other contemporary data sources: A review and reappraisal	Applications; Data mining; Experiential learning; Knowledge discovery in databases; Methodologies; Methods; Review; Tools	10.1080/10580530.2010.493846
2008	Shim, Dong Chul; Eom, Tae Ho	International Journal of Public Administration	E-Government and Anti-Corruption: Empirical Analysis of International Data	Corruption; E-government; E-participation; International data; Transparency	10.1080/01900690701590553
2014	Conradie, Peter; Choenni, Sunil	Ecological Economics	Modelling and measuring sustainable wellbeing in connection with the UN Sustainable Development Goals	Ecosystem services; GPI; Natural capital; Social capital; Wellbeing	10.1016/j.ecolecon.2016.07.009
2019	Huovila, Aapo; Bosch, Peter; Airaksinen, Miimu	Government Information Quarterly	On the barrier for local government releasing open data	Data release; Open data; PSI; Process barriers	10.1016/j.giq.2014.01.003

Open data has been defined by Janssen et al. (2012) as “non-privacy-restricted and non-confidential data which is produced with public money and is made available without any restrictions on its usage or distribution”. As with many data and technology-related topics, it has been discussed at length in recent years (Conradie & Choenni, 2014; Janssen et al., 2012) and, since it is not the subject of this project to provide further insights in this area, its discussion will focus mainly on the intersectionality of open data with the topics of government and public policy.

The dissemination of public data is often perceived as a potential solution towards greater transparency between governments and the public. Even though most studies have focused on transparency regarding government and employee behaviour, data collected and released through ICT has often been regarded as an effective tool to combat corruption and improve the relationship between public entities and citizens as well (Bertot et al., 2010; Shim & Eom, 2008). In fact, this relationship and transparency has often been the main driver for governments to release data in the hopes of involving its citizens in decision-making processes to improve said government through smarter and more interactive public entities (Conradie & Choenni, 2014; Janssen et al., 2012).

However, these benefits and advantages of releasing data to the public are riddled with barriers that should first be overcome. At the outset, the public must not only be accepting of ICTs and data, but also be able to properly interact with it. This means that releasing the data on its own has little underlying benefit if it is not supported by an accompanying infrastructure that enables its use. Often, the data is hard to find and unwieldy, being spread out across several websites, in large pools of information that are hard to analyse, without proper documentation and metadata, and so on (Bertot et al., 2010; Conradie & Choenni, 2014; Janssen et al., 2012; Zurada & Karwowski, 2011). These are issues that a government aiming to open its information to the public must tackle.

One of the ways governments can provide this extra infrastructure to assist in the interpretation and usage of open data is by developing dashboards that allow its visualisation. Governmental data scientists can combine their knowledge of policies and legislation to provide better context for the data and better represent it through a visual dashboard for communication with the public. Matheus et al. (2020) defines a dashboard as “the visualization of a consolidated set data for a certain purpose, which enables to see what is happening and to initiate actions” and highlights 15 risks and challenges when developing governmental dashboards as well as 10 design principles that aim to tackle them like ensuring data is updated in real time and is accurate, clear presentation and customizable views, and interactive support.

3. METHODOLOGY

Given the context of the current state-of-the-art in literature related to the central themes of this project, it is clear that much is still left to be explored regarding the design of frameworks aimed at measuring cities' environmental sustainability. The very central concepts of this project are muddled with ambiguity and lack of definition, and efforts at standardizing indicators and frameworks fall short of what cities truly require. Additionally, we find ourselves surrounded by a plethora of governmental policies and international agreements, each setting its own targets and guidelines, attempting to build a more sustainable future.

If the main goal of this project is to design a new framework for urban environmental sustainability, a clear and strong methodology is required. The approach used here is an adaptation of the steps presented by Verma & Raghubanshi (2018), each linked with a minor goal, which can be seen on Table 9.

Table 9 – Adapted methodology from Verma & Raghubanshi (2018) to help guide the construction of the framework and set clear goals for each step of the process.

Number	Name	Description	Goal
1	Preliminary Assessment	This step is, for the most part, realized through the previous literature review, especially chapter 2.3. "Policies, Deals and Agreements related to environmental sustainability". Here, the international and national needs are outlined, guiding the general areas that the framework should measure. Despite most of the targets and guidelines presented in these policies, deals, and agreements being too broad and vague for individual cities to put into practice or measure, they still present a basis for what we should focus on.	Understand the general needs and areas to be measured, general goals to be achieved and the context surrounding the framework
2	Selecting Performance Indicators and Targets	Based on chapter 2.4 "Existing frameworks" of the previous literature review, this step will consist of two sub-phases: 1) indicator selection from the standard frameworks based on the taxonomy developed by Huovila et al. (2019) to create a preliminary, general framework and 2) indicator selection from the preliminary framework alongside city officials from Lisbon to create a tailored framework.	Create an initial, general framework and a second, tailored framework for Lisbon's case study
3	Application	Applicating the framework to the real-world case of Lisbon, with open data as the input, starting with the baseline data and then the current state data.	Develop a data model based on open data and a dashboard using a Business Intelligence (BI) tool; identify lacking data and show the importance of ICT for sustainability

As evident, this adapted methodology omits certain steps from the original presented in the study. Namely: second and fifth steps, "Choosing Outcomes/Goals" and "Selecting Targets", which are incorporated in the first step; fourth step, "Set performance Baseline", which is included in the third step; and steps seven to ten, which require follow-up after the implementation of the framework and, once again, go beyond the project's timeline and scope.

The only data collected throughout this methodology – other than the one already presented throughout the literature review – comes with the second sub-phase of the second step, where interviews with city officials from Lisbon will provide qualitative and quantitative data which will allow the adaptation of the general framework to the city's specific needs.

3.1. STEP 1 – PRELIMINARY ASSESSMENT

As indicated in the introduction to this chapter, this step is mostly realized through the information collected throughout the literature review, namely chapter 2.3. However, a summary of said information is presented here as a baseline for the next steps based on Table 10.

Table 10 – Summary of the previously set goals and preliminary assessment of areas to measure to help guide the choice of indicators.

Goals	General Context	Preliminary Areas to Measure
Reduce GHG emissions	Perhaps one of the most common and prevalent goals, the reduction of GHG emissions has been the goal of major policies, from the very first UNFCCC to the most recent Paris Agreement. Portugal, under the RNC, the European Green Deal and the Paris Agreement, hopes to achieve a carbon-neutral economy by 2050.	GHG emissions (C02, CH4, N2O, PFCs, HFCs, SF6, NF3), particle concentrations, emissions by sector (especially energetic sector).
Energy efficiency	Efficient energy usage is paramount to reducing energy consumption, thus mitigating the environmental problems associated with energy production.	Energy consumption per capita, energy consumption of public buildings, energy storage capacity.
Renewable energy	Also a major focus of most policies due to the interconnectedness with the other goals as energy production affects GHG emissions, air and water quality, etc. It is contextualized through European and Portuguese policies.	Share of renewable energy in energy consumption, energy consumption per capita, city services and functions consumption of energy.
Urban areas	All the frameworks analysed have indicators regarding the built environment of cities, with special prevalence in the SDG 11 Goal.	Urban renewal in total construction, public transport infrastructure and usage, green areas in the city.
Air and Water	Tied with most of the other goals, this goal focuses mostly on air and water quality within the context, for the most part, of the CCV and the SDG 11 Goal.	Water pollution, water and air quality, water consumption and efficiency, water loss in the system.

3.2. STEP 2 - SELECTING PERFORMANCE INDICATORS

3.2.1. General Framework

With this preliminary assessment, we can then look at the indicators analysed by Huovila, et al. (2019) and select the ones related to each Goal. A summary of this process can be found in Figure 2. To do this, we can filter the indicators to only consider those with, at least, 1 point in the Planet aspect of Sustainability as attributed by the authors in accordance with their scoring system so we consider only the indicators related to environmental sustainability. Then, we can map the indicators to the 5 Goals mentioned in Table 10 based on their scores in the other categories of the taxonomy, as well as on the metadata provided by the technical documentation, similar to what the authors of the study did. The results of this scoring can be found in Annex A.

Following this initial, broad selection, we can look at the remaining indicators for each goal. To further streamline the pool of indicators, we looked, first, at the ones categorized as being of the "Impact" type by Huovila et al. (2019) following their description of this type of indicators: "Impact indicators measure the state with regard to a set city target (impact of policy), e.g. city's energy consumption, and can be used to evaluate for example the sustainability impacts of smart solutions". These indicators are, thus, more appropriate to measure whether a city is on track to reach a certain target or goal, which is in line with the objective of this project, given the aforementioned context of the policies, deals, and agreements. When no suitable indicators can be found after applying this filter, indicators of other types were selected. Considering that these frameworks often overlap, some indicators can be found in more than one framework, often with different names but measuring the same thing – sometimes changing the measurement units, other times slightly changing the methodology. When this occurs, the choice defaulted to the frameworks developed by ISO, which have, for the most part, the most detailed definitions and methodologies, thus allowing for a better understanding of the indicators.

It is also worth mentioning that not all targets have a corresponding indicator in these frameworks. This happened with a lot of the targets presented by the CCV. In these cases, the default indicator was the one worded in the target itself (e.g.: one of the CCV targets is to improve energy efficiency from 129 toe/€m GDP in 2013 to 101 toe/€m GDP in 2030 (Republica Portuguesa, 2014); thus, the indicator will be the city's energy efficiency).

Following this selection process, a set of 18 core indicators was chosen and can be found on Table 11.

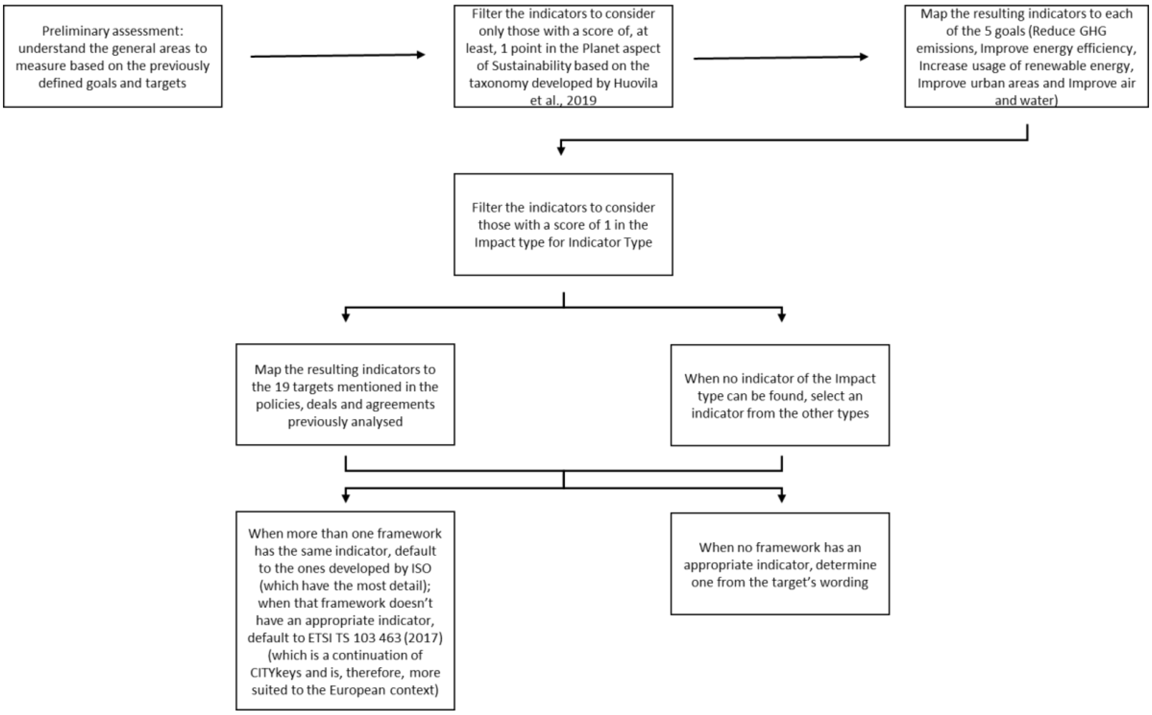

Figure 2 – Summary of indicator selection process.

Table 11 – The 18 chosen indicators and the targets they relate to.

*The RNC has an intermediate target for 2030; however, only the target for 2050 is shown here.

**These targets do not have any corresponding indicator in the analysed frameworks.

Goals	Policy	Target	Indicator	Standard
Reduce GHG emissions	PNAC	30% to 40% compared to 2005 levels	Greenhouse gas emissions measured in tonnes per capita	ISO 37120:2018
	2030 climate & energy framework	40% compared to 1990 levels		
	RNC	85% to 90% compared to 2005 levels*		
	CCV	Cap CO2 emissions between 52.7-61.5 Mt	CO2 emissions	ETSI TS 103 463 (2017)
Energy efficiency	PNEC	35% improvement in energy efficiency	Total end-use energy consumption per capita (GJ/year) Final energy consumption of public buildings per year (GJ/m2)	ISO 37120:2018
	2030 climate & energy framework	32.5% improvement in energy efficiency		
	CCV	101 toe/€m GDP	Energy intensity**	-
Renewable energy	PNEC	47% share of renewable energy	Percentage of total end-use energy derived from renewable sources (breakdown by source and sector)	ISO 37120:2018
	2030 climate & energy framework	32% share of renewable energy		
	CCV	40% share of renewable energy		
	PNEC	20% share of renewable energy in transportation		
Urban Areas	CCV	23% urban renewal in total construction	Percentage of urban renewal**	-
		15.296 million public transport passengers	Number of public transport passengers ** Percentage of population living within 0,5km of public transit running at least every 20 min Annual number of public transport trips per capita	- ISO 37120:2018 ISO 37120:2018
	SDG – Goal 11	100% proportion of population with access to public transport	Proportion of population that has convenient access to public transport, by sex, age and persons with disabilities.	UN IAEG SDG 11+ (2016)
		Increase proportion of solid and water waste collected and properly discharged	Proportion of urban solid waste regularly collected and with adequate final discharge out of total urban solid waste generated, by cities. Municipal solid waste	UN IAEG SDG 11+ (2016) ETSI TS 103 463 (2017)
Air and Water	CCV	Reduce to 20% water loss in the network	Water losses	ETSI TS 103 463 (2017)
		100% bodies of water with “Good or Better” rating*	% of bodies of water with “Good or Better” rating**	-
		Average of 2 days with Air Quality Index “poor” or “bad”	Average of days with Air Quality Index “poor” or “bad”** Air quality index	- ETSI TS 103 463 (2017)
	SDG – Goal 11	Decrease annual mean levels of fine particulate matter	Annual mean levels of fine particulate matter (e.g. PM2.5 and PM10) in cities (population weighted).	UN IAEG SDG 11+ (2016)

3.2.2. Lisbon’s Framework

Following the initial selection of indicators based on the frameworks analysed by Huovila et al. (2019) and the policies and targets in place for Portugal and the city of Lisbon, it is necessary to bring some more specificity to the framework so it can be applied to the context of the project. As was seen before, debates around standardized frameworks for sustainability in cities highlight the need for city-specific indicators that answer the city’s needs (Huovila et al., 2019; Moreno Pires et al., 2014; Reed et al., 2006). To tackle this challenge, an interview with a sustainability expert working for Lisbon’s municipality and its executive body (Câmara Municipal de Lisboa, henceforth CML) was held with the goal of understanding the work that is already being done, as well as any new initiatives or existing frameworks that the city officials are already working with.

From this conversation, we were able to derive that CML is currently working on a proposal for sustainability targets to be presented sometime in 2021 through their own “Climate Action Plan 2030” (*Observatories*, n.d.). These targets can be found in Table 12. As is clear, there is already some overlap between these targets and the indicators selected in the previous chapter. This is not surprising, as the framework presented in Table 12 was built based on the policies and targets set in place for Portugal which, by extension, also apply to Lisbon. However, the city itself as its own goals, with some not completely aligning with the scope of this project, which is focused mainly on environmental sustainability. Thus, targets such as “Energy Poverty” or “Noise” will not be considered thenceforth.

By combining these two, we can derive a Lisbon specific framework, as presented in Table 13.

Table 12 – Lisbon's sustainability targets

Target	Sub Target	Target Year
Reduce GHG emissions	Carbon neutrality	2050
	2,3 tCO2e	2030
	-70% compared to 2002 emissions	
Renewable energy	100 MW of solar power installed	
	100% renewable energy on CML buildings	2021/25
Mobility	34% commute in individual cars and 66% in other alternative means	2030
	5.000 charging stations for electric cars installed	
	No diesel vehicles in the city center	
Water	-30% water consumption in CML buildings compared to 2018	
	+25 sustainable drainage solutions	
Green Infrastructure	25% city area with green spaces	
	+30 urban vegetable gardens	
Municipal Solid Waste and Recycling	-15% waste per capita	
	50% selective retrieval	
	60% recycled waste	
Noise	Reduce exposure to roadway noise	
Air Quality	Comply with WHO reference values	2025
	Better air quality	
Energy poverty	End energy poverty	2050

Table 13 - Final Framework for Lisbon's case study

Target	Sub Target	Indicator	Standard	Target Year
Reduce GHG emissions	Carbon neutrality	CO2 emissions	ETSI TS 103 463 (2017)	2050
	2,3 tCO2e	Greenhouse gas emissions measured in tonnes per capita	ISO 37120:2018	2030
	-70% GHG emissions compared to 2002			
Renewable energy	100 MW of solar power installed	Percentage of total end-use energy derived from renewable sources (breakdown by source and sector)	ISO 37120:2018	
	100% renewable energy on CML buildings			2021/25
Mobility	34% commute in individual cars and 66% in other alternative means	Number of public transport passengers **	-	2030
Water	-30% water consumption in CML buildings compared to 2018	Water consumption	-	
Municipal Solid Waste and Recycling	-15% waste per capita	Municipal solid waste	ETSI TS 103 463 (2017)	
	50% selective retrieval	Proportion of urban solid waste regularly collected and with adequate final discharge out of total urban solid waste generated, by cities.	UN IAEG SDG 11+ (2016)	
	60% recycled waste			
Air Quality	Comply with WHO reference values	Annual mean levels of fine particulate matter (e.g. PM2.5 and PM10) in cities (population weighted).	UN IAEG SDG 11+ (2016)	2025
	Better air quality	Air quality index	ETSI TS 103 463 (2017)	

3.3. Step 3 – Application

As will be discussed further in the "Limitations" chapter of this document, one of this project's major obstacles when it comes to its real-world application is the data, or lack thereof. Thus far, this project has been developed with the assumption of an ideal setting whereby any and all data is available and collected following the international standards referenced in chapter "2.4 Existing Frameworks". However, such ideal setting is far from the constraints of the real world. In the case of Lisbon, as was mentioned by the city expert with whom we discussed the topic, data availability is still a problem and, when it is available, it is often old and outdated.

Therefore, this project's application will follow 2 approaches:

1. When possible, it will set the theoretical groundwork for a future implementation keeping the ideal setting in which the actual dashboard should be built.

2. Otherwise, it will adapt to the current reality and use the available data to build a proof of concept that can be used, in the future, as a basis for the final project.

3.3.1. Data sources

The data used was provided by the previously mentioned city official through Excel files that can also be obtained through the “Observatórios Lisboa”, an open data portal reporting data related to the “Climate Action Plan 2030” (*Observatories*, n.d.). This data is, in turn, provided by several city partners, such as Lisbon’s water company, the Portuguese energy providers, etc. By the definition of “open data” presented in chapter 2.5., these files are not considered as such since they are reported by private companies and not produced through public funding. However, it is publicly available and published by a public entity and it is also the most accurate and complete data in regard to these themes that is currently available.

Nonetheless, as was mentioned before, the quality of this data is far from ideal: it is only updated annually, which prohibits rapid decision-making and somewhat inhibits the goal of a dashboard to guide data-driven decision making (this is further hindered by the fact that municipal elections are held every 4 years in Portugal, which means policies can change quickly and decisions have to be made fast); additionally, most of the data is only updated up until 2 years prior, which means decisions would be made based on old, no longer relevant data. This goes against some of the design principles mentioned in chapter 2.5. of this project, whereby data quality and its real-time update are highlighted as necessary pillars for an efficient governmental dashboard.

However, the data provided in this open data portal is not enough to calculate the indicators proposed in this project’s framework. Therefore, data was further gathered from other open data portals, such as: “Instituto Nacional de Estatística” (INE), “Base de Dados Portugal Contemporâneo” (PORDATA), QualAr (by Associação Portuguesa do Ambiente). The following targets had no available data in the aforementioned sources: “Percentage of total end-use energy derived from renewable sources (breakdown by source and sector)”, “Number of public transport passengers” and “Air quality index”. Instead, dummy data was used as a stand-in to allow for the construction of the dashboard prototype.

3.3.2. Dimensional Modelling

Before proceeding with the application of the previously designed framework and before bringing the project into fruition, it is necessary to take a step back and determine *how* the data will be structured and organized so it can properly sustain the final dashboard.

There are, broadly speaking, two ways of structuring a data warehouse: dimensional modelling and normalized modelling. In both, the information is the same, it is just the way it is structured that changes. That said, they are usually also used for different purposes. Normalized Modelling aims to remove data redundancies by normalizing the data and dividing it into several, discrete, and individual tables that relate to each other. It is usually considered for operational purposes since updates and inserts only alter the data in one point. On the other hand, these normalized models are extremely complex for BI purposes. Due to the high number of tables and relations, queries can take long to process, and it becomes harder for users to intuitively understand the model and navigate it.

The alternative, Dimensional Modelling, aims to structure data in a way that is intuitive for business users and allows for fast querying. In this way of structuring, data is divided into two types of tables:

fact tables and dimension tables. Fact tables store business measurements such as sales, users, quantities, and the like. Dimension tables provide the context for the fact measured in the Fact table by answering the questions of "who, what, where, when, how, and why". For example, a Fact table measuring orders across a website, might have a Dimension table with demographic information regarding said users. The Fact table can tell us how many orders were placed through the website, but the Dimension tables expand on that knowledge by letting us know that 500 were in the United Kingdom and 200 of those used a mobile device (Kimball & Ross, 2016).

In this type of modelling, databases can usually follow 2 structures: star-schema and snowflake-schema. In the star-schema, the Fact table contains all measurements and foreign keys (fk) that allow for it to be related to the Dimension tables (which contain the primary keys or pk). With the Fact table at the centre and the Dimension tables around it with their respective relations, the model looks like a star, hence the name. In the previous example of the website, the Fact table could contain the orders placed through the website, as well as a set of foreign keys that connect to the Dimension tables, like the example in Figure 3.

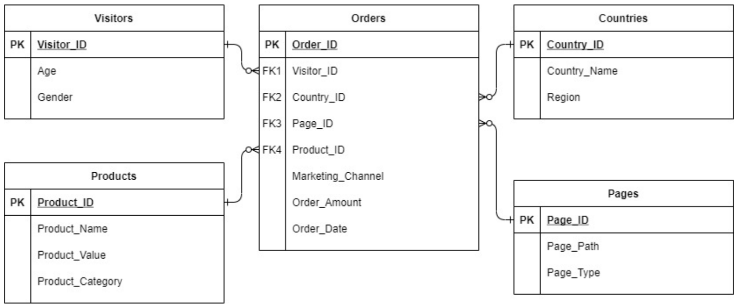

Figure 3 – Example of a Star-Schema

In the snowflake-schema, the Dimension Tables can have extra sub-Dimension tables that provide even more context to the data. For example, the Country table could have another table with the more information about that country's market type and another table could further contextualize the category of the products sold as exemplified in Figure 4 (Levene & Loizou, 2003).

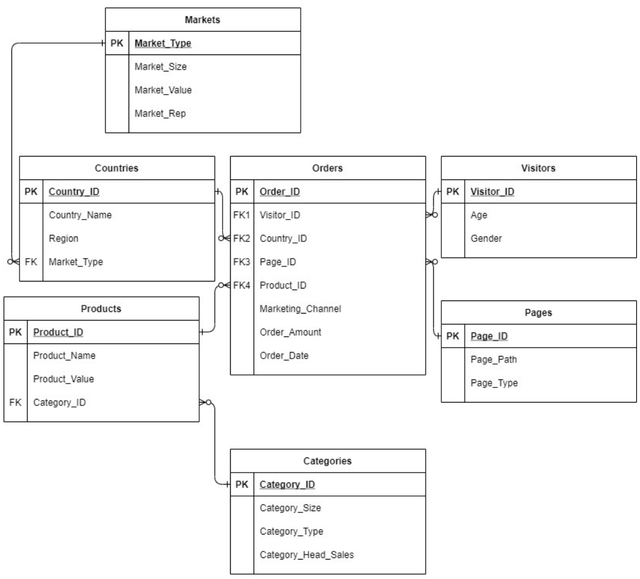

Figure 4 - Example of a Snowflake-Schema

In this case, a Star-Schema will be used to structure the data:

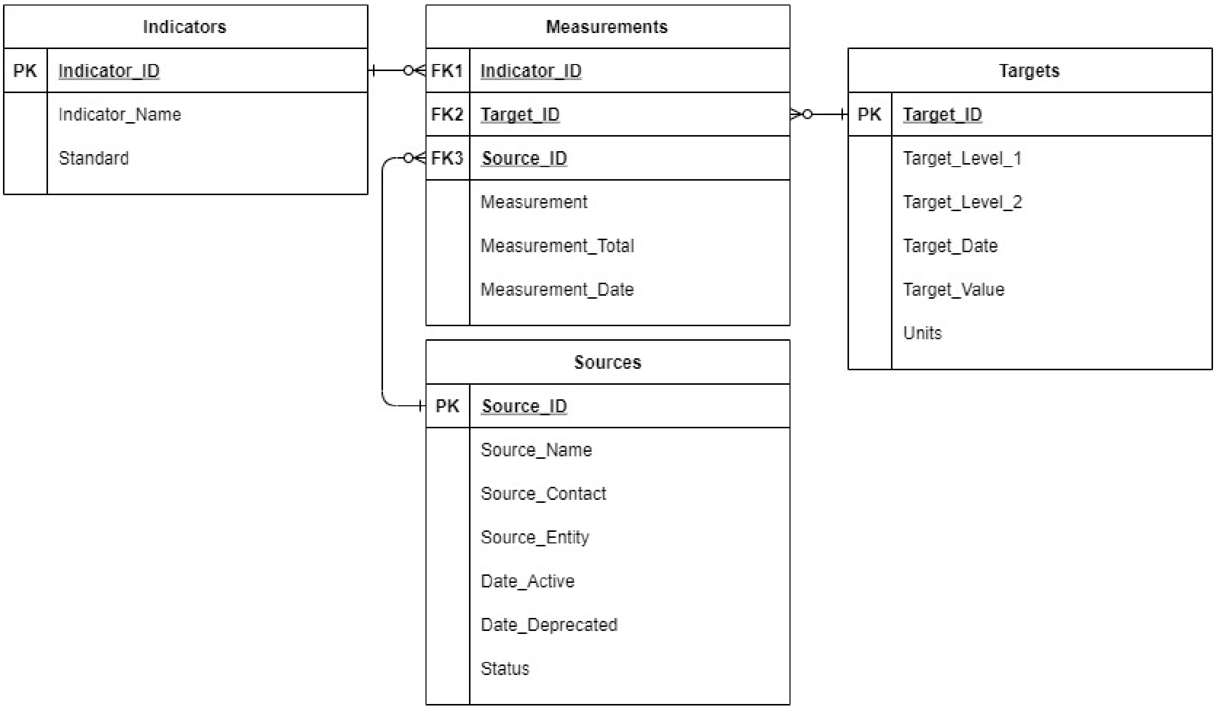

Figure 5 - Final data model for the project

The metadata for these tables can be found in Annex B. However, a brief explanation of the model is warranted. The table "Measurements" acts as the Fact Table in the schema, housing the data that allows for the calculation of the metrics and KPIs; it has 3 dimensions:

- **Indicator_ID:** identifies the indicator used for the measurement and connects to the "Indicators" dimension table.
- **Target_ID:** identifies the target the entry aims to measure and connects to the "Targets" dimension table.
- **Source_ID:** identifies the source of the measurement and connects to the "Sources" dimension table.

This Fact Table is, thus, connected to 3 Dimension Tables, one for each of the previously mentioned dimensions. Each provides extra information about each of the dimensions: the "Indicators" table, which tells us the name of each indicator, as well as which standard it comes from (when it applies; "Targets" lists the major targets the dashboard sets out to measure, as well as their target values and dates and the unit they are measured in; "Sources" identifies which sources are providing the data for which indicators and the names and contacts of the people responsible for the data from each source in case questions about certain measurements arise.

3.3.3. Extra calculations

Most KPIs were already calculated in the Excel files provided but others had to be calculated through other values before inserting into the dataset:

Table 14 - Extra calculations for the dataset

Indicator	Calculation
PM10 concentrations	Average of daily yearly average of PM10 concentrations measured in the measuring stations in the city of Lisbon provided by QualAr: Olivais, Entrecampos, Avenida da Liberdade, Restelo and Santa Cruz de Benfica
PM2.5 concentrations	Average of daily yearly average of PM10 concentrations measured in the measuring stations in the city of Lisbon provided by QualAr: Olivais, Entrecampos

Additionally, a “Custom Time Periods” table was created to facilitate the creation of time-intelligent filters (such as “Last 2 Years”, “Last Month,” etc.) and a “Last Date Table” with the last available dates for each indicator in case an indicator is measured more than once in the same month and only the last measurement is to be considered. Both of these tables are calculated within the BI tool and update automatically whenever the dashboard is updated.

4. RESULTS, CONCLUSIONS, AND DISCUSSION

The research question of this project was: "*what are the necessary metrics and indicators to develop a relevant framework to measure cities' environmental sustainability?*". In summation, there is no single relevant framework to measure a city's environmental sustainability. As was reiterated throughout the literature review, the topic of sustainability and its intersection with modern cities is plagued with questions, indecisions and doubts. Simply put, each city is a specific case and requires a specific and uniquely tailored approached.

With that information, this project applied the uncertainty of developing sustainability frameworks for cities to the specific case of Lisbon and, through conversations with city officials and by looking at current policies in place to develop a sustainable future, developed a tailored framework for the city and designed a prototypical dashboard to measure it.

The results can be found in the dashboard developed using Power BI published here: https://app.powerbi.com/groups/me/reports/53fc6932-be89-43b2-8619-900df4acb02d/ReportSection9963fb458700024138b0. Examples of it can be seen in Figures 6 and 7. In Figure 6, the "Target Overview" page is shown, with gauge charts to measure which targets have been achieved, and which haven't, as well as the latest measurements for each and their respective target values. Through this page, anyone can quickly determine the progress that has been made, as well as how much there is still left to do, understand which targets are far from completion and require more attention, and which are on track.

Figure 6 - Target Overview page – greyed out charts have dummy data

In Figure 7, an example of a page deep diving into a specific target is shown. Each of the five targets has a page like this, with a small description of the relevance of the target and the data sources, as well as their respective sub-targets. For each sub-target, the latest measurement and the target values are shown, as well as year-over-year (YoY) percentual changes and absolute volumes with, again, an indication of the target value. Finally, at the bottom, the target year for each sub-target is shown, accompanied by the predicted year it will be achieved if the latest YoY% change is kept (i.e.: for the "Reduce GHG -70% compared to 2002 levels" sub-target, the latest YoY% was -5%: if this pace is kept for the next years, the target will be reached in 2036). These "predicted years" turn red if higher than the target year and green if lower.

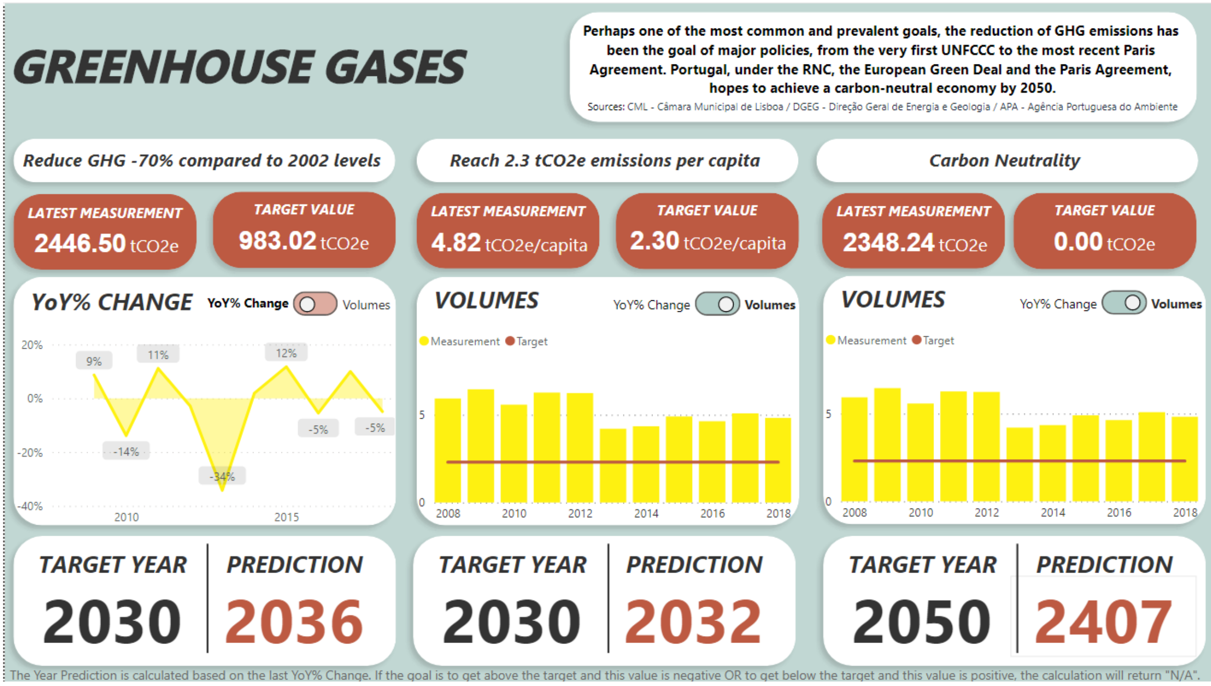

Figure 7 - Example of a page from the dashboard dedicated to one of the targets

As is apparent, the prototype dashboard is somewhat limited due to the lack of good quality data. The available data only contained values up to 2018 (3 years before the development of this project) and was only updated annually. Its most granular level was city-wide, and some wasn't even available and had to be made up in order to show some visuals.

Reality is far from the ideal setting often discussed in literature, especially in regard to topics such as sustainability, which, by lacking a definitive definition, can often be politicized. Adding that to the context of a city, whose governing body changes every 4 years, and the situation gets muddled and confusing. In truth, what this project ended up highlighting was the severe lack of investment in ICT infrastructure, essential for projects such as this and, as shown in chapter 2.2., for cities aiming towards a sustainable future. The dashboard produced is far from the design principles highlighted in chapter 2.5., as there's no real-time data and the data that is available is often scarce, inaccurate or outdated.

The city of Lisbon has defined targets and goals it hopes to achieve in the near future, often guided by policies at the national and European levels, but these targets become irrelevant when faced with the lack of data to measure them. How can the city hope to achieve 64% of commuters using alternative means if it doesn't have the infrastructure to know how many currently use them? How can the city officials make decisions for the near future, if the only data available has a 3-year lag? How can a dashboard whose purpose is to show data be constructed, if there's still no infrastructure to even *measure* the data?

5. LIMITATIONS AND RECOMMENDATIONS FOR FUTURE WORKS

As previously mentioned, the main limitation with this project lies in the data, or lack thereof. Ideally, the data would be collected and stored through automatic processes using sensors, cameras, machine learning and the like to measure and, if necessary, calculate the required data points, storing them in a properly structured DataMart which would then allow for the proper ETL processes. In summation, the city requires a well-developed, well-structured ICT network to collect, measure and store the necessary data.

Instead, the current situation leaves CML officials reliant on third parties to provide the data, which often comes with years of delay and without the necessary granularity levels, in Excel files that require manual handling to transform the data into a workable state. In some cases, data wasn't even available in the development of this project, which makes the drafting of their respective targets irrelevant (how can the city determine whether it's on the path towards achieving said target if it cannot know its current state?).

The city of Lisbon has not officially set out to become a smart, sustainable city. However, recent efforts towards sustainability (such as the "Climate Action Plan 2030") show that the city is on a tangential path and, if its goals align with those of smart cities, so must its methods. As chapter 2.2. highlighted, ICT are paramount for cities paving a more sustainable future and, unfortunately, Lisbon is currently far from having the necessary infrastructure to achieve these goals.

That said, this project aims to provide a prototype of what can be achieved if said infrastructure is present by showing what is possible with the current situation. In the future, if the city starts collecting more and better-quality data, dashboards such as the one presented here could be improved upon to provide even more insights and metrics, feeding into data-driven decisions that allow for more flexibility and faster policy changes to tackle the issue of sustainability.

Future works should, thus, wait for this data and ICT infrastructure to be implemented first, before implementing dashboards such as these. After all, a dashboard requires data to work and, if said data is not available, said dashboard is unusable. Additionally, as mentioned in chapter 2.5., dashboards should be updated frequently with the latest available data: dashboards updated yearly with data from 3 years past is, simply put, useless.

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