Are "Smart Cities" also "Climate Smart"? An Assessment of the EU Mission "Climate-Neutral and Smart Cities"

Monica Salvia*, Filomena Pietrapertosa
Institute of Methodologies for Environmental Analysis
National Research Council of Italy, C. da S.Loja, 85050 Tito Scalo (PZ), Italy
email: monica.salvia@imaa.cnr.it, filomena.pietrapertosa@imaa.cnr.it

Paola Clerici Maestosi
National Agency for New Technologies, Energy and Sustainable Economic Development
(ENEA TERIN-SEN), Lungotevere Thaon di Revel, 76, 00196 Roma, Italy
email: paola.clerici@enea.it

Sofia G. Simoes
The National Energy Laboratory of Portugal (LNEG), Unit on Resource Economics
Estrada da Portela, Bairro do Zambujal Ap 7586, 2720-999 Amadora, Portugal
email: sofia.simoes@lneg.pt

Diana Reckien
Faculty of Geo-Information Science and Earth Observation
University of Twente, PO Box 217, 7500 AE Enschede, Netherlands
email: d.reckien@utwente.nl

ABSTRACT

Urbanization and the concentration of energy-consuming economic activities make cities responsible for more than 70% of global greenhouse gas emissions. At the same time, cities are becoming increasingly vulnerable to climate change impacts. The EU Mission "Climate-Neutral and Smart Cities", recently launched a call for starting a pathway towards "100 climate-neutral and smart cities by 2030". The list of 336 candidate cities (86% from the EU-27 and 14% from associated or negotiating countries) was published in February 2022. The cities constitute a very large and diverse sample that was used to conduct this timely research to identify the main factors that can drive and support a smart and sustainable transition of urban areas. A critical analysis of the main achievements in five main driving factors (local climate planning, climate emergency declaration, participation in networks, international projects and competitions) provides insights on the main factors driving cities towards climate smart actions. Results show that 76% of the cities have a local climate, in 82% of cases developed under the Global Covenant of Mayors for Climate and Energy, which involves about 75% of the candidate cities. URBACT is the most popular funding programme, with 23% of cities involved in at least one funded project. The five selected driving factors seem to capture fairly well the level of "activism" of the sample cities in pursuing smart and climate-related projects and initiatives (15 of the 16 cities that have initiatives and activities in their background that fall into all five sets of the Venn diagram are among the 112 cities selected in this first phase of Mission 100 CNSC). 90% of the sample cities are part of at least one Transnational Municipal Network, which is the most important influencing factor, among the five analysed, for cities applying for this Mission. The original results of this timely study can be useful to decision-makers at all levels, but especially to other cities, to enhance knowledge on steps to be taken to accelerate the transition to carbon neutrality. Moreover, the rich dataset made available by this research represents an important knowledge base not only for future monitoring of the selected cities' progress during the implementation phases, but also for the desired replication effects in other urban areas.

KEYWORDS

Climate Neutrality, Local Climate Plans, Transnational Municipal Networks, Climate Emergency Declarations, City Awards.

INTRODUCTION

Over 72% of the EU population lives in urban areas - defined as cities, towns and suburbs, covering 17% of the land area - and nearly a quarter of the EU population is still at risk of poverty and/or marginalisation [1]. The urban population has continued to grow in the last 50 years at the expense of the countryside that has gradually been depopulated [2].

Urban areas are part of the nexus for the transformations to achieve EU targets of the European Green Deal and to fulfil commitments related to the UN's Agenda 2030 Sustainable Development Goals (SDGs), UN-Habitat's New Urban Agenda, the New European Urban Agenda, the Paris Agreement and to support the New European Bauhaus movement [3]. The latest IPCC's report on Mitigation of Climate Change devotes Chapter 8 to "Urban systems and other settlements" [4] where it is highlighted that although the global share of emissions that can be attributed to urban areas is increasing, these areas can create opportunities to increase resource efficiency and significantly reduce greenhouse gas emissions (GHG) through systematic transition pathways of infrastructure and urban form towards net zero emissions.

Many new categories of cities and their combinations have entered the political discourse, as highlighted by De Jong et al. [5]. These include the 'sustainable city', the 'low-carbon city', the 'smart city' and, recognising the role ICT can play in realising the vision of a sustainable city also the 'intelligent sustainable city' [6]. The concept of 'smart city' has been quite fashionable in the political arena in recent years [7] and there are many definitions for it. One of the most widespread definition is based on the identification of six 'axis' (dimensions): smart economy; smart mobility; smart environment; smart people; smart living; and, smart governance [8]. Complementarily, there is a growing need for urban sustainability monitoring [9] and benchmarking for cities [10]. There have also been several attempts to measure the performance of sustainable [11], green [12], and smart cities [13] based on an indicator system. The use of a set of indicators is also at the basis of EU initiatives for urban sustainability, such as the Green City Accord (GCA) [14], and city awards, such as the European Green Capital Award (ECGA) [15].

In accordance with the ongoing scientific debate on cities and urban areas as drivers of transformation for the achievement of the SDGs, the EC Horizon Europe research and innovation framework program 2021-2027 launched a Mission (in the following referred as "100 CNSC Mission") aimed at delivering "100 climate neutral cities in Europe by 2030". The Mission also aims to ensure that these cities act "as experimentation and innovation hubs to put all European cities in a position to become climate-neutral by 2050" [16]. The 100 CNSC Mission is currently in an "early delivery" phase (2020-2022) in which cities set the foundations before moving to the "main phase" (2022-2030) during which "the main body of cities will implement their strategy towards transformation and climate neutrality" [16]. Following this first step, selected municipalities will compile and sign a Climate City Contract (CCC), which formulates "goals and targets, and a strategy and action plan for transformation, with the involvement of stakeholders and their responsibilities [16]. The Mission considers a "Smart city as an enabler of climate-neutral city" pointing out the key role played by smart grids in an urban energy system and the need to systematically integrate smart city projects in the context of cities' decarbonization [16]. Following the Call for Expression of Interest (EoI), deadline on 31st January 2022, the list of eligible cities applying for the 100 CNSC Mission was published on 24 February 2022 and updated on 4 March 2022. Two months later, on 28 April 2022, the list of 100 EU cities plus 12 cities from countries associated with "Horizon Europe", the EU's

research and innovation programme (2021-2027), was published. These cities were selected by expert reviewers according to the evaluation criteria included in the Info Kit for Cities [17], which include the cities' level of ambition, preparedness, existing and planned commitment to climate neutrality, commitment to involve citizens and stakeholders, as well as inclusiveness, diversity and geographical balance. Within this context, the purpose of this paper is to draw a cognitive picture of the cities taking part in the EC challenge to become climate neutral, in order to identify the determining factors that drive cities to "get involved" and set ambitious medium-to long-term goals.

In agreement with Shabb et al. [18], who see the 100 CNSC Mission as strongly rooted in the commitment that many cities have demonstrated for decades through climate action, this paper argues that this commitment can be operationally expressed through five groups of 'driving factors'.

First, Local Climate Planning, which is mainly carried out by policy-makers and major stakeholders and is only recently adopting participatory models. Its objective is to address climate change mitigation, by reducing the release of greenhouse gases into the atmosphere, and/or adaptation, by reducing the vulnerability of natural and human systems to the effects of these changes [19]. Reckien et al. [20] distinguish between "dedicated" Local Climate Plans (LCPs) and 'vertically' or 'horizontally' mainstreamed LCPs, depending on whether climate objectives are addressed within 'sectoral' or 'cross-sectoral' plans.

Second, Climate Emergency Declarations (CEDs), which since 2016, when Melbourne's Darebin Council became the first local government in the world to declare a climate emergency, are reaffirming the climate leadership of local governments [21]. As pointed out by Rode [22], we are witnessing an "acceleration in climate policy debates, consciousness and activism that had long seemed unimaginable", while local governments are calling for "stronger climate planning, and the development of more in-house capacity to respond" [23].

Third, Transnational Municipal Networks (TMNs). Climate actions in TMNs are "growing strategies for urban climate governance" [24] and the number of cities participating in TMNs has increased significantly in recent decades [25]. As Schroeder et al. [26] point out, these networks act as drivers of local action by facilitating cities through international cooperation.

Fourth, International competitions and City Awards. Cities participating in an international competition are driven by a desire to get involved and to show that they are already on the road to green transition and innovation to create a healthier and smarter environment for their citizens. The awards enable the presentation of design principles and models for other cities and encourage the exchange of good practice [27]. Winning the award can, thus, bring several advantages, especially in terms of prestige, good reputation and tourist attraction and can trigger, as in the case of the European Network of Green Capitals, new collaborations between the cities involved.

Fifth, participation in International Projects on energy and climate related issues. The EU and the Commission offer several funding programmes to support cities in promoting sustainable urban development and active cooperation [28]. Among them, the European Commission's H2020 Framework has provided different funding opportunities on urban issues [29], particularly aimed at Lighthouse cities, helping to define the standards that smart cities should achieve [30]. Participation in international projects is almost always decided and carried out mainly by municipal staff and any external consultants.

The entire panorama of activities and efforts deployed by cities makes clear the increasingly important role that 'urban experimentation' can play in translating the vision of carbon neutrality into concrete strategies and action plans through the implementation of Climate City Contracts (CCCs), as also emphasised by Shabb et al. [18]. Among the various forms of successful urban experimentation, Urban living labs (ULLs) can enable municipalities, citizens and stakeholders to develop and test social, technical and organisational innovations through co-creation and

stakeholder involvement to address the challenges of climate change and urban sustainability. [31]. This applies, in particular, to the Mission on 100 climate-neutral and smart cities, where urban experimentation can allow new innovations, technologies and policies to be tested with citizens and stakeholders under real conditions that can induce radical social and technical transformations. [32].

Specifically, two main research questions are addressed by this research:

i) *How "active" are the 100 Carbon Neutral and Smart Mission cities in pursuing smart and climate related projects and initiatives?*

ii) *What are the most important influencing factors, among the five analysed, that prompted cities to apply for this Mission?*

This paper is structured in five main sections. After this introduction, a description of the sample analysed, and the methods adopted is provided. The main results obtained are presented and critically discussed, to then conclude with key messages and further research needs.

MATERIALS AND METHODS

This research work was developed through the following interconnected and sometimes temporally overlapping phases:

(i) *Preparation:* it dealt with the definition of the research questions, the identification of the sample of cities to be analysed, the initial identification of the research methods to be used, the selection of the main driving factors and the appropriate indicators to help answer the research questions.

(ii) *Data collection and preliminary analysis:* key information and data for the selected cities were, first, collected and organised according to the selected driving factors and indicators in a spreadsheet dataset. A preliminary analysis of this data was then carried out to check its completeness and availability for the selected sample. The research questions and methods were then refined according to the actual availability of the data.

(iii) *Results and discussion:* Using the ad hoc research methods defined for this study, the dataset was analysed, first for each driver and then in aggregate. The comprehensive analysis was conducted using two main tools: a 5-dimensional Venn diagram and a purpose-built scoring system along these 5 factors. The cities were also compared using a benchmarking study based on the SDEWEX Index Atlas. A critical comparison of the results obtained allowed the authors to derive lessons learnt, and future perspectives.

The research took place in the period February - May 2022.

The sample of cities analysed, the main data collected, and the analytical framework based on the comparison of cities across the selected driving factors are described below.

City sample

The analysed sample contains all cities that gave their consent to be named as applicants for the Climate-Neutral and Smart Cities Mission (published on 24 February 2022 and updated on 4 March 2022). The participation of European cities was limited to those with at least 50,000 inhabitants, with the exception of countries with few larger cities (Croatia, Cyprus, Estonia, Ireland, Latvia, Lithuania, Luxembourg, Malta, Slovenia and Slovakia) for which this threshold was lowered to 10,000 inhabitants.

This resulted in a sample consisting of **289 cities in the EU 27,** and **47 cities from associated countries** and countries in the process of negotiating association (Albania, Bosnia and Herzegovina, Iceland, Israel, Montenegro, Norway, Turkey and United Kingdom), for a **total of 336 cities**. Figure 1 shows how the 100 CNSC Mission candidate cities are distributed among countries: Italy is the most represented country with 36 applicant cities (11% of the overall

sample), followed by Germany (30 cities, 9%), Spain (25, 7%), Turkey (24, 7%) and France (23, 7%). Figure 1 also shows the distribution of these cities by population size, which makes clear the great interest from smaller cities. In particular, 132 cities (39% of the total sample) have a population lower than 100,000 inhabitants (size S), followed by 100 cities (30%) between 100,000 and 250,000 inhabitants (size M); 43 of them (13%) have between 250,000 and 500,000 inhabitants (size L); 39 (12%) between 500,000 and 1,000,000 inhabitants (XL) and only 2 cities have a population between 1,000,000 and 5,000,000 inhabitants (XXL).
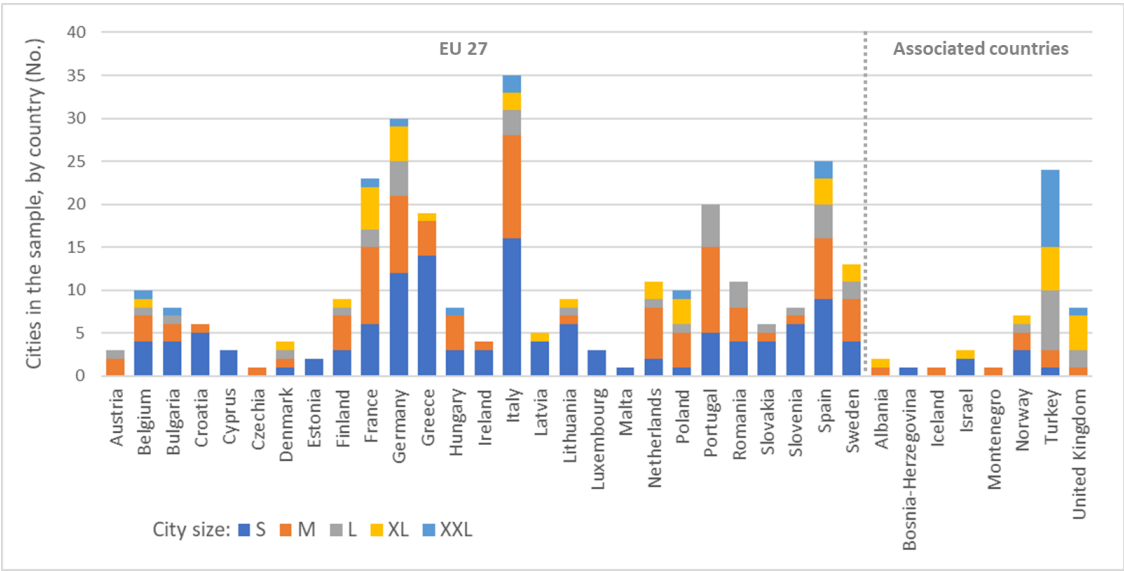

Figure 1. Number of EU 27 and Associated Countries cities in the sample (100 CNSC Mission candidate cities), by country and by city size

Data collection and analysis in a 5-dimensional approach

The research method was aimed at characterising the cities in the sample with reference to their level of engagement in previous activities and initiatives related to five main driving factors: 1) development of Local Climate Plans (LCPs), 2) participation in Transnational Municipal Networks (TMNs) and initiatives, 3) Declarations of Climate Emergency (CEDs), 4) involvement in international research and demonstration projects, and 5) participation in International competitions and city awards. For each of these, publicly available data were collected and analysed, as described below. To ensure consistency of data, the work was primarily based on latest available data from pan-European databases retrieved from the web (e.g., Eurostat, websites of transnational climate alliances and international cooperation programmes, CORDIS, etc.).

Local Climate Plans (LCPs): Previous studies (e.g., [20,33,34]) have shown that Sustainable Energy (and Climate) Action Plans - SE(C)APs developed in the framework of the Covenant of Mayors (CoM) are currently one of the most widespread types of LCP in European cities. Therefore, the main source for data for LCPs was the dataset of GHG inventories for 6,200 cities from EU, EFTA countries and UK, Western Balkans, Eastern and Southern EU neighbourhood countries, signatories of the Global Covenant of Mayors for Climate and Energy (GCoM) initiative as of end of 2019, made available by Kona et al. [35]. Each sample city was then searched in this dataset and the following information was retrieved: Year of adhesion, reference years in EDGAR, Mitigation reduction target 2020 [%], Mitigation reduction target 2030 [%], reduction_type_id (including also the target year). The subset of the extracted dataset was further verified on the CoM website [36] with a twofold purpose: to update existing information on the city sample, and remove those cities that have not yet adopted a

SEAP/SECAP, but only a Baseline Emission Inventory. Furthermore, for the EU27 and UK cities included in the Urban Audit database without a SEAP/SECAP, basic information on the existence of a local climate mitigation plan and, if so, the name and website of the plan, were derived from the datasets [37,38] developed from two previous studies. The first, by Reckien et al. [39], collected, analysed and classified local climate mitigation and adaptation plans across 885 urban areas of the EU-28. The second, by Salvia et al. [40], analysed the mitigation targets of 327 European cities, as declared in their local climate plans. Unfortunately, there are no similar studies for the associated countries considered in the sample that would allow us to derive such information from LCPs other than SEAP/SECAP. This approximation concerns 22 cities, or 6.5% of the sample.

Transnational Municipal Networks (TMNs) and initiatives: In this study we researched and analysed the main TMNs on climate change active in Europe with an eye for particular attention on those supporting cities in developing LCPs. For each of the 12 energy and climate-related networks and initiatives listed in Table 1, the participation of each of the candidate cities in the 100 CNSC mission was verified and recorded in our dataset in binary form (0/1).

Table 1. Overview of the transnational municipal networks and the initiatives and the main web sources used in this study.

Name (acronym)	Main aim	Web source
100 Intelligent Cities Challenge	EC initiative with ~136 cities to achieve intelligent, socially responsible and sustainable growth via advanced technologies on citizen participation and digitisation, green economy, etc.	https://www.intelligentcitieschallenge.eu/cities
C40 Cities (C40)	Global network of mayors of circa 100 world-leading cities collaborating to deliver the urgent climate action.	https://www.c40.org/cities/
Carbon Neutral Cities Alliance (CNCA)	Collaboration of leading global cities working to achieve carbon neutrality in the next 10-20 years	https://carbonneutralcities.org/cities/
Cities Race To Zero Campaign	Global campaign to rally leadership and support from cities for a resilient and zero carbon recovery from the pandemic. It is part of the Race To Zero global campaign mobilising a coalition of 1,049 cities, 67 regions, etc. committed to achieving net zero carbon emissions by 2050 at the latest.	https://racetozero.unfccc.int/join-the-race/whos-in/
Climate Alliance (CA)	A group of 2,000 municipalities, districts, regional governments, NGOs and other organisations across 25 EU countries working to combat climate change. Each city member commit to continually cut GHG emissions, aiming for a 95% reduction by 2050	https://www.climatealliance.org/fileadmin/Inhalte/2_Municipalities/2022-01-Member_List_International.pdf
Energy cities	Community of thousands of cities in 30 EU countries committed to reach climate neutrality by 2050 and to align their local strategic development with the Paris Agreement.	https://energy-cities.eu/members/
Eurocities	The leading network of major European cities, working together on different focus areas including Climate change and energy transition Smart cities & digital transformation, Clean and active mobility	https://eurocities.eu/cities/
Covenant of Mayors for Climate and Energy (CoM)	Global initiative originating in Europe in which circa 11 000 signatory mayors commit to achieve climate neutrality by 2050, undergoing a structured LCP process including mid-term targets	https://www.covenantofmayors.eu/plans-and-actions/action-plans.html
Local Governments for Sustainability (ICLEI)	Global network of more than 2500 local and regional governments across 125+ countries. Actions go beyond climate and cover sustainability policy and "local action for low emission, nature-based, equitable, resilient and circular development"	https://iclei-europe.org/our-members/

POLIS transport innovation	Network of European cities and regions collaborating to develop innovative technologies and policies for local transport.	https://www.polisnetwork.eu/who-we-are/members/
Resilient Cities Network	Global urban resilience network bringing together knowledge, practice, partnerships, and funding to empower their members to "build safe and equitable cities for all"	https://resilientcitiesnetwork.org/downloadable_resources/Press_Room/Member_Cities.pdf
Aalborg Charter	Urban sustainability initiative approved by the participants at the first European Conference on Sustainable Cities & Towns in Aalborg, Denmark	https://sustainablecities.eu/fileadmin/repository/Aalborg_Charter/Aalborg_Charter_signatories.pdf

Climate Emergency Declarations (CEDs): More and more cities around the world are declaring a climate emergency, the main purpose of which is to raise public awareness and can also help trigger local planning processes [41]. Several initiatives are emerging to encourage and support municipalities that adopt a CED, as the Council Action in the Climate Emergency (CACE) [42]. Some climate networks, such as the Climate Alliance, also provide city members with a template for drafting their own CE resolution and declaration.

Information on the existence of a CED for the sample cities was taken from the Climate Emergency Declaration & Mobilisation in Action (CEDAMIA) website [43], which contains the most comprehensive and up-to-date list of national and local jurisdictions, that have declared a CE. Also in this case, the CEDs availability for each sample city was verified and recorded in our dataset in binary form (0/1).

International projects: A major part of the work consisted of searching the online archives and datasets of six major European city funding programmes that count cities as beneficiaries. The search was carried out for each funding programme by ad-hoc topics and/or keywords concerning climate, environment, energy and smart cities issues, as specified in Table 2. The partnerships of the set of projects obtained was then analysed, one by one, and compared with the list of cities in the sample. The result of this work is a spreadsheet in our dataset in which the title, the topic and website of the projects involving the sample cities are reported by funding programme.

Table 2. Overview of international projects, search criteria and main web sources used in this study.

Name (acronym)	Main aim	Search criteria	Web source
H2020	The Smart City and Communities Lighthouse projects have resulted in important innovations in the domains of mobility, smart buildings, smart infrastructure, citizen engagement and data platforms, as well as city governance.	Projects were searched on the EC CORDIS database based on the topics: H2020 lighthouse projects, energy, climate change, society, transport and mobility.	https://cordis.europa.eu/search/en
Urban Innovative Actions (UIA)	It is an Initiative of the European Union that provides urban areas throughout Europe with resources to test new and unproven solutions to address urban challenges.	Focusing on these topics: Climate adaptation, Air quality, Circular economy, Culture and cultural heritage, Digital transition, Energy transition, Housing, Sustainable use of land and nature-based solutions, and Urban mobility.	https://uia-initiative.eu/en/uia-cities

Interreg Europe	This cooperation programme, co-financed by the European Union, aims to help reduce disparities in the levels of development, growth and quality of life in and between European regions.	Using the online search tool, 228 approved projects in the "Green" and "Smart" topics were found. The partnership of each project was analysed and compared with the list of cities in the sample.	https://www.interregeurope.eu/search-approved-projects
Interreg MED	The programme aims to promote sustainable growth in the northern Mediterranean regions.	The online list of beneficiaries of projects financed in the 2014-2020 period was compared with the sample of cities in the study. Projects relate to the programme axes: 1. Smart and sustainable growth, 2. Low-carbon strategies and energy efficiency, 3. Natural and cultural resources and 4. Governance.	https://interreg-med.eu/projects-results/our-projects/
LIFE	The LIFE Programme is entirely dedicated to environmental, climate and energy objectives. It aims to contribute to the transition to a clean, circular, energy-efficient, climate-neutral and climate-change resilient economy.	Projects funded between 1992 and 2021 were searched on the EC LIFE Public database, using the keyword "climate" among their "Titles", "Themes" and/or "Keywords" and identifying those projects that include the sample cities among the "Beneficiaries".	https://webgate.ec.europa.eu/life/publicWebsite/search
URBACT	It aims to foster sustainable integrated urban development in cities across Europe. It helps cities to work together and develop integrated solutions to common urban challenges.	The list of 681 projects funded by the URBACT III programme (2014-2020) was filtered through four four thematic objectives (1. Research, technological development and innovation; 2. Access to and use of ICT; 4. Low carbon economy in all sectors; 6. Environmental protection and resource efficiency) and the sample cities identified.	https://urbact.eu/files/list-urbact-iii-beneficiaries

International competitions and city awards: They represent a valuable experience for a city that can bring several benefits in terms of increased international (and national) visibility and attention, greater attractiveness for future projects and investments, and renewed public interest and sense of belonging among citizens. Winning cities can then serve as role models to inspire other cities and promote best practices to all other cities. Three major awards were looked at dealing with sustainability and innovation (Table 3).

Table 3. Overview of the city awards and the main web sources used in this study.

Name (and acronym)	Main aim and key information	Web source
European Green Capital Award (ECGA)	Each year it rewards cities that stand out for their environmentally friendly urban lifestyle. Starting in 2010, one European city (EU 27) is selected each year as the European Green Capital of the year.	https://ec.europa.eu/environment/europeangreencapital/
European Capital of Innovation Award (iCapital)	A prize to the most innovative cities ecosystems recognising the experimentation of governance practices by city administrators	https://eic.ec.europa.eu/eic-funding-opportunities/eic-prizes/european-capital-innovation-awards_en

European Capital of Smart Tourism	An award for cities that successfully respond to the new challenges and demands of the tourism sector, including the evolution of digital tools, products and services and sustainable development.	https://smart-tourism-capital.ec.europa.eu/cities/competition-winners-2020_en

As concerns the EGCA, the winning and finalist cities for the 14-year period from 2010 to 2023 were collected and compared with the list of sample cities. In the case of iCapital, the study focused on the winner (ranked 1st) and runners-up cities (ranked 2nd, 3rd, etc.) awarded from 2016 to 2020 (5 years). Finally, the award-winning cities, the winners of the four categories and the finalists selected for the European Capital of Smart Tourism award (2019, 2020 and 2022) were analysed. For cities that competed several times for the same award, only the best finish was considered (e.g., for Finland's Lahti, which was a finalist of the ECGA in 2019 and winner in 2021, only the latter result was considered for scoring purposes).

Analytical framework for comparing cities across the 5 driving factors

The set of data collected and organised in the previous phases of the research formed an important knowledge base on which to implement an analytical approach based on the three tools described below.

Venn diagram. Venn diagrams are "representations of the relations between particular classes of concepts" [44] and are mainly used to explore the similarities and differences between different lists of elements, showing the intersections between them. They can be applied in a wide variety of contexts, for instance for providing insights into regression analysis [45] or even as an intuitive resource to teach students about climate action [46].

In this study a 5-dimensional Venn diagram was built from a large spreadsheet table showing for each city the data collected for each of the five dimensions considered. The cities that demonstrated similar behaviour in terms of belonging to one or more of the five dimensions considered were then grouped together, the number of cities that fell within each subset of intersections between the different sets was counted, and then these numbers were reported in a colourful Venn diagram to numerically characterise the intersections in our sample case.

Scoring system: Several studies have addressed the need to assess the level of integration [47] and ambition of urban mitigation and adaptation plans in different urban areas in the UK [48] and Italy [49], through the definition of appropriate scoring systems.

To assess and compare the level of activism of the cities analysed in this study in which local climate planning is only one of the driving factors considered, a simple scoring system was developed based on the use of the main data collected for the sample cities. Following the approach used by Otto et al. [50] to analyse the adaptive readiness of 104 German cities, each driving factor was weighted by one fifth of the total score obtainable, i.e., 20 points each for a maximum of 100 points. Only in the case of the Awards driving factor, a maximum possible score of 60 points is considered for the three awards, which is then normalised to 20 to ensure parity of weighting with the other factors. The scoring system adopted is illustrated in Figure 2.
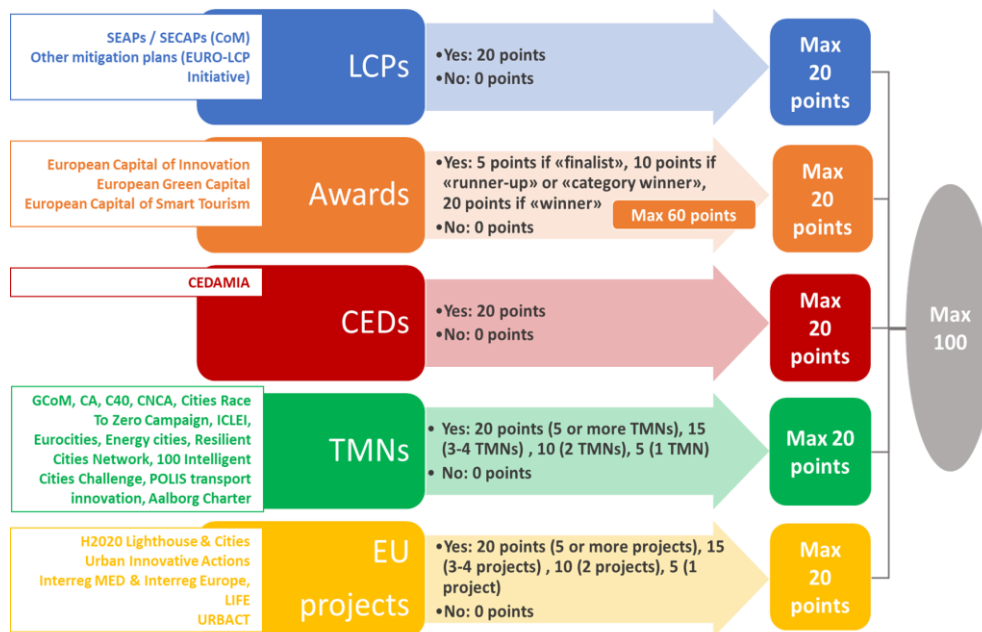
Figure 2. Scoring system adopted for the 5 considered driving factors

Benchmarking study. Benchmarking studies are usually based on common indicators and indices which can provide comparative assessments of city performance and facilitate communication among stakeholders. Among the several indexes currently available [10], the SDEWES index [51] is used to benchmark the sustainability of urban energy, water and environment systems. Based on that, the SDEWES Index Interactive Table [52] provides normalized scores and final ranking for 120 cities around the world based on 7 dimensions and 35 main indicators. The 100 CNSC Mission cities for which the SDEWES Index was available were then also compared using this index for city benchmarking.

RESULTS

This section begins by presenting the key findings for each of the five considered driving factors. These are then overlaid across the driving factors to provide a comprehensive knowledge base on the efforts deployed by the candidate cities for the 100 CNSC Mission and lay the groundwork for critical comparison and discussion.

Key findings by driving factor

Regarding **LCPs,** this analysis showed that 211 cities (62.8%) have a SEAP and/or SECAP and 46 (13.7%) other cities in the EU-27 and UK have another type of LCP (Figure 3).
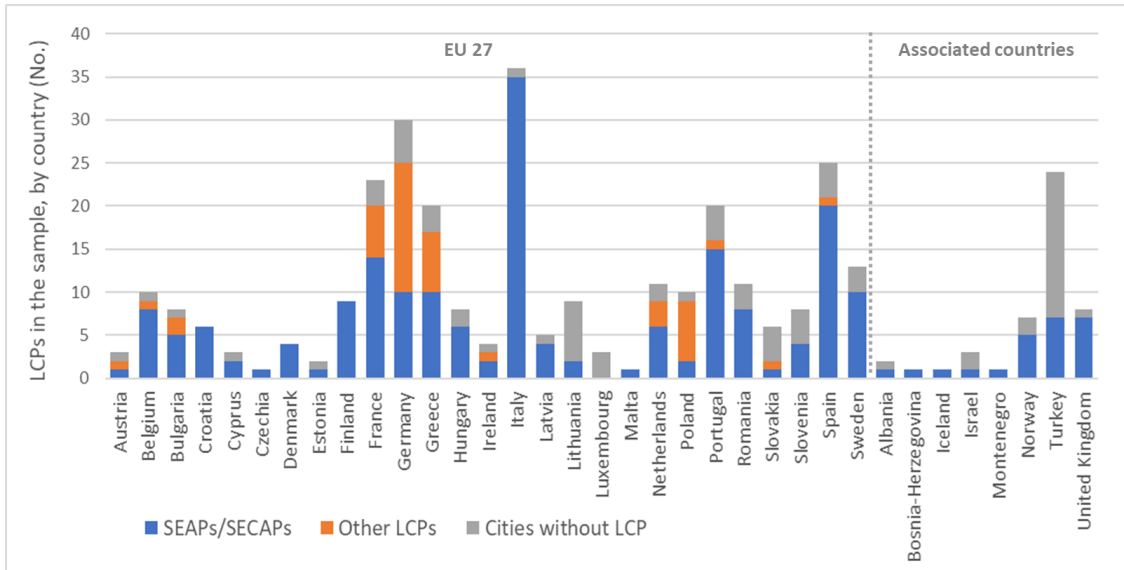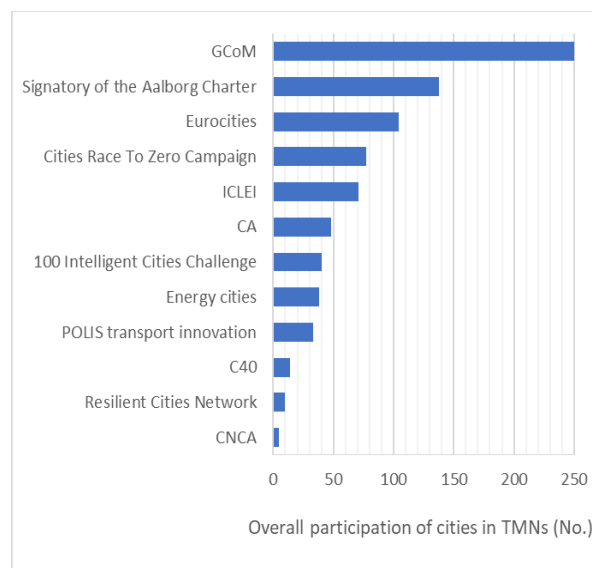
Figure 3. Number of cities in the sample with and without an LCP (SEAP/SECAP and other types), by country and city size.

Regarding the previous involvement of cities in **TMNs** and other international energy and climate initiatives, Figure 4.a shows that the GCoM confirms its predominant role in climate networking (as found, for instance, in [33]) involving 250 cities (74.4%). It is followed by the urban sustainability initiative Aalborg Charter, which involves 138 cities (41.1%) and Eurocities (104 cities or 31.0%). Interestingly, 40 cities (11.9%) participated in the 100 Intelligent Cities Challenge, while only 5 (1.5 %) of the sample cities are members of CNCA (22 cities). This overall trend also returns with reference to the participation of sample cities by country: Figure 4.b shows the importance of CA in Germany (28 cities in this country are members of this alliance out of a total of 48), the Cities Race To Zero campaign mainly in France (12 cities out of a total of 77) followed by Germany, Sweden and the United Kingdom (7 cities each), Eurocities (104 in total) with the main contributors coming from France (11), Slovenia (10) and Germany and Italy (8 each), Energy cities for France (15 out of 38), while the signatories of the Aalborg Charter are almost all Italian and Spanish (21 each out of 138) followed by 11 Portuguese and 10 German cities.
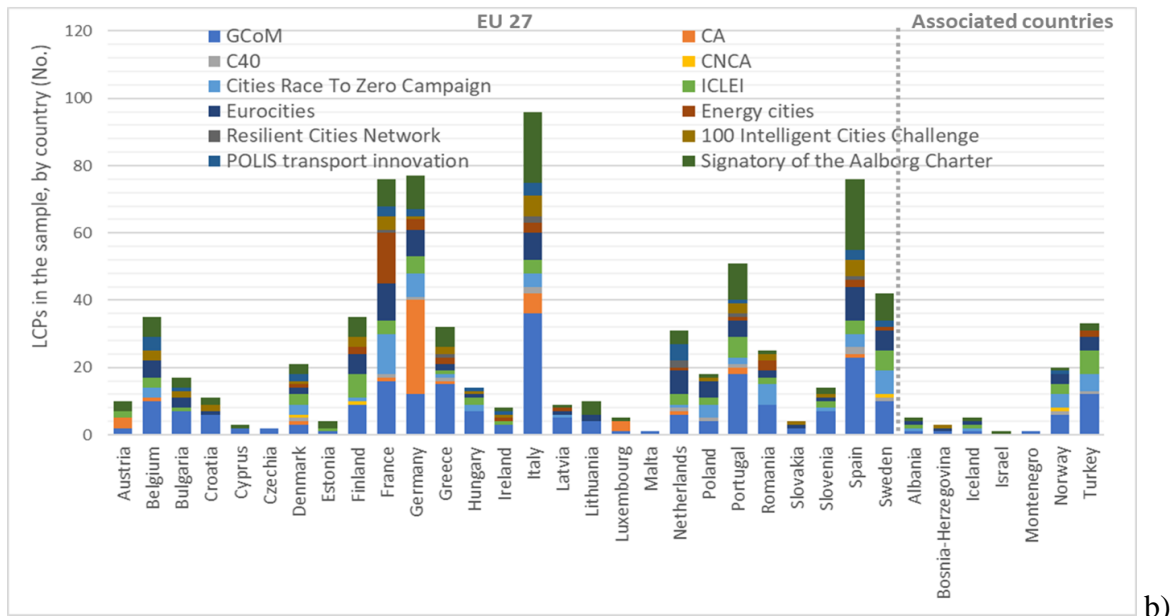

a)

11

Figure 4. Total number of cities in the sample involved in a TMN (a) and per country (b).

Looking at the **CEDs,** the data search pointed out that only 58 cities (20,1% of the sample) have declared climate emergency. CEDs are found only in 13 countries out of 35, specifically the United Kingdom and 12 European countries (Figure 5.a). Italy and Germany are the countries with the largest number of CED cities (13 and 12 respectively), representing 36% and 40% of the total number of cities analysed (Figure 5.b). This range goes from 11% in Finland and Lithuania to 100% in UK cities, highlighting the widespread presence of CEDs in this country as reported in the CEDAMIA dataset [43].
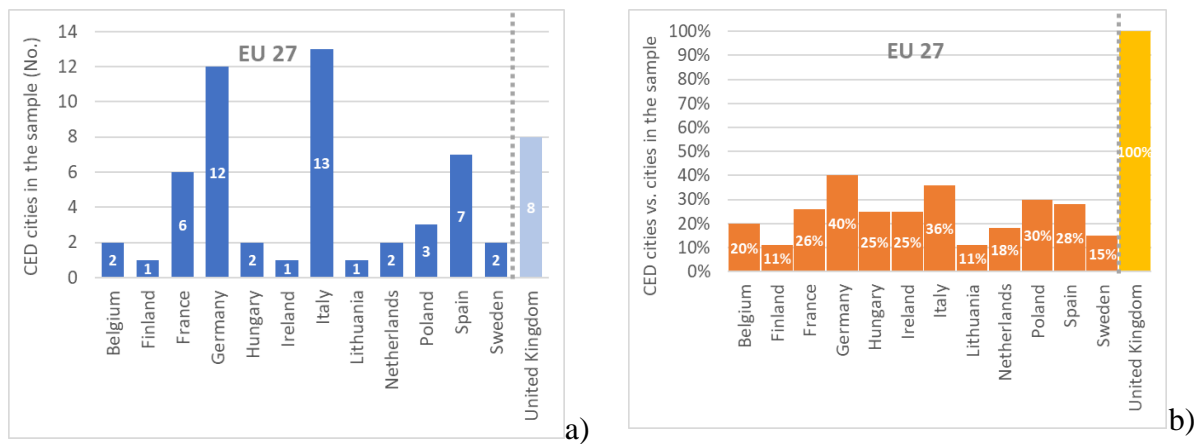

Figure 5. Cities in the sample that have declared a climate emergency: total number (a) and percentage values compared to sample cities (b).

Turning to the analysis of the sample cities' involvement in **international projects**, Figure 6.a summarises the distribution of city projects by funding programme. It can be seen that, as far as sample cities are concerned, URBACT is the most popular funding programme, followed by Interreg Europe, LIFE, H2020 Lighthouse & Cities, UIA and Interreg MED. The overall participation of the sample cities in the six funding programmes considered in this study is summarised in Figure 6.b. It highlights the great interest and capacity of Italian cities to participate in international projects (78 projects or 20.4% of the total number), followed by

12

Spain (34 projects, 8.9%) and Portugal (25 projects, 6.5%). Therefore, it is interesting to better understand these results in the same order of importance found for funding programmes.

Within the *URBACT* programme, 121 projects involving 77 candidate cities to the 100 CNSC Mission were implemented. The best performing cities in this funding programme are: Parma (IT), Wrocław (PL), Alba Iulia (RO), and Manchester (UK) with 4 projects each, followed by Tartu (EE), Paris (FR), Trikala (EL), Gdansk (PL), Braga (PT), Porto (PT), and Suceava (RO) with 3 projects each. Looking at the distribution of projects per country, it can be seen that again Italy has the most projects (18, or 14.9% of the 121), followed by Portugal (13, or 10.7%) and Romania (10, or 8.3%).

Of the 228 projects approved under the 'Green' and 'Smart' themes of the *Interreg Europe* programme, 92 involved 55 CNSC candidate cities, of which 94.6 per cent were from the EU 27. Focusing on the sub-themes most closely related to the 100 CNSC Mission, Zero-carbon urban mobility is the most frequent sub-theme with 19 projects (19.4%), followed by Circular economy with 12 projects (11.8%), Renewable energy and Energy efficiency counted a total of 11 projects, Digitisation 7 projects (7.5%), while Climate change involved only 3 projects (3.2%). Looking at the leading cities in this involvement, Tartu (EE) and Bologna (IT) are the most active cities within Interreg Europe, being involved in 5 projects each, followed by Reggio Emilia (IT) with 4, Gabrovo (BG), Florence (IT), Genoa (IT), Rome (IT), Turin (IT), Timisoara (RO), Gävle (SE) and Birmingham (UK) with 3.

Turning to the EC *LIFE* programme, 46 European sample cities participated in 60 projects. Bologna (IT) is undoubtedly the most active city with 5 projects, followed by Malmö (SE) with 3, while only 8 cities, Helsinki (FI), Turku (FI), Florence (IT), Milan (IT), Reggio Emilia (IT), Turin (IT), Rotterdam (NL) and Seville (ES) participated in 2 projects. This is only partly reflected in the country distribution: Italy is represented with 18 projects (30.0%) involving 10 cities, followed by Finland with 9 projects (15.0%) involving 6 cities and Spain with 8 projects (13.3%) involving 7 cities.

55 projects involving the 100 CNSC mission cities were funded as *H2020 Smart City and Communities Lighthouse* projects. This analysis, which updates the results discussed in Clerici et al. [29], shows that with the exception of Rotterdam (NL), financed under 3 projects, and Bratislava (SK) and Gothenburg (SE), financed under 2 projects, 48 cities in the sample were involved in a single project financed under this H2020 programme theme. The countries with the highest number of funded cities (6) are in Spain and 5 in the Netherlands and Italy. Regarding the *Urban Innovation Actions (UIA)*, 27 European cities and 1 UK city were involved in 33 projects, with Ghent (BE) participating in 3 actions and Brussels (BE), Paris (FR) and Budapest (HU) in 2 actions each. Almost a third of the UIA projects involving the sample cities are divided into two main topics: Air quality and Circular economy (5 projects each), 4 projects on Climate adaptation (plus 1 on Sustainable use of land and nature-based solutions), 4 on Housing and Urban mobility and 3 on Digital transition and Energy transition.

16 cities in the Mediterranean area were involved in 21 *Interreg MED* projects, with Bologna (IT) participating in 2 projects and Rethymno (EL), Rhodes (EL) and Rome (IT) participating in 2 projects each. Half of these project (11) were funded on Low-carbon strategies and energy efficiency (Axis 2), 5 on Natural and cultural resources (Axis 3), 4 on Smart and sustainable growth and only 1 on Governance (Axis 4).
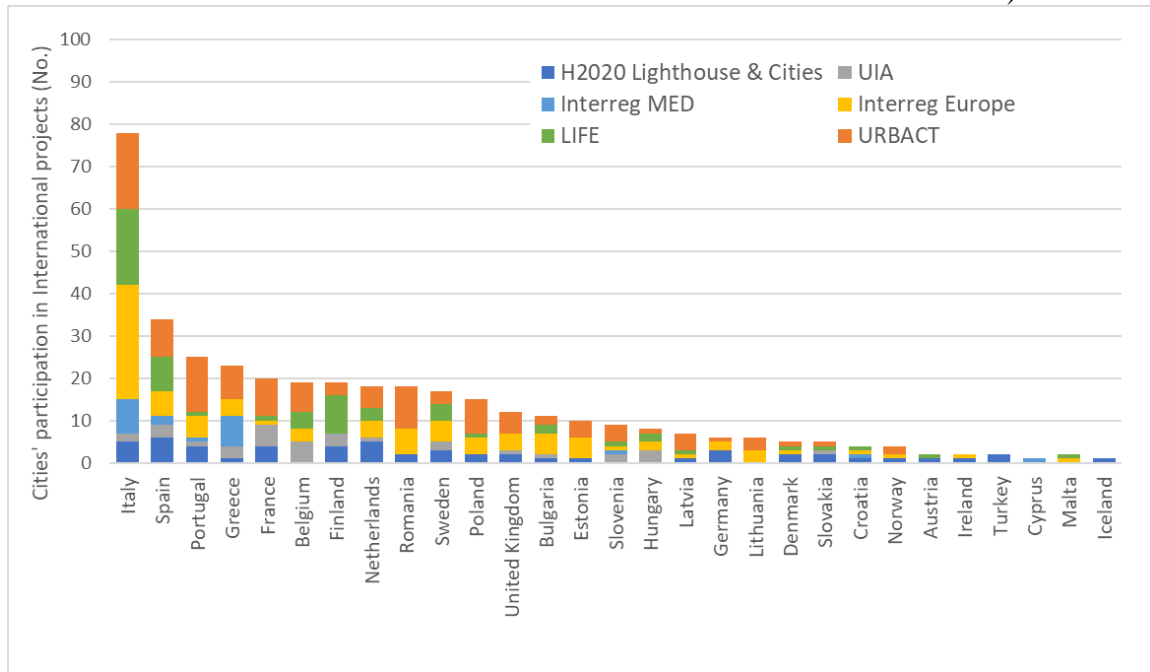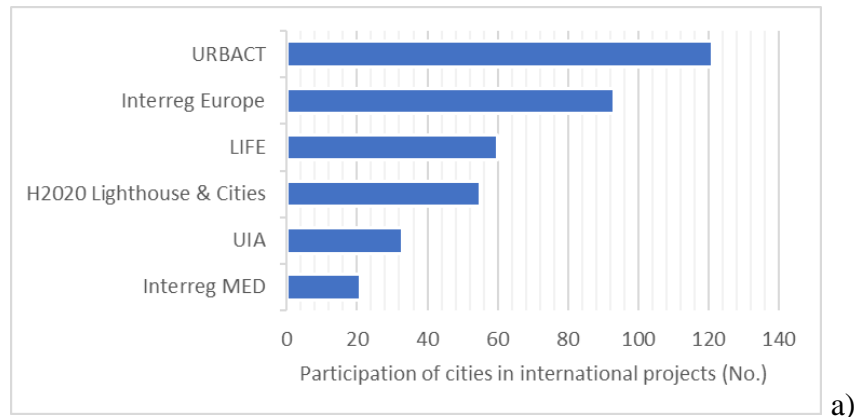
Figure 6. Number of cities in the sample participating in European projects, by funding programme (a) and by country (b).

The cities in the sample are quite active in terms of participation in **international competitions and city awards**, as shown in Figure 7. The successes achieved by the EU 27 and UK cities in the three European competitions considered in this study can be summarised as follows: 5 winner cities of the *European Green Capital Award* - Copenhagen (DK), Lahti (FI), Grenoble (FR), Lisbon (PT) and Bristol (UK), 3 of the European Capital of Smart Tourism - Linz (AT), Copenhagen (DK), Ljubljana (SI), and 2 of European Capital of Innovation - Leuven (BE) and Athens (EL). Moreover, 14 finalists of the *ECGA*, 17 finalists and 12 runners-up of the *European Capital of Innovation*, 4 finalists and 3 category winners of the *European Capital of Smart Tourism*. Copenhagen (DK) is the only city to have won 2 awards (ECGA and the European Capital of Smart Tourism). In addition, it was a finalist in the European Capital of Innovation competition.
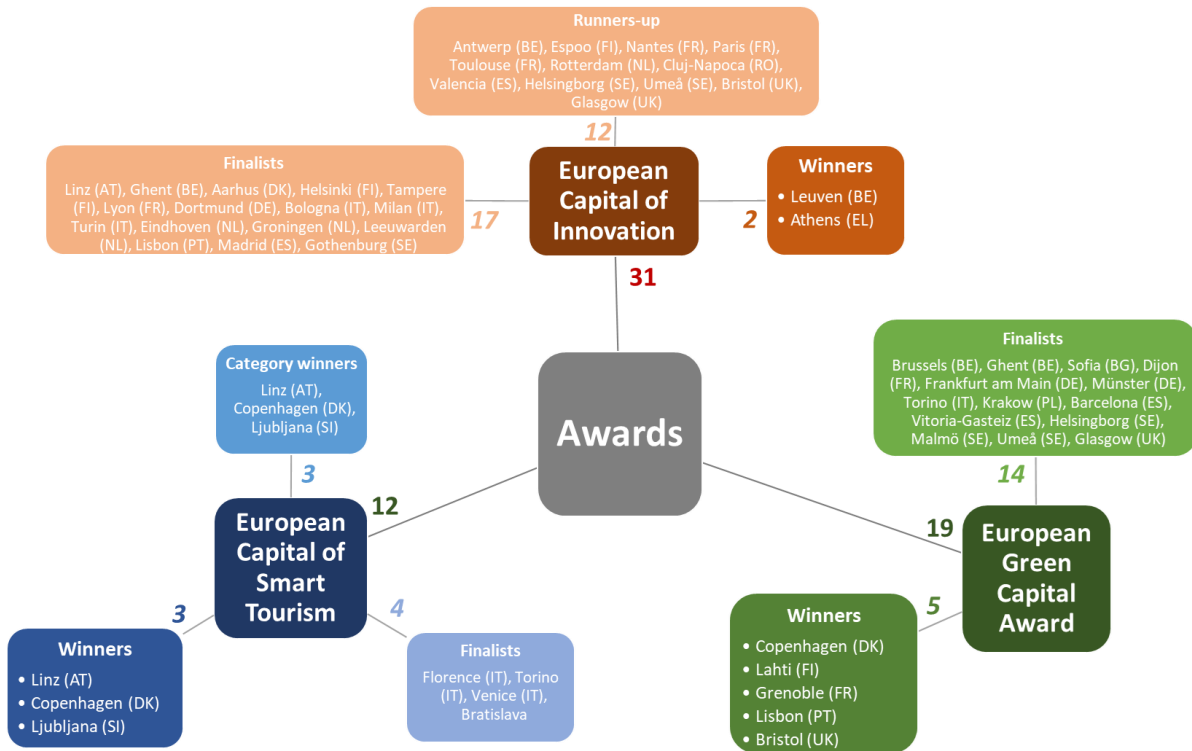
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Figure 7. Number and list of cities in the sample that won an award in the three competitions considered by the study

Comparison of cities' activities and experiences across the 5 driving factors

The 5-set Venn diagram in Figure 8 shows that only 22 (6.5%) candidate cities for the mission have no experience in any of the activities described by the 5 driving factors considered in this study, whereas there are 16 cities that have in their background initiatives and activities falling under all five. Interestingly, except for Toulouse (FR), 15 of these are among the 112 selected cities in this first phase of the 100 CNSC Mission (Figure 10): Brussels (BE), Barcelona, Madrid and Valencia (ES), Helsinki (FI), Lyon, Nantes and Paris (FR), Bologna, Milan and Torino (IT), Krakow (PL), Malmö (SW), Bristol and Glasgow (UK). It can also be noted that 46 cities (13.7%) can count on previous experiences falling under one driving factor, which is mainly represented by networking (37 cities in TMNs) and only marginally by LCPs (5 cities), EU projects (3 cities) and CED (1 city), while no city obtained an award without having been involved in other activities. The importance of networking for the 100 CNSC Mission candidate cities is also made evident by the fact that 301 cities (around 90% of the sample) participate in TMNs. Furthermore, the most frequent joint participation in two of the initiatives and activities described by the 5 dimensions of the Venn diagram is TMNs and LCPs, as found for 248 cities (73.8%) and outlined in the summary table in Figure 8. This is followed by TMNs and EU projects (147 cities) and LCPs and EU projects (136 cities), also highlighting the very important role played by international projects in promoting local climate planning and activating new collaboration networks.
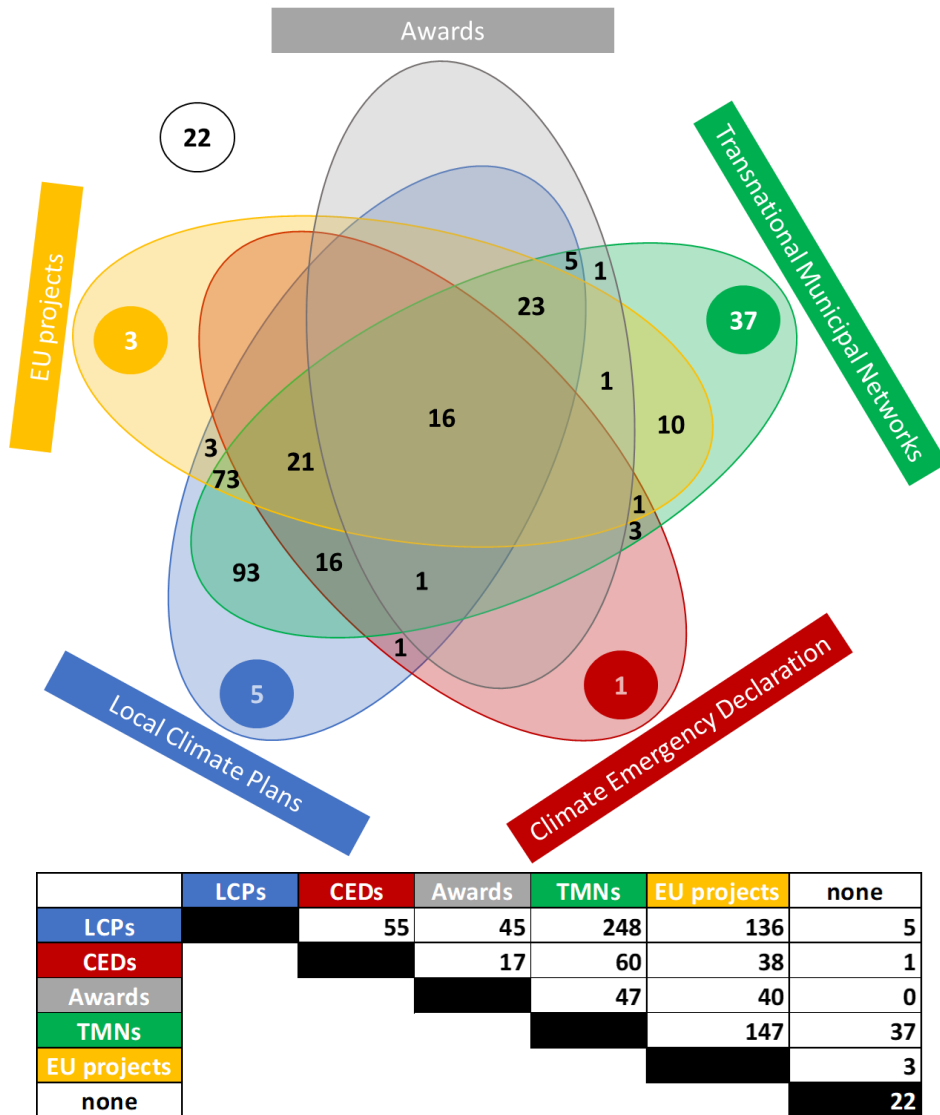
Figure 8: Venn diagram and summary table with the number of cities that fall within the overlap between the five driving factors considered.

	LCPs	CEDs	Awards	TMNs	EU projects	none
LCPs		55	45	248	136	5
CEDs			17	60	38	1
Awards				47	40	0
TMNs					147	37
EU projects						3
none						22

Using the scoring system described in the methodology section, the top 30 cities and the 30 mid-ranking cities are shown in Figure 9. All the top 30 cities have an LCP, are members of at least one TMN and have participated in two or more international projects (only Bristol, Nantes and Toulouse were involved in only one project). 93% of these cities have declared a climate emergency and 60% of them were winners or finalists of a city award. Looking at the 30 mid-ranking cities, the situation is similar only with regard to LCPs (97% have one) and participation in TMNs (all of them) while only 30% of them have had experience in only one international project, CEDs are found only in 3% of them and none of these cities has ever climbed the ranking in any of the city awards considered.
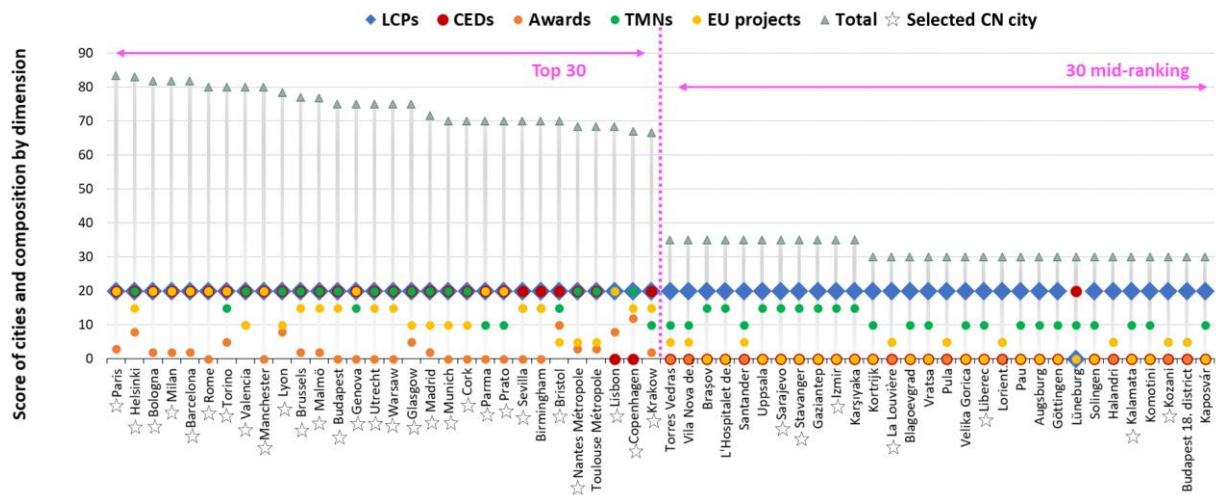
Figure 9. Total scoring and its composition of the top 30 cities and the 30 mid-ranking cities (from position 154 to 183).

Comparison with the SDEWES a benchmarking study

In our dataset there are 61 cities benchmarked by the SDEWES Atlas according to the 4 quartiles, among which: **6** candidate cities are "**Challenged Cities**" (< 25%): Sofia (BG), Athens (EL), Warsaw (PL), Sarajevo, Antalya, Istanbul; **17** are "**Solution Seeking Cities**" (25-50%): Antwerp, Burgas, Varna, Paris, Kalamaria, Florence, Rome, Brașov, Cluj-Napoca, Bratislava, Madrid, Murcia, Sevilla, Tirana, Podgorica, Bursa, Birmingham; 22 are "**Transitioning Cities**" (50-75%): Karlovac, Pula, Rijeka, Grenoble-Alpes Métropole, Lyon, Frankfurt am Main, Heraklion, Budapest, Bologna, Genova, Milan, Torino, Venice, Porto, Vila Nova de Gaia, Timisoara, Izola, Kranj, Maribor, Valencia, Zaragoza, Glasgow; and 16 are the top "**Pioneering Cities**" (Top 25% , that is >75%): Klagenfurt am Wörthersee, Leuven, Aalborg, Aarhus, Copenhagen, Espoo, Helsinki, Pécs, Rīga, Vilnius, Lisbon, Ljubljana, Velenje, Barcelona, Gothenburg, and Stockholm. It is interesting to note that among the SDEWES Top 25% cities, only Helsinki, Barcelona, Lisbon and Copenhagen are in the top 30 of this study, occupying the 2nd, 5th, 28th and 29th places respectively.

DISCUSSION

As of 28 April 2022, the selected cities for the CNSC Mission include **100 EU cities** plus **12 cities from countries associated with the Horizon Europe programme** (2021-2027) [50], as shown in Figure 10. The selection was based on four main criteria: Cities from every Member State, Capital cities, small, medium, and large cities, Frontrunners and less prepared cities. Compared to the public list of candidate cities on which this study was based, 7 more cities are included among the winners, of which 4 are capital cities: Zagreb (HR), Dublin (IE), Amsterdam (NL), Bucharest (RO), plus Thessaloniki (EL), Padova (IT), and Differdange (LU).
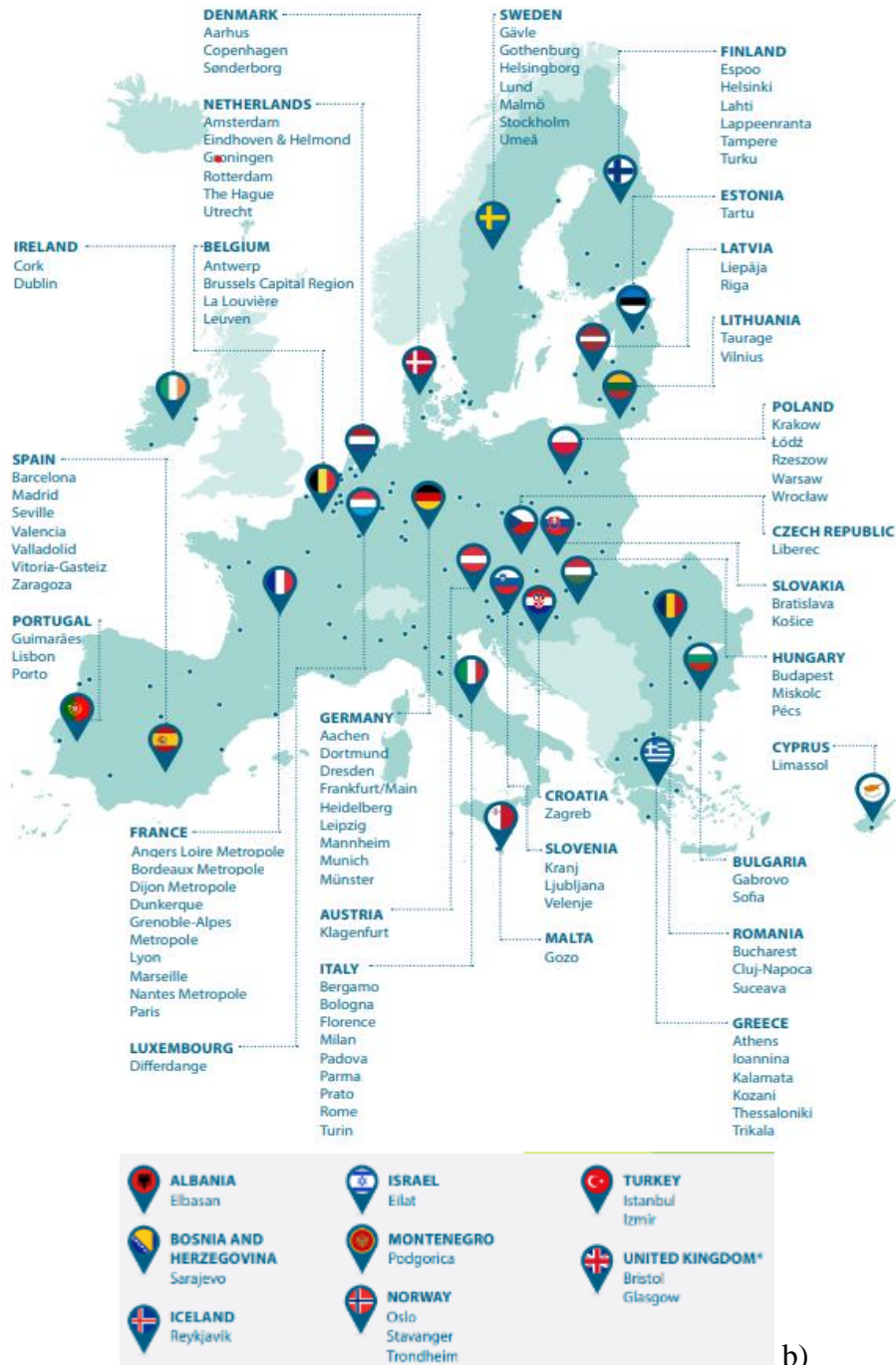
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Figure 10. The **100 EU cities (a)** and **12 cities in associate countries (b) selected** in the first Call of the 100 CNSC Mission (source: [50]).

Practically all the top 30 scoring cities in this paper (Figure 9) were selected, with the only exceptions of Birmingham and Toulouse. According to the score here developed, the biggest differentiating driving factors between these 28 top cities are the degree of participation in TMNs and EU projects, as they all score similarly along the other three driving factors.

Practically all winning/awarded cities in the city sample here studied have an LCP with only five exceptions: Tauragė (LT), Suceava (RO), Gävle (SE) and Elbasan and Istanbul, respectively in Albania and Turkey. Likewise, practically all are members of at least one TMNs (the sole exceptions are Eilat and Elbasan in Israel and Albania), with 45 of the selected cities participating on at least five TMNs (75 cities participate in three or more TMNs). On the

contrary, only 31 of the awarded cities in the city sample had issued a CED and only 42 had received at least one award. Finally, 78 of the selected cities in the sample have participated in at least one EU project.

The biggest difference between selected and not selected cities within the studied city sample seems to be the number of received awards and participation in EU projects, which is substantially lower. 72% of the selected cities had participated in at least one EU project and 40% received at least one award, whereas the corresponding values for the not selected cities are of only 2% and 32%, respectively. Both selected and not selected cities have a high participation in at least one TMNs (87% and 86% respectively), but selected cities are engaged in more TMNs simultaneously (42% of the selected cities participate in five or more TMNs versus 4% of non-selected cities). The share of cities with CED is relatively similar for selected and non-selected cities (29% and 13%, respectively).

Therefore, it seems that the most relevant influencing factors driving cities to be recognised as "experimentation and innovation hubs to put all European cities in a position to become climate-neutral by 2050" (besides naturally, ensuring member state and population size representativeness), are the engagement with EU projects, varied TMNs and awards.

The results show that several Transnational Municipal Networks (TMNs) are serving as drivers of local action facilitating cities through international cooperation [26]. Membership to TMNs gives members a better chance for entering the competition given that they generally support the cooperation between cities and the sharing of good practices also through ad-hoc platforms (such as ICLEI).

CONCLUSIONS AND FURTHER DEVELOPMENTS

This study did not aim to verify the work of the expert evaluators in selecting the cities for the EU Mission "Climate-Neutral and Smart Cities", nor to measure and evaluate the overall sustainability performance of the candidate cities, but it did aim to learn more about the candidate cities and to assess their level of activism on climate and smart issues.

Through an in-depth research and data analysis of five main driving factors (local climate planning, climate emergency declaration, participation in networks, international projects and competitions) for a sample of 336 cities from 35 countries (EU27, UK plus other associated countries and countries under association negotiations), this study provides a unique and timely overview of the main efforts currently being made by cities to commit to climate neutrality. To our knowledge, there is no study of this kind that addresses all five of these factors, especially with such a large and diverse sample provided by the candidate cities. Specifically, the sample analysed by the research consisted of 336 candidate cities for the 100 CNSC Mission, of which 86% were from the EU-27 and the remaining 14% from associated or negotiating countries. 132 cities (39% of the total sample) have a population of less than 100,000 inhabitants.

This study is particularly important to shed light on the possible motivations for cities to voluntarily embark on the ambitious path towards climate neutrality. The analysis of the results by individual driving factor showed that 257 cities in the EU-27 and the UK have a local climate plan, which in 82% of cases is a SEAP/SECAP developed within the Global Covenant of Mayors for Climate and Energy (GCoM). This may be related to the fact that three quarters of the candidate cities for the 100 CNSC Mission are members of the GCoM, less than half (41.1%) are signatories of the Aalborg Charter. Cities declaring climate emergency are only one fifth of the sample, 100% of the UK candidate cities, followed by 40% of German cities and 36% of Italian cities. With regard to the distribution of city projects by funding programme, the study shows that URBACT is the most popular funding programme with 121 projects involving the sample cities, followed by Interreg Europe (93), and almost tied LIFE (60) and H2020 Lighthouse & Cities (55). Italian cities seem to be the most successful in participating in international projects (78 projects or 20.4% of the total number), followed by Spain (34

projects, 8.9%) and Portugal (25 projects, 6.5%). Copenhagen (DK) is the only city in the sample to have won 2 awards (ECGA and the European Capital of Smart Tourism) and was also a finalist in the European Capital of Innovation competition.

The comprehensive analysis conducted through a 5-set Venn diagram showed that 314 cities in the sample, i.e. 93.5%, had experience in at least one of the activities described by the 5 driving factors considered in this study, while only 16 cities (4.8%) had experiences that fell into all five categories. The five selected driving factors seems to capture quite the well the level of "activism" of the sample cities in pursuing smart and climate related projects and initiatives. In fact, 15 out of 16 cities, i.e 94%, that have in their background initiatives and activities falling under all the five sets of the Venn diagram are among the 112 selected cities in this first phase of the 100 CNSC Mission. Networking represents the most important influencing factor, among the five analysed, for cities to apply for this Mission. In fact, 301 cities (around 90% of the sample) participate in TMNs and 248 cities (73.8%) are part of a climate network and have developed a local climate plan. This is also confirmed by the application of the scoring system: all the top 30 cities have an LCP, are members of at least one TMN and have participated in two or more international projects. 93% of these cities have declared a climate emergency and 60% of them were winners or finalists of a city award.

These findings and the rich dataset made available by this research can be useful for researchers, planners and decision-makers in defining effective models for making cities greener, more resilient and smarter.

Further developments of the research will, in the short term, concern two fundamental aspects. First, the geo-referencing and mapping of the candidate and selected cities, in order to highlight the location (geographically and in terms of other socio-economic indicators) of the most successful cities and try to better correlate it with their past experiences, represented by the five driving factors analysed in this study. Secondly, the redefinition of the weighting factors used in the scoring method, possibly based on the ambition of the local climate plans before the accession to the 100 CNSC mission and taking into account, if available, the action plans after the climate emergency declarations. In addition, consideration will be given to comparing the sample cities with other benchmarking studies, such as the ranking of smart cities based on the Cities in Motion index [53], generated annually by IESE.

In the long term, it would be interesting to monitor the pathways of the 112 cities to assess the effective *co-creation with local stakeholders and citizens*, the level of implementation of the actions foreseen by the Climate City Contracts (mainly on mobility, energy and urban planning) and, the effective replicative effect of the 100 CNSC mission in the urban areas of all participating countries.

In the long term, it would be interesting to monitor the pathways of the 112 selected cities in order to assess the effective co-creation with local stakeholders and citizens, the level of implementation of the actions foreseen by the Climate Contracts (mainly on mobility, energy and urban planning) and the actual replication effect of the 100 CNSC mission in the urban areas of all participating countries.

DATA AVAILABILITY

The supplementary spreadsheet dataset will be archived and made publicly available as a Mendeley dataset.

ESSENTIAL NOMENCLATURE

CCCs - Climate City Contracts, CEDs - Climate Emergency Declarations, CNSC – Climate-Neutral and Smart Cities, CoM - Covenant of Mayors for Climate and Energy – Europe, EC - European Commission, LCPs - Local Climate Plans, SC - Smart City, SE(C)AP - Sustainable Energy (and Climate) Action Plan, TMNs - Transnational Municipal Networks,

Country codes: *AT – Austria, BE – Belgium, BG – Bulgaria, HR – Croatia, CY – Cyprus, CZ – Czech Republic, DK – Denmark, EE – Estonia, FI – Finland, FR – France, DE – Germany, EL – Greece, HU – Hungary, IE – Ireland, IT – Italy, LV – Latvia, LT – Lithuania, LU – Luxembourg, MT – Malta, NL – Netherlands, PL – Poland, PT – Portugal, RO – Romania, SK – Slovakia, SI – Slovenia, ES – Spain, SE – Sweden, AL – Albania, BA – Bosnia and Herzegovina, IS – Iceland, IL – Israel, ME – Montenegro, NO – Norway, TR – Turkey, UK – United Kingdom.*

ACKNOWLEDGMENT

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