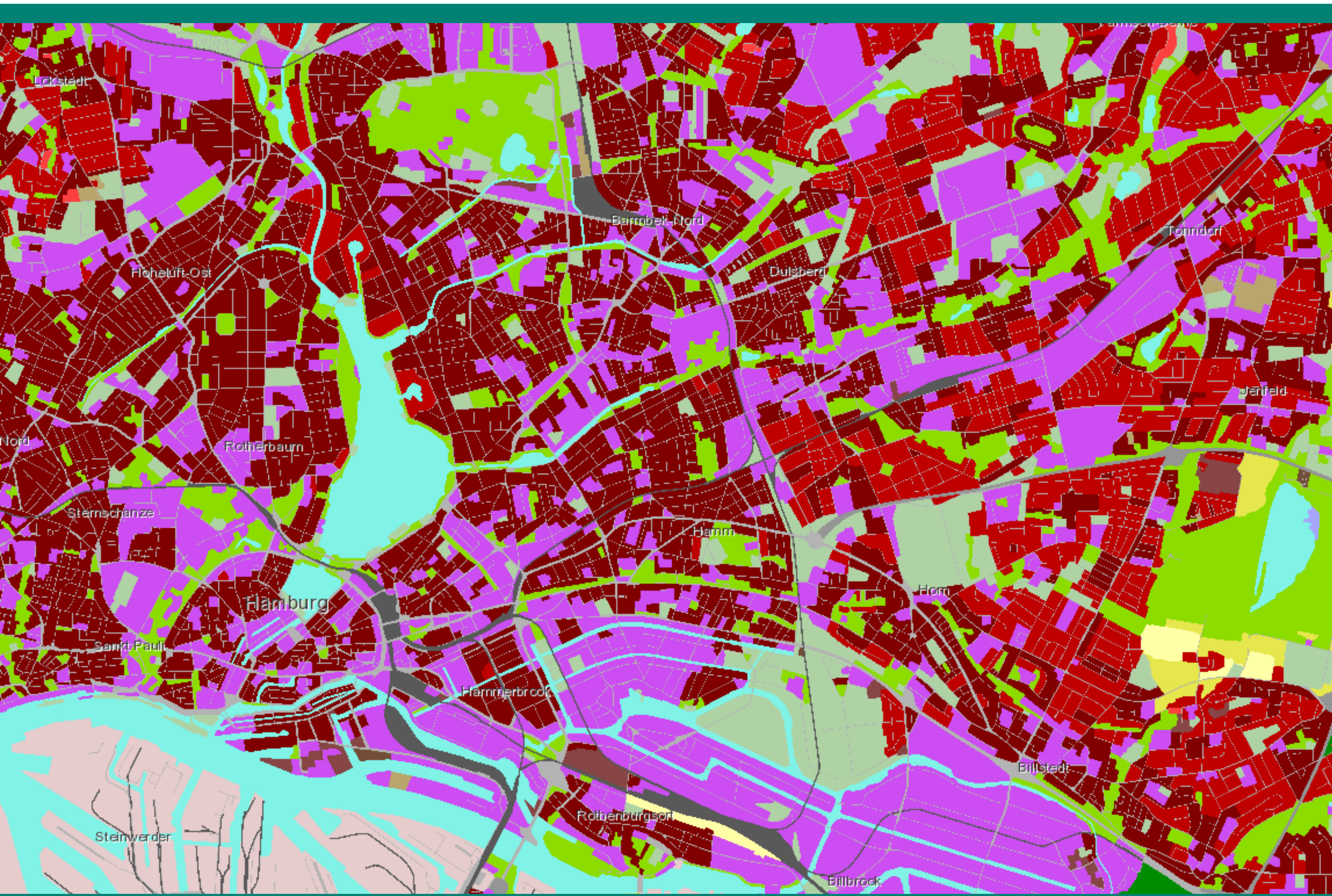
ETC/ULS Report | 03/2018

Similarities and diversity of European cities

A typology tool to support urban sustainability



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European Environment Agency
European Topic Centre on Urban, Land and Soil Systems

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Abbreviations

7th EAP	Seventh Environment Action Programme
CICES	Common International Classification of Ecosystem Services
CLC	Corine Land Cover
COP	Conference of Parties
EC	European Commission
EEA	European Environment Agency
EEA-39	39 member and cooperating countries of the EEA
EU	European Union
EU-28	28 Member States of the EU
FUA	Functional Urban Area
GHG	Greenhouse Gas
GI	Green Infrastructure
LEAC	Land and Ecosystem Accounting
LUZ	Larger Urban Zone
NO_2	Nitrogen Dioxide
NUTS	Nomenclature des unités territoriales statistiques
O_3	Ozone
PM	Particulate Matter
PO	Priority objective
SDG	Sustainable Development Goal
UN	United Nations
WHO	World Health Organization

Glossary

City	The administrative delineation that corresponds to the historic city and does not reflect the limit of the building space continuity or the borders of the real economic limits and the real behavioural patterns of people (EC, 2011a). It represents the local administrative unit (LAU) where the majority of the population lives in an urban centre of at least 50,000 inhabitants (EC and Eurostat, 2016a).
Degree of urbanisation	The degree of urbanisation classifies local administrative units (at LAU2 level) into (i) cities (or densely populated areas), (ii) towns and suburbs (intermediate density areas), or (iii) rural areas (thinly populated areas). The classification is based on a combination of geographical contiguity and minimum population thresholds applied to 1 km^2 population grid cells (EC and Eurostat, 2015a).
Functional Urban Area	The FUA can be explained as the core city plus its associated hinterland. The functional urban area is defined as "a territorial unit resulting from the organisation of social and economic relations within that. Its boundaries do not reflect geographical particularities or historical events. It is thus a functional sub-division of territories." (OECD, 2002, p. 11). It defines the travel-to-work catchment and gives an image of the actual role played by a city within and beyond the region in terms of functions. The functional urban area encompasses a system of surrounding towns and villages that are economically and socially linked with the core centre.
Megacity	A metropolitan area with a total population of more than 10 million inhabitants.
Towns and suburbs	Municipalities where 50% of the population lives in an urban cluster and which is not a city (EC and Eurostat, 2016a).
Urban area	The sum of all cities, towns and suburbs, relates to a certain delineation or typology (EC and Eurostat, 2016a).
Urban Morphological Zone	The Urban Morphological Zone deals with the physical layout of an urban area (EEA, 2014) and is usually larger than the administrative unit. It is the morphological approximation of the "real" city. It describes the urban tissue of an area and the continuity of the artificial space. Generally, land use reflects the human activity on a territory. A city is organised around a densely populated node, characterised by an urban landscape and a historical core.

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Executive Summary

Context and objectives

Today, 52 % of the global population lives in cities, another 33 % in towns and suburbs, a trend that is going to continue (EC and UN-Habitat, 2016). On a European level, around 72 % of the population is already living in cities and towns, also with the expectation to increase (EC and UN-Habitat, 2016). Compared to the global situation, however, Europe is characterised by a much higher number of medium- and small-sized cities (EC and UN-Habitat, 2016). In this context, the main challenge ahead is to find a way to accommodate a greater number of people while at the same time reducing impacts upon and from the environment and improving the quality of life of cities' residents.

This report makes an attempt to characterise 385 European cities with respect to their main environmental and socio-economic conditions. To this end, we identified and selected 41 parameters from different thematic domains (urban dimension and land use, urban form and distribution, climate, socio-economics, waste, water, air quality, transport and mobility, as well as governance) and calculated clusters of cities based on those parameters. The resulting typology should help to analyse the characteristics of cities in similar situations (i.e. cities from the same group or cluster) because there are simply too many cities in Europe. An individual analysis of each city would not provide the information needed at the European level to lay the ground for appropriate policy- and decision-making. The study is to a certain extent data-driven, i.e. the final selection of data has pragmatically been led by their availability, reliability, quality and the time period. The general reference year is 2012 whereas information changes cover the period from 2006 to 2012. However, although data driven, the analysis covers enough important fields to give an idea of the environmental performance of the studied cities and, more broadly, their sustainability.

The report is intended as 'food for thought' and information source for policy- and decision-makers at national, sub-national and municipal levels, and for researchers and interested citizens alike. The report highlights the strengths and weaknesses of each of the city clusters. In addition, cities that are member of a certain group get to know their positioning with respect to other cities and groups. Altogether, this allows cities on the one hand to assess their own situation and on the other hand to compare themselves to other cities in similar situations or to cities of similar general characteristics that have taken a different development path. There is currently no regular environmental reporting on urban areas and this report intends to fill a knowledge gap. It can be considered as the first step of a long process of the analysis of the environmental performance of cities over time.

The basics of urban sustainability

Sustainable development should meet "the needs of the present without compromising the ability of future generations to meet their own needs" (Brundtland Commission, 1987). In that sense, the challenge of urban sustainability is to meet the needs of current and future inhabitants without imposing unsustainable demand on local and global resources and without exporting pollution and waste (Alberti, 1996). Assessing circular economy aspects, an ideal sustainable city would be one for which the inflow of material and energy resources, and the disposal of wastes, do not exceed the capacity of the city's surrounding environment (Kennedy et al., 2007). In the context of further increasing numbers of urban dwellers both in Europe and globally, this also means to decouple the expected growth from resource use. However, urban systems are inherently complex which needs to be recognised in order to properly address sustainability challenges. The urban system is a socio-ecological-technical system (McPhearson et al., 2016) that is characterised by the impact of society, i.e. the inhabitants and their lifestyles and demands, the natural environment as basis for the provision of much needed ecosystem services, and the technical responses and infrastructures in the cities.

Today, European cities face a number of challenges that pose a risk to their sustainable development. These are related to health (in particular health risk due to poor air quality and noise pollution), the urban environment (e.g. high use of natural resources, waste or land consumption by urban sprawl) and climate change and the need to adapt. To ensure or increase the quality of life of their citizens, policy- and decision makers need to respond to these challenges by identifying appropriate solutions and provide the regulatory basis. Urban planning and policies play a fundamental role in the way forward. This report and the typology aim at providing a contribution to the information that is required to be able to respond appropriately.

Selected findings

Cities can be more or less similar. When looking at cities at a European perspective, some cities have enough properties in common to be considered as having roughly a comparable potential of transformation. This coarse assumption is acceptable at a European scale given the high number of cities and the lack of information on them.

A typology in general is a system to put specific objects into groups based on similarities. In this report, 385 cities have been grouped, using the 41 parameters and a clustering algorithm, into five clusters or groups of cities (four bigger and a smaller one) and three sub-clusters for each big cluster. The sixth cluster consists of London alone as a one-city cluster and is therefore considered as an outlier rather than a separate cluster. The typology is understood as both quantitative and qualitative characterisation of cities, which should be structured in hierarchical systems providing a broad view on cities, their situation and basic functions, their individual performance and main activities, their threats and their most important changes (i.e. potential pressures and development paths).

The major difficulty of this approach was to find comparable and relevant data for the same time period and for a significant number of cities. The final selection of indicators and analysed cities was driven by data availability rather than by analysing all dimensions of urban sustainability. However, given the large number of data and covered domains, this approach can be considered as a good approximation to analysing urban sustainability. The Urban Audit database ([1]) and the Copernicus Urban Atlas ([2]) are the main sources of data. They both cover the same number of cities and the same areas. In 2006, Urban Audit and Urban Atlas included 321 Larger Urban Zones from EU-27; in 2012, 695 Functional Urban Areas (most of EU-28 cities over 50,000 inhabitants) are covered.

Looking at the results of the typology, it becomes clear that all five (or six, if London is counted) clusters show specificities that differentiate them from one another and allow creating an interesting picture of European cities. First of all, London always appears as a stand-alone city that does not belong to any of the other clusters, irrespective of how many clusters were used during the calculation of the typology. This means that London possesses many strong characteristics that sets it apart from all other cities: size, number of inhabitants, urban sprawl problems, relatively few green spaces, high levels of soil sealing. Therefore, London is not considered to be a cluster, but can be counted as an outlier city when compared to all other clusters.

Two clusters have a very strong geographic pattern that is directly related to climatic, political and socio-economic impacts on those cities that shaped their urban development in the recent and more distant past. Cluster A is almost exclusively composed of cities from the former Eastern Bloc, i.e. the former socialist or communist countries in eastern Europe. In the past years, they all experienced a strong population loss and today consist of a relatively young population. The common political past is obviously the main reason for them being in one cluster. Only the capital cities of four of those countries

([1]) http://ec.europa.eu/eurostat/web/cities/overview

([2]) https://land.copernicus.eu/local/urban-atlas, accessed 08/08/2016.

(i.e. Warsaw, Prague, Budapest and Bucharest) have managed to develop into economically attractive metropolitan cities and are therefore located in the Cluster E.

The second cluster with a clear geographical pattern is Cluster B that consists of cities of three Mediterranean countries, Portugal, Spain and Italy. Due to the urban development history, Mediterranean cities tend to be very compact and are very much characterised by their specific climatic conditions. However, it is likely that the most determinant factor for their grouping is the impact of the financial crisis of the years 2007 to 2009 on their inhabitants. The cities of this cluster have the highest unemployment rates, the strongest decrease in their government effectiveness and the highest old-age dependency, i.e. the highest proportions of older citizens. By consequence, they also possess the highest at-risk of-poverty rate.

While the largest Cluster C is the most heterogeneous one and does also not show a clear geographical pattern, it is the group with the highest share of green spaces, but at the same time experiencing a sprawling, low-density development pattern. On the other hand, Cluster D, which is also geographically heterogeneous, coincides with Europe’s most prosperous regions, possesses the highest government effectiveness index and is the only cluster with cities which do not have an aging population. This is most likely due to their attractiveness as university and economically active cities. Finally, Cluster E consists of some of the biggest, mostly capital cities in Europe and shows the lowest unemployment and at-risk-of-poverty rates, so is a kind of counterpart to Cluster B. With only 14 cities, it moreover could be considered a second-tier cluster to the London outlier as these cities also have very remarkable and similar characteristics that set them apart from the large majority of the cities, but group them into a distinct cluster.

Concluding, this study provides extensive and relevant information for filling knowledge and information gaps on the environmental performance of cities on a European level using cluster analysis, typologies and indicators. Therefore, it supports both the 7th EAP priority objective 5 on the need for knowledge and information and priority objective 8 asking for the development of a set of indicators for urban sustainability. Because of several, to a large extent data-related issues, further research is needed. However, this study provides a sound basis for European analysis and follow-up work.

1 Introduction

1.1 What is the urban context

We are living in an urban world. Today, 52 % of the global population lives in cities, another 33 % in towns and suburbs (EC and UN-Habitat, 2016). In the future, this trend towards urbanisation will continue. By 2050, about two-thirds of humanity is likely to reside in urban areas (UN, 2014). On a European level, around 72 % of the population is already living in cities and towns, also with the expectation to increase (EC and UN-Habitat, 2016). Today, densely populated areas host 41% of Europeans and intermediate populated areas, mainly town and suburbs, are home to 31% of the European population (see Glossary and (Dijkstra and Poelman, 2014) for definitions).

Compared to the global situation, however, Europe is characterised by a much higher number of medium- and small-sized cities. Only 16 % of Europeans live in cities with more than 5 million inhabitants; in Asia, it is 30 % of the population, in North America 28 %. Likewise, the average population density of European cities is different than in Asian (denser) or American (less dense) cities (EC and UN-Habitat, 2016).

In this context, the main challenge is to find a way to accommodate a greater number of people whilst reducing impacts upon and from the environment and improving the quality of life of cities' residents. To offer people a healthy living space and to reduce environmental impacts, the current model of urban development requires a profound transformation. The new type of cities should engage in developing citizen-oriented policies, transform unsustainable urban forms of the previous century in more innovative and resilient forms, create conditions for a higher provision of public goods, and offer greater heterogeneity and functionality. To achieve these objectives, cities have to be efficiently and smartly planned, designed, renovated, managed and governed (German advisory council on global change, 2016).

Cities are at the centre of our environmental future and they face a number of challenges (German advisory council on global change, 2016; Sassen, 2009). They drive global environmental change and are affected by it at the same time. As a major contributor to greenhouse gas emissions, mitigation of climate change requires a profound transformation of urban areas. Simultaneously, given the concentration of people, assets, infrastructure and productive activities, they are particularly vulnerable and have to adapt to climate change. Cities are also important sources of air pollution, with sources such as road transport, industry, household heating, etc contributing to poor air quality. Recent findings from EEA show that more than 90 % of people living in European cities are exposed to unsafe levels of air quality (EEA, 2017), which adversely affects human health. In the same way, well-being and health of citizens depend on the supply of goods and services from ecosystems. But increasing uncontrolled urbanisation threatens ecosystems and biodiversity, and generates habitat loss, degradation and fragmentation. Moreover, urban expansion causes the destruction of productive soils for crops although cities require massive amounts of food.

Cities have opportunities to be transformed and adapted to meet future challenges, i.e. they need to become more resource-efficient to reduce their ecological footprint (EEA, 2015c; 2015e). Relevant examples show that some front runners are already developing transformative measures ([3]), including for example urban green infrastructure which could contribute to achieve EU 2020 biodiversity targets. Even if the urban system generates high levels of pollution and concentrates pressures on the environment, increasing urban density while at the same time integrating urban green and blue areas is an efficient model and the most cost-effective solution for providing transportation, potable water, sanitation services, electricity, and other social services (Wu, 2013). The per capita consumption of

([3]) The European Green Capital Award website provides numerous examples:
http://ec.europa.eu/environment/europeangreencapital/ accessed 15/07/2016.

resources and energy is lower in densely populated areas than in relatively sparsely populated areas (Krausmann et al., 2008). Compactness contributes to reduce the distance of commuting, energy demand, land-take and soil destruction, and fragmentation of habitat. It allows economies of scales for citizen-oriented services such as collective transport, power, water and sanitation services, and waste management. In addition, due to the concentration of economic and political power, cities have financial and human resources to innovate and be transformed.

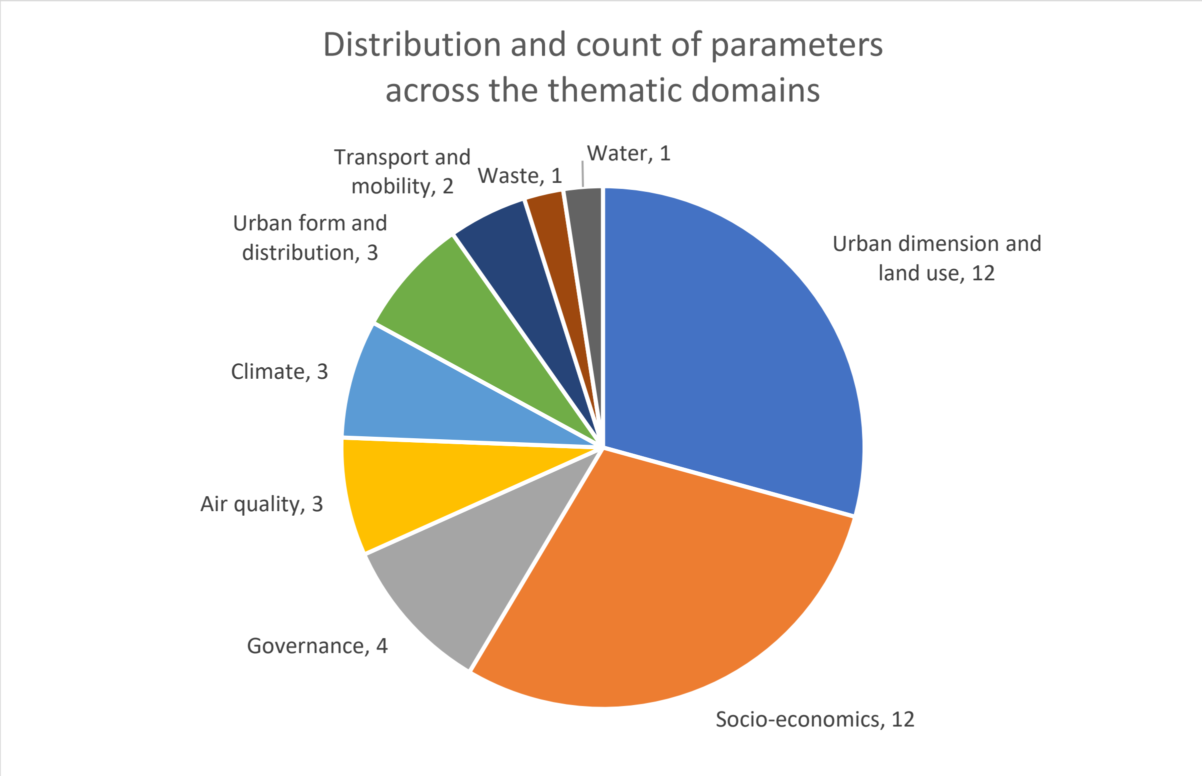
1.2 Scope of this report

What are the main environmental and socio-economic characteristics of European cities? Are there groups of cities that show similar conditions? What are the specific characteristics of these groups that set them apart from other groups? This report addresses these questions from an integrative perspective, considering a multitude of currently available data at a European level. The approach has inherent limitations given the data gaps or restrictions in certain thematic areas (such as energy, water, waste, mobility or noise). However, it tries to provide the most comprehensive overview possible by identifying the most relevant components that explain similarities and differences between European cities. The main objective is to give a synthetic view of the real situation of European cities in an easy-to-understand way in order to facilitate the communication of important key messages. This approach can be helpful for policy makers during the decision-making process to deal with the complexity of urban challenges and to learn from other cities belonging to the same group. In particular, city planners get to know the shortcomings of their cities with respect to certain sustainability criteria, e.g. towards the targets identified in SDG11 on sustainable cities on access to open and green spaces or improving citizens health by improving air quality. Moreover, the analysis also identifies knowledge gaps that would require further efforts.

The study is based on 385 European cities and 41 parameters covering several thematic domains and representing a majority of the characteristics describing the urban system: urban dimension and land use, urban form and distribution, climate, socio-economics, waste, water, air quality, transport and mobility, as well as governance (see Figure 1.1). To a certain extent, the study is data-driven. The final selection of data has pragmatically been led by their availability, reliability, quality and the time period. The general reference year is 2012 whereas information changes cover the period from 2006 to 2012; i.e. the change period includes the years of the recent major economic crisis in Europe (2008 and 2009) ([4]). However, although data driven, the analysis covers enough important fields to give an idea of the environmental performance of the studied cities and, more broadly, their sustainability.

([4]) Since 2012, Croatia has joined the EU. Due to the lack of comparable data, though, Croatian cities are not included in this study.

Figure 1.1: Distribution of parameters across the thematic domains



Finally, given the difficulty to define what is a city and what is the limit of urban areas, this report uses in an interchangeable way the terms 'urban area' and 'city'. The notion of urban areas incorporates the core city (or 'City', see Glossary), generally characterised by a high density of people and activities and a high degree of soil sealing, and the areas around, i.e. intermediately dense areas, but functionally linked to the core. A description of the delineations and terminology used in this report is provided in Box 2.1 and the glossary at the beginning of the report.

The report is intended as 'food for thought' and information source for policy- and decision-makers at national, sub-national and municipal levels, and for researchers and interested citizens alike. The report highlights the potential for actions as well as the strengths and weaknesses of each group. In addition, cities that are member of a certain group get to know their positioning with respect to other cities and groups. Altogether, this allows cities on the one hand to assess their own situation and on the other hand to compare themselves to other cities in similar situations or to cities of similar general characteristics that have taken a different development path. There is currently no regular environmental reporting on urban areas and this report intends to fill a knowledge gap. It can be considered as the first step of a long process of the analysis of the environmental performance of cities over time.

1.3 How to read this report?

The report is divided into four chapters.

While the current chapter 1 provides the context and scope of the report, chapter 2 highlights the key factors of urban sustainability and their interdependences. It helps to understand the complexity of the urban system and its inter-scalar dimensions, the challenges cities are currently facing that pose a threat to urban sustainability and the current responses to the urban challenges. All these elements are relevant to interpret and understand the results presented in chapter 3.

Chapter 3 is the core of the report and presents the city typology (including a short description of the approach) and analyses the resulting clusters and their characteristics. Five groups of cities with common characteristics have been identified; London appears as single-city cluster. This analysis provides a broad view on cities, their situation and basic functions, their individual performance and main activities, their threats and their most important changes. This approach aims to be helpful for policy makers.

Finally, chapter 4 provides conclusions and a short discussion. This chapter could be read independently from the other parts of the report. However, we strongly recommend to have a look, at least, to section 2.2 on the complexity of urban systems to better interpret the results.

2 Urban sustainability

2.1 Overview

Sustainable development should meet "the needs of the present without compromising the ability of future generations to meet their own needs" (Brundtland Commission, 1987). The challenge of urban sustainability is to meet the needs of current and future inhabitants without imposing unsustainable demand on local and global resources and without exporting pollution and waste (Alberti, 1996). Assessing circular economy aspects, an ideal sustainable city would be one for which the inflow of material and energy resources, and the disposal of wastes, do not exceed the capacity of the city's surrounding environment (Kennedy et al., 2007).

Prosperity of cities depends on several capitals and their mutual relationships (EEA, 2015d):

- natural capital (provides ecosystems services and natural resources);
- manufactured (or building) capital (related to material and physical features such as roads and buildings);
- human capital (refers to personal competences and capabilities such as skills and knowledge);
- cultural and social capital (based e.g. on relations to other people through norms, trust, commitment, institutions); and
- economic or financial capital (i.e. assets and money needed to provide goods and services and cover unexpected losses).

In an urban environment, the form of these components is extremely diverse due to diversity of actors (e.g. culture, age, behaviour), diversity of built environment (e.g. historic, recent) and natural assets (e.g. river, green urban spaces, coastal areas). Interactions between these endogenous factors determine the differentiation of the development potential of a place and its growth pattern (Camagni and Capello, 2013).

In addition, sustainability is not a static situation, but rather a permanent process of change, a permanent reinvention. There is no universal rule that can be applied anywhere and at any time. From that perspective, this diversity is an opportunity for cities to develop their own capacity of transforming and adapting to continuous changes. Therefore, the issue of urban sustainability cannot be addressed by looking only at one specific aspect of the urban system, but by taking into account all the components and their interactions. That is what this study is trying to do within the limits of available data.

2.2 The complexity of urban systems

2.2.1 Identification of the main components

Complexity is an inherent characteristic of urban systems (see Figure 2.1) and, therefore, needs to be recognised in order to properly address sustainability challenges. This complexity relates to both geometry and inter-scalar dimension. Cities are linked to many scales, from buildings, building blocks or streets up to patterns and structures at a regional or national level and beyond. Basic elements (e.g. streets, buildings, open and green spaces) are connected to generate an urban fabric, then a city, then a metropolitan area. Moreover, this complexity is interwoven with the interaction between natural and man-made elements interacting with society.

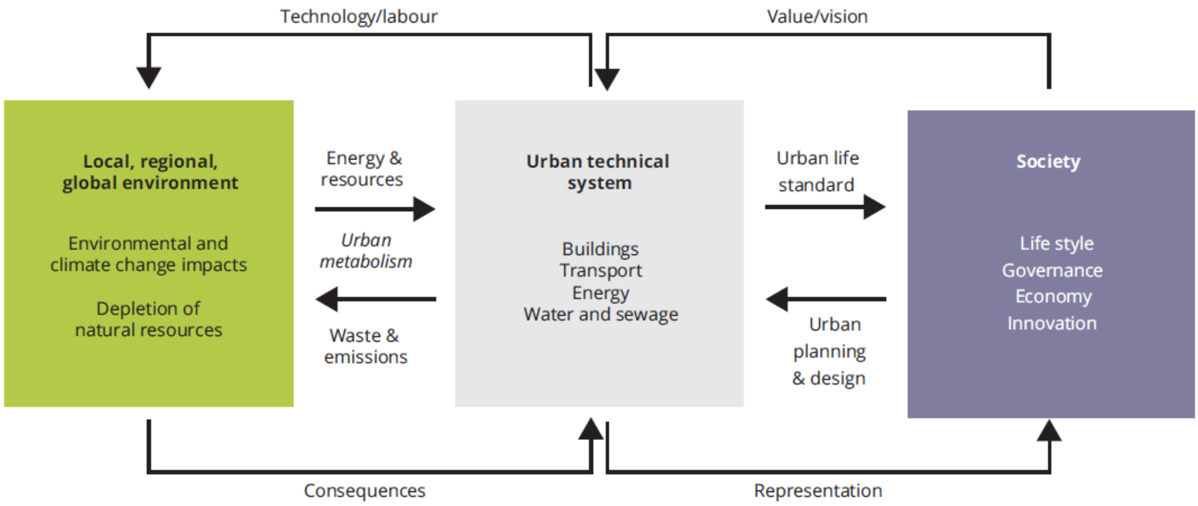
The condition of the urban system depends on its natural environment for ecosystems services (e.g. food, clean air, clean soil, water, timber, thermal regulation), on the technical system for the supply of basic services for daily life (e.g. drinking water, sanitation, waste management, collective transport), on the demand of goods and services by society - flows and material inputs are determined by lifestyle and economical activities - and on how the relationship between society and nature is organised (i.e. urban culture, institutions, policies, regulation).

Consequently, the urban system is a socio-ecological-technical system (McPhearson et al., 2016). The challenge is to simultaneously transform the interdependent components of the system in a harmonised way:

- Technical system or 'grey infrastructure', i.e. the built-up urban environment, transport system, energy system, water and sewage system, brownfield, industrial and commercial infrastructures, determines the spatial extent of the city and the urban pattern (urban form, density, design). It shapes how people live, work and move and is, therefore, determinant for the needs of materials, energy and water.
- 'Green infrastructure' is the network of urban green spaces situated within the boundary of the urban ecosystem (within and around cities). Green infrastructure is defined as 'a strategically planned network of natural and semi-natural areas with other environmental features designed and managed to deliver a wide range of ecosystem services. (EC, 2013). Green infrastructure (GI) brings social, ecological and economic benefits to the urban population, such as air filtration, temperature regulation, flood protection, aesthetic landscape, recreational areas, positive effect on health, etc. Urban green spaces include all sorts of vegetation from single tree to large forest, i.e. balconies, green roofs and walls, hedges, pocket gardens, urban parks, river banks, playgrounds, cemeteries, urban farms, large forests in the surrounding areas or vacant or derelict land (EC, 2016). To ensure sustainable green (or blue) infrastructure, remediation of soil and sediments can be necessary.
- Society contributes to the city's 'territorial capital' ([5]) through behaviour, lifestyles or values. Governance and the policy-making process determine the ability to implement efficient integrated urban planning and to design a vision for the future. The transformation of a complex system cannot be met only with incremental technical improvements, but requires systemic changes and society is the motor of changes.

([5]) Territorial capital is defined as the set of localised assets – natural, human, artificial, organizational, relational and cognitive – that constitute the competitive potential of a given territory (Camagni, 2008).

Figure 2.1: The urban system



Source: adapted from (Bai and Schandl, 2011)

A city is an open system that cannot be viewed at and analysed in isolation. It has direct and indirect impacts on the immediate and wider environments. The urban hinterland, in the past represented by the surrounding rural areas, is today made up of a "global hinterland". To satisfy the demand in goods, food, raw material, or energy, cities rely on the surrounding areas as well as worldwide imports. Pollution and emissions expand beyond the city boundaries into the immediate hinterland and in some cases impact at the global scale (e.g. greenhouse gas emissions). In addition, urban areas provide goods and services not only for local population, but also for populations worldwide. This interdependence between urban areas and their surroundings, far from city boundary, pose major problems of governance (Sauer et al., 2016).

2.2.2 Complexity of the European patterns of human settlement

Historical process

Almost all cities were built along waterways, or along a coast of an ocean, sea or lake. Water and cities are intrinsically tied to each other. This relationship has structured and influenced the development of metropolitan areas, cities, towns, rural areas, villages, and even neighbourhoods throughout history and will continue to do so (EEA, 2016a). Furthermore, connectivity is also at the heart of urbanisation. Cities need to be connected to other cities and their hinterland. Transport infrastructure is indispensable to transport goods, to trade, to develop local economy, to satisfy the demand for travel of people. Generally, a change in the transportation system, such as extension of the road network, acts as a motor for the dispersion of human settlement. In former times, water also created a natural barrier which made the city easier to defend.

City development occurs in irregular cycles. Over time, cities were made in the image of the predominant technology of their age. During the Industrial Revolution, cities were shaped by the emergence of factories. In the age of the railways, cities were opened up to the surrounding countryside and nations were centralised around their capital cities through radial rail networks. In the age of steel, new technologies allowed cities to grow vertically. In the age of mass production and the car, cities expanded horizontally. In the current age of information technology cities are increasingly interconnected in terms of flows of finance, labour, information, goods, services and tourists. Changes in technology and global competition have modified criteria for localisation of economic activities. (EEA, 2015c)

Some global cities gathering firms with highly specialised central functions are emerging (Sassen, 2005). The reason for being is becoming more volatile and vulnerable, trying to capture fleeting quality of life factors or highly mobile skilled professionals (Ravetz, 2017). Today, because of environmental problems and expectations of citizens regarding health and well-being, some cities are front-runner for developing sustainable urban areas.

Box 2.1: How to define an urban area?

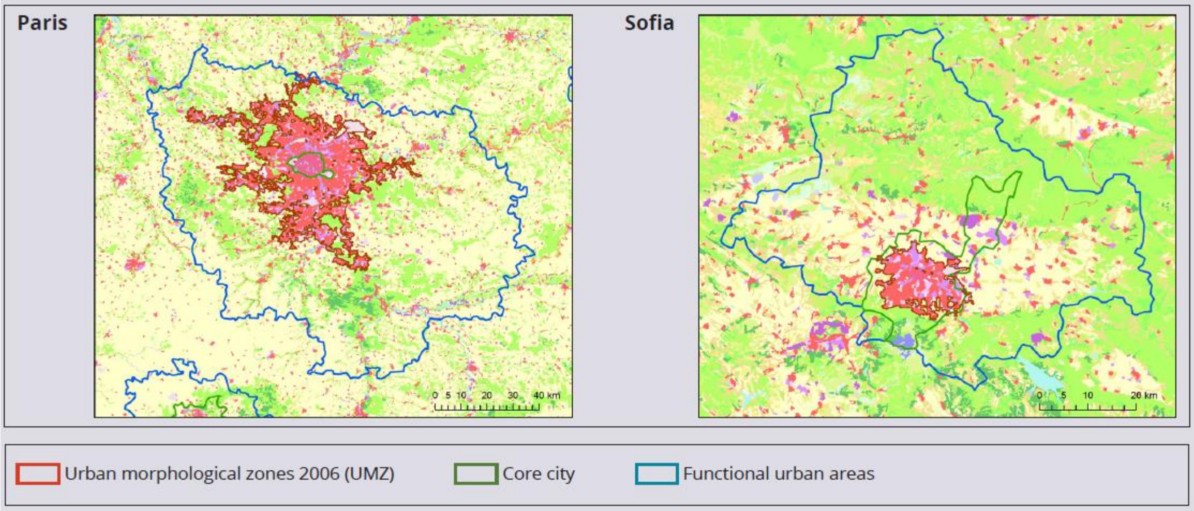
The definition of a city or urban area can differ substantially depending on the question. In this report, we have considered different units:

The Administrative unit (also named core city): Generally, the administrative delineations correspond to the historic city and do not reflect the limit of the building space continuity or the borders of the real economic limits and the real behavioural patterns of people (EC, 2011a). The administrative boundaries are relatively stable entities compared to the ones based on economic, mobility or density patterns. Due to varying structures of local government, the definition of cities varies significantly from country to country.

The Urban Morphological Zone deals with the physical layout of an urban area (EEA, 2010) and is usually larger than the administrative unit. It is the morphological approximation of the “real” city. It describes the urban tissue of an area and the continuity of the artificial space. Generally, land use reflects the human activity on a territory. A city is organised around a densely populated node, characterised by an urban landscape and a historical core.

The Functional Urban Area: The municipality limits are generally too small in spatial terms to be used in the comprehensive analysis of regional and city development trends. The FUA can be explained as the core city plus its associated hinterland. The functional urban region is defined as “a territorial unit resulting from the organisation of social and economic relations within that. Its boundaries do not reflect geographical particularities or historical events. It is thus a functional sub-division of territories.” (OECD, 2002). It defines the travel-to-work catchment and gives an image of the actual role played by a city within and beyond the region in terms of functions. The functional urban region encompasses a system of surrounding towns and villages that are economically and socially linked with the core centre.

Figure 2.2 Relationship between different types of delineations (Paris and Sofia)



Source: CLC2006; UMZ: UMZ 2006 (EEA); Core city and Functional Urban Area: Urban Audit (Eurostat 2010).
http://epp.eurostat.ec.europa.eu/statistics_explained/index.php/File:Defining_the_boundaries_of_the_larger_urban_zone_%E2%80%94_Barcelona_(ES)_and_Zagreb_(HR).PNG (accessed 25 July 2014).

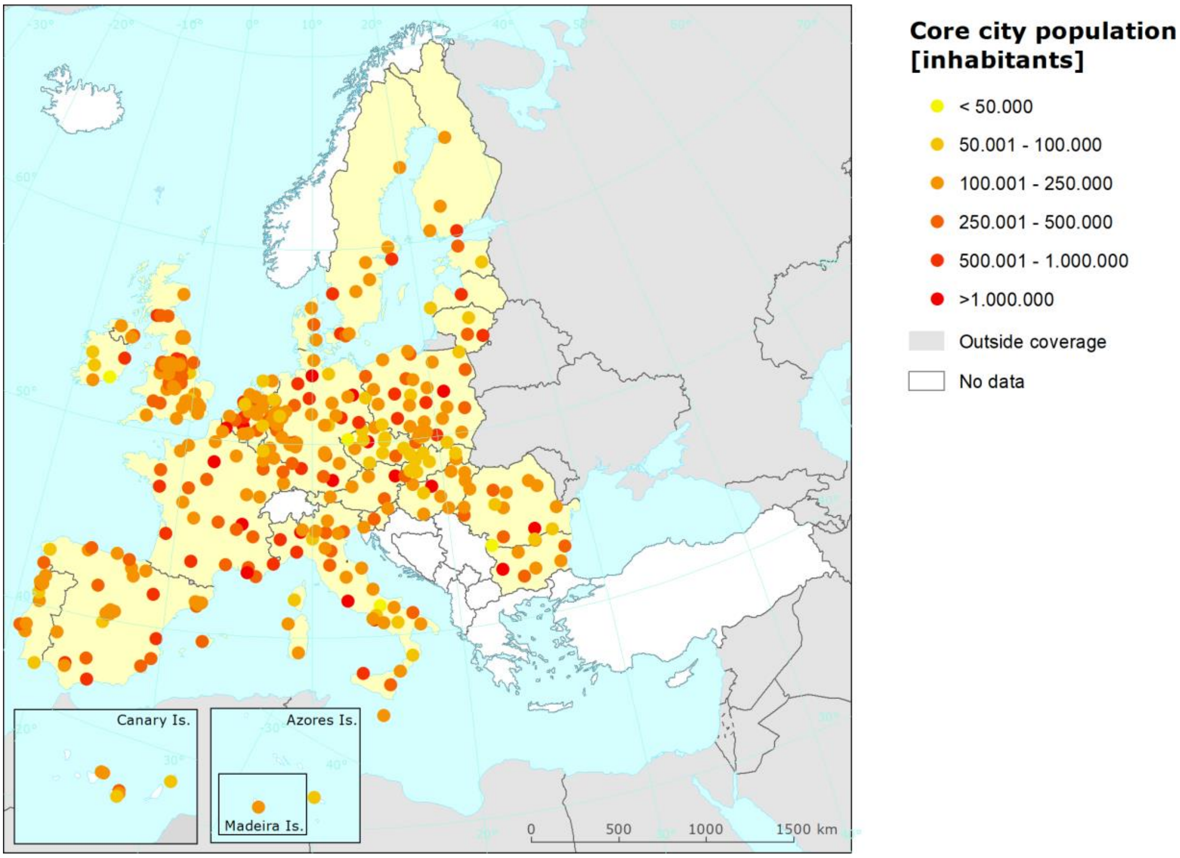
Current situation of urban areas

Small and medium sized cities predominate

Urban areas, defined as cities, towns and suburbs, provide a home to almost three quarters (72 %) of the EU-28's population (EC, 2014). A large part of the urban population lives in cities with between 50 000 and 250 000 inhabitants, spread across Europe which have developed over a long period of time. More than half of the total amount of the cities have less than 150 000 inhabitants. The network of cities is particularly dense in a vast area across Belgium, the Netherlands, western parts of Germany, northern Italy and the southern half of the United Kingdom. This highly urbanised area is also characterised by a long history of industrialisation, with none or only limited environmental regulations, and now plays a dominant role in Europe's economy. Compared with the rest of Europe, per capita income is higher and unemployment rates are lower. Europe's traditional growth axis from London to Milan is commonly known as 'Blue Banana' (Hospers, 2002).

In contrast, the distribution of cities is sparser in Nordic Member States, France and the interior of Spain and Portugal. Some models show greater population increases in the future for Europe's large and medium-sized agglomerations than for its smallest ones (Kabisch and Haase, 2011).

Map 2.1: Population living in European cities (2012)

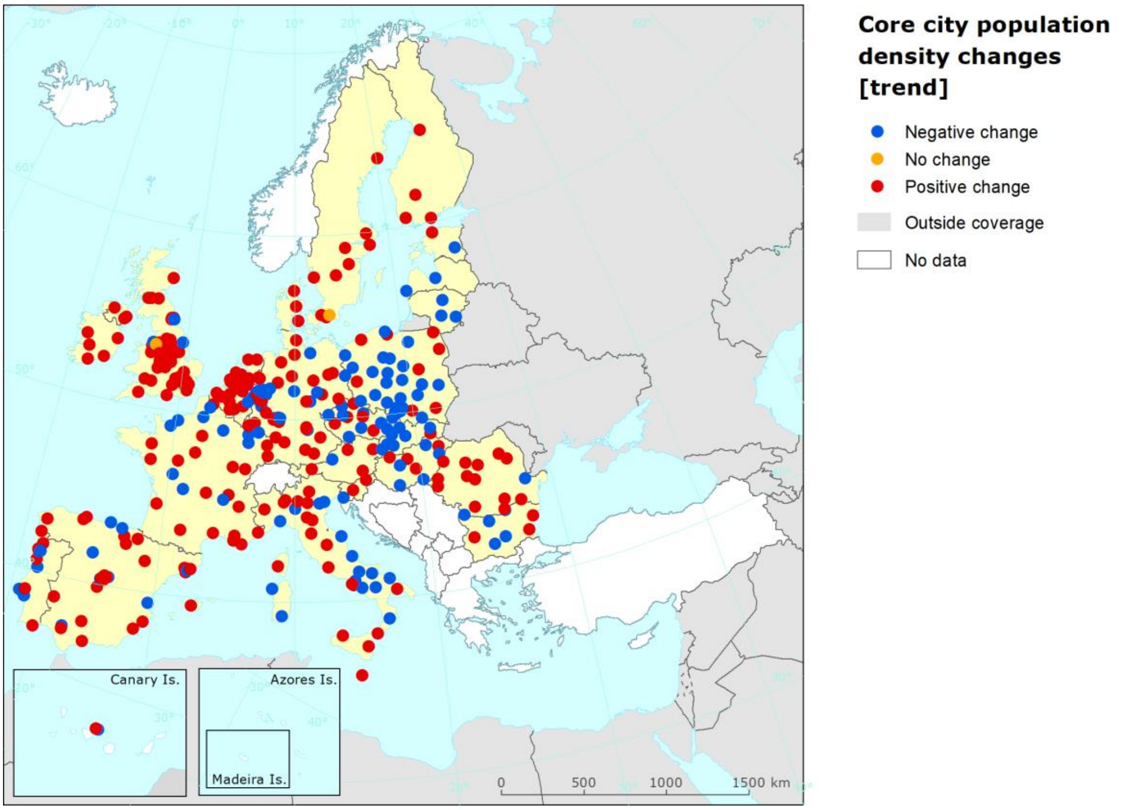


Source: Eurostat, based on the Urban Audit (only cities with more than 100,000 inhabitants considered)

There are only two megacities in Europe (EC and UN-Habitat, 2016). In 2012, the largest functional urban areas were London (12.2 million inhabitants) and Paris (11.8 million inhabitants ([6])), followed by Madrid (6.6 million in 2012), the urban agglomeration of the Ruhrgebiet in Germany ([7]) (5.1 million inhabitants), and Berlin (just over 5 million inhabitants). There are four functional urban areas with between 4 and 5 million inhabitants, all of which are located in the southern EU Member States, namely, Athens (data are for 2009), Rome, Milan and Barcelona (EC and Eurostat, 2015b). However, the number of inhabitants residing in capital cities as a share of national populations grew in the period 2004-2014 in all Member States except Greece (EC and Eurostat, 2016b).

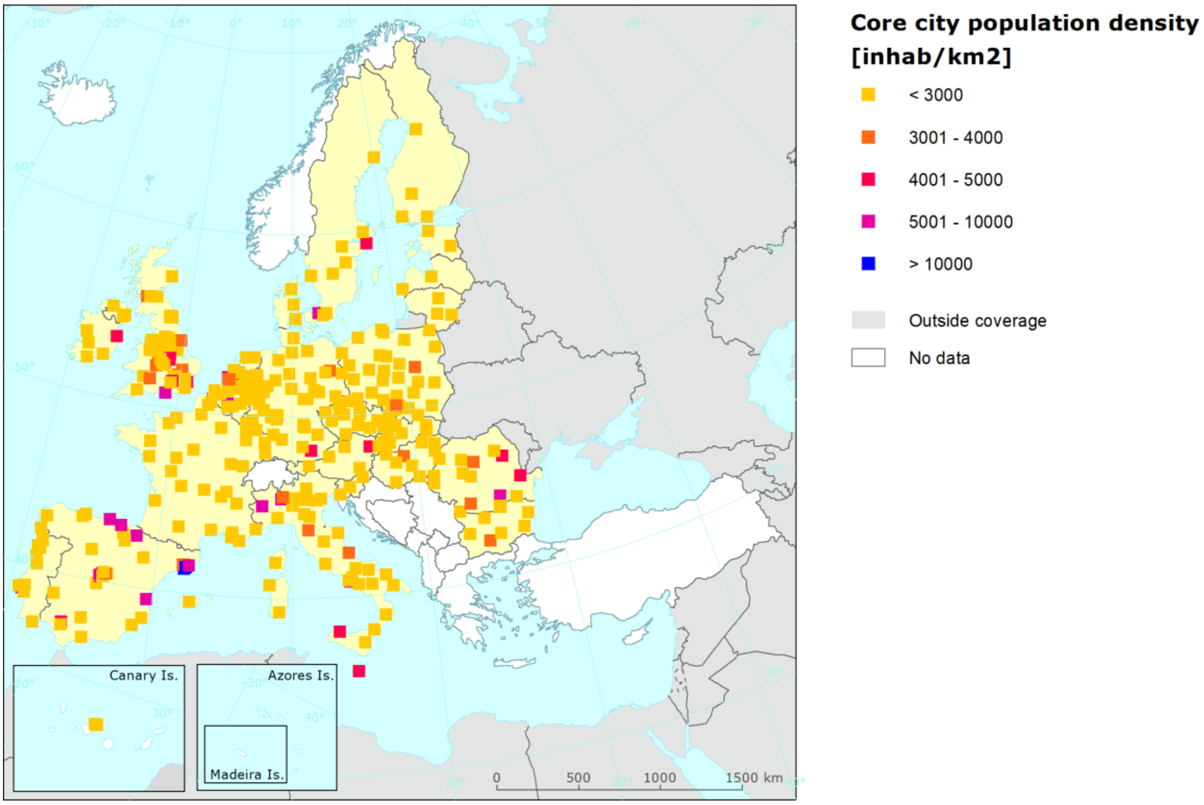
([6]) In 2011.
([7]) The urban agglomeration of the Ruhrgebiet includes, among others, Bochum, Dortmund, Duisburg, Essen and Oberhausen.

Map 2.2: Population changes between 2000 and 2012



Source: Eurostat, based on the Urban Audit (only cities with more than 100,000 inhabitants considered)

Map 2.3: Density of population in Core city



Source: Eurostat, based on the Urban Audit (only cities with more than 100,000 inhabitants considered)

Polycentrism

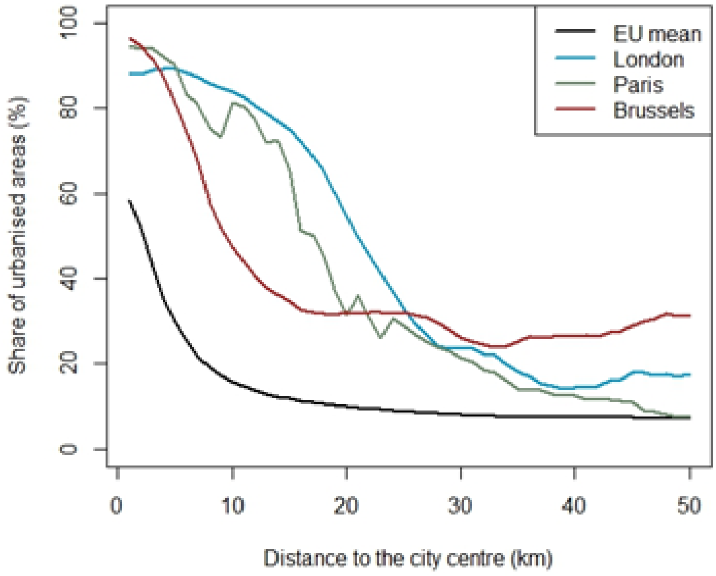
Polycentrism is one of the major characteristics of the current urban landscape. Polycentrism relates to the urban morphology, i.e. the distribution of urban areas in a given territory (number of cities, hierarchy, distribution), and the relations between urban areas, i.e. the networks of flows and cooperation, at proximity or afar (ESPON, 2004). Polycentrism is the opposite of the monocentric model, in which service provision and territorial management is concentrated in a single centre.

Large metropolitan areas have become polycentric and are increasing in complexity (Vasanen, 2012). More and more activities and functions are relocated outside the centres of agglomerations in dynamic sub-centres emerging at the urban edge. Most of the largest cities are embedded in a large network of cities, towns and villages. As a result, concentration of employment and population, and therefore commuting patterns, are modified. In a polycentric model, cities perform different functions. For example, in the Dutch Randstad, Amsterdam is the financial centre, Rotterdam is the main sea port and The Hague is the seat of government (Kloosterman and Musterd, 2001). The form differs depending on the historic form (corridor, radial, ring, etc.) and the geographic location (e.g. valley). Being a polycentric urban region does not necessarily show features of urban sprawl, even though it may include large agricultural or green areas (OECD, 2012). It can simply be a network of compact cities, towns or villages.

Cities with no clear limits

The limit of the city as an administrative area does no longer reflect the physical layout or the socio-economic reality that is better described by the labour market basin, the commuting pattern and the large interconnected urban spatial structure of sub-centres that are economically and socially dependent on the major urban centre (EC — Regional Policy, 2011). The urban structure is becoming more complex and cities are becoming bigger and fuzzier. The distinction between rural and urban is dissolving with the growing sub-urbanisation and commuting, even urban conditions diffuse to non-urban areas through the expansion of transport, telecommunication and utilities infrastructures (Helminen et al., 2012). Typically, European cities are dense but they become less dense (i.e. lower population density, fewer buildings and less infrastructure) the further away one is from the city centre (see Figure 2.3). This transitional area, between urban and rural, is typically split among numbers of administrative areas that complicate the spatial integration of policies and the decision-making process.

Figure 2.3: The urban profile in Europe



Source: Corilis ([8]), 2006 (2000 for Greek cities) based on Corine Land Cover v16.

Graph showing the urbanisation pattern from the city centre to a maximum distance of 50 km from the centre for the Urban Audit's selection of cities of over 50 000 inhabitants. Each line represents the proportion of urbanised area (%) in a 1-km buffer ring from the city centre (centroid of city boundaries, as defined by Urban Audit) for selected cities (London, Paris and Brussels) and the European mean value.

The percentage of built-up areas, in individual bands of 1-km width, is measured from the city centre out to a maximum distance of 50 km. Taking Brussels as an example, roughly 30 % of the 20-km band is built up. On average, for 571 European urban areas over 50 000 inhabitants (Urban Audit's selection), 10 % of the 20-km band is built up.

2.3 Challenges

Key challenges currently faced by cities, that pose a threat to urban sustainability, can be grouped into three major domains: challenges related to (i) health, (ii) the urban environment and (iii) climate change.

2.3.1 Health

Many problems in cities are directly related to urban density. Therefore, the challenge is to develop healthy dense and compact urban areas. In this context air pollution and noise need to be mentioned as major environmental stressors in urban areas. They are mainly caused by road transport, shipping, energy generation, residential heating, industry, agriculture and waste (EC and UN-Habitat, 2016). Health and environment are very closely connected and a green growth economy is required to protect both health and environment.

[8] http://www.eea.europa.eu/data-and-maps/data/corilis-2000-2 accessed 4 November 2015.

Air quality

Poor air quality adversely affects human health and many European cities still struggle with improving their air quality despite some progress (EC and UN-Habitat, 2016). Both short-term and long-term exposure to air pollution harms health. Air pollution is the largest environmental health risk in Europe as it is a key contributor to heart diseases and strokes, both being the most common reasons for premature deaths. Besides that, air pollution induces a wide range of diseases, such as respiratory and cardiovascular diseases and cancer, with both long and short-term health effects (Tainio et al., 2009; EEA, 2015a).

Up to 30 % of Europeans living in cities are exposed to air pollutant levels exceeding EU air quality standards. And around 95 % of Europeans living in cities are exposed to levels of air pollutants deemed damaging to health by the World Health Organization's (WHO) more stringent guidelines (EEA, 2015a). In 2014, estimates of the health impacts attributable to exposure to air pollution indicates that in the EU-28 $PM_{2,5}$ concentrations (long-term exposure) were responsible for about 428 000 premature deaths, NO_2 (long-term exposure) concentrations for 75 000 and 0_3 concentrations (short-term exposure) for 13 600 premature deaths (EEA, 2015a).

Figure 2.4: Percentage of the urban population in the EU-28 exposed to air pollutant concentrations above certain EU and WHO reference concentrations (2011–2013). Source: EEA, 2017.

Pollutant	EU reference value (a)	Exposure estimate (%)	WHO AQG (a)	Exposure estimate (%)
$PM_{2.5}$	Year (25)	7-8	Year (10)	82-85
PM_{10}	Day (50)	16-20	Year (20)	50-62
O_3	8-hour (120)	7-30	8-hour (100)	95-98
NO_2	Year (40)	7-9	Year (40)	7-9
BaP	Year (1)	20-25	Year (0.12) RL	85-91
SO_2	Day (125)	< 1	Day (20)	20-38

Key				
	< 5 %	5-50 %	50-75 %	> 75 %

Notes: (a) In µg/m³; except BaP, in ng/m³.

The reference concentrations include EU limit or target values, WHO air-quality guidelines (AQGs) and an estimated reference level (RL).

For some pollutants, EU legislation allows a limited number of exceedances. This aspect is considered in the compilation of exposure in relation to EU air-quality limit and target values.

The comparison is made for the most stringent EU limit or target values set for the protection of human health. For PM_{10}, the most stringent limit value is for the 24-hour mean concentration and for NO_2 it is the annual mean limit value.

The estimated exposure range refers to the maximum and minimum values observed in a recent 3-year period (2013-2015) and includes variations attributable to meteorology, as dispersion and atmospheric conditions differ from year to year.

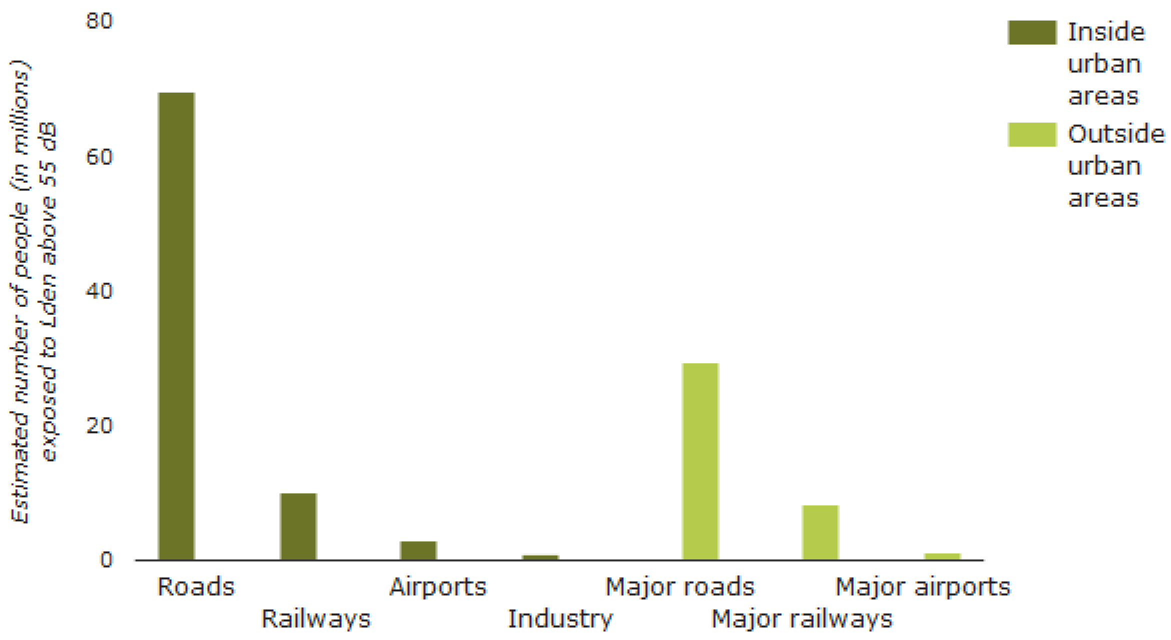
As the WHO has not set AQGs for BaP, the reference level in the table was estimated assuming WHO unit risk for lung cancer for PAH mixtures and an acceptable risk of additional lifetime cancer risk of approximately 1 in 100 000.

Noise

Noise pollution remains a major environmental risk to human health in Europe with road traffic being the dominant source affecting around 100 million people harmfully, i.e. above the threshold level defined in the Environmental Noise Directive (EU, 2002). Other major sources are railway traffic, aircraft noise and industrial noise. (EEA, 2017)

Almost one in four city inhabitants suffers from noise exposure compared to only one in ten inhabitants in rural areas (EC and UN-Habitat, 2016). Noise exposure from transport sources and industry can lead to annoyance, stress reactions, sleep disturbance, and increases in the risk of hypertension and cardiovascular disease. Environmental noise causes approximately 16 600 cases of premature death in Europe each year, with almost 32 million adults estimated to suffer annoyance and over 13 million adults estimated to suffer sleep disturbance (EEA, 2017). The WHO (2011) identified noise as the second most significant environmental cause of ill health, the first being air pollution. The 7th EAP (EU, 2013) includes an objective to significantly decrease noise pollution by 2020, moving closer to WHO recommended levels.

Figure 2.5 Number of people in the EEA-33 member countries exposed to noise levels above 55 dB Lden, 2012 (EEA, 2017).



Source: EEA, 2017

2.3.2 Environmental urban challenges

Diversity of cities and actors is an opportunity for innovation and flexibility. Each city must develop its own integrated approach towards sustainability because solutions have to be tailored to local circumstances, i.e. its own territorial capital. Territorial capital can be seen as the set of localised assets – natural, human, artificial, organizational, relational and cognitive – that constitute the competitive potential of a given territory (Camagni, 2008). Likewise, detecting cities with similar characteristics can help in understanding the potential of changes and the adverse factors. A city may also learn from experiences of similar cities facing the same problems, in particular from front-runners experimenting with innovative solutions.

Most European cities are mature cities that have grown over a long period and today evolve relatively slowly compared to emerging cities. Environmental challenges have to be mastered within existing urban structures. Therefore, urban sustainability in European cities is mainly based on retrofitting existing infrastructure and buildings, conversion of low density into high density areas, upgrading of unsustainable settlements, conversion of underused or abandoned industrial zones, development of green urban spaces including architectonical green infrastructure (green roofs and walls) and high quality public spaces including safe pedestrian and bicycle paths (Faehnle et al., 2015). Changes in dense urban systems are very demanding, since the slightest transformation may generate systemic effects affecting different scales.

Developing green growth

Urban agglomerations are a strategic level for economic growth and developing a green economy (UN Habitat, 2012a). A green economy is characterised by policies and innovations that enable society to generate more value each year, while maintaining the natural systems that sustain it (EEA, 2015d). Cities concentrate consumers, workers, businesses, innovators and the most educated people and are major hubs and nodes for transport networks. Density and proximity provide socio-economic advantages such as economies of scale, agglomeration effect, easy social interactions, efficient infrastructures and services. The challenge is to achieve environmental sustainability while at the same time developing economic prosperity and jobs. There is no opposition between both objectives; it is often underlined that cities with balanced economic growth and environmental quality have better prerequisites to be more productive, competitive, innovative and prosperous (UN Habitat, 2012b).

Transforming urban metabolism

As living organisms, cities require massive natural resources (e.g. raw material, food, water, land) and energy to sustain daily life. The challenge is to develop an urban model using less material, carbon and nutrients as inputs while releasing less emissions, effluents and waste as outputs (EEA, 2015c). Technical solutions alone are not enough to achieve this objective. Minimising the use of resources requires developing better integrated urban planning and urban design (EEA, 2015e). Compactness offers potential to avoid unnecessary land uptake and soil sealing (EEA, 2015e), to diminish the cost of infrastructure development and its maintenance, to reduce the length of the pipes network, and therefore leakages, to reduce car dependency and encourage the use of public transport, walking and cycling, etc. (Ekins et al., 2016). However, the adverse effects of compactness, such as traffic congestion, high energy demands or loss of green and public spaces, should also be considered in planning policies (OECD, 2012). Another way to avoid unnecessary land uptake and soil sealing is brownfield remediation and development.

Limiting urban sprawl

Land provides space for human activities and supports terrestrial ecosystems that provide vital services for urban society. Land use and management are one of the factors determining the capacity of ecosystems to provide these services and to adapt to uncertain future conditions (e.g. climate change, water scarcity, food insecurity). Services provided by terrestrial ecosystems are considerably limited by soil sealing resulting from urban sprawl. The uncontrolled expansion of built-up areas and transport infrastructure around cities generates high rates of land take and soil sealing and degrades soil quality. Soil sealing generates harmful effects such as an increase in the heat island effect in urban areas and a decrease in the infiltration and acceleration of the run-off of water. Urban sprawl, which is characterised by the development of low-density dispersed settlements, contributes to numerous other pressures such as transport congestion, a decline in landscape quality, destruction of highly fertile soils, habitat degradation and social fragmentation (EEA and FOEN, 2016). The challenge is to develop a compact healthy city with a high level of quality of life. That means controlling the urban expansion and developing livability (e.g. green urban areas) through strong urban planning policies (Faehnle et al., 2015).

Box 2.2: Monitoring urban sprawl in Europe

The trend of continuing urbanisation in Europe leads to an increasing need and interest in including indicators of urban sprawl in systems for monitoring sustainable development, the state of the environment, biodiversity and landscape quality. In 2016, the European Environment Agency published a report jointly developed with the Swiss Federal Office for the Environment (FOEN) on Urban sprawl in Europe (EEA and FOEN, 2016). This EEA-FOEN report presents a method of urban sprawl analysis that was developed in and for Switzerland by the Swiss Federal Institute for Forest, Snow and Landscape Research (WSL) and Concordia University, Canada. The analysis is based on the pan-European high-resolution layer which maps the degree of imperviousness and is produced every three years as an EU Copernicus land monitoring service. The EEA-FOEN report investigates the degree of urban sprawl in 32 countries in Europe by considering two points in time (2006 and 2009) at three spatial levels. The three levels include the country level, the NUTS 2 regional level (based on the Nomenclature of Territorial Units for Statistics (NUTS)) and the 1-km² cell level (based on the Land and Ecosystem Accounting (LEAC) grid). The comparison of two points in time allowed an assessment of temporal changes in urban sprawl.

This report uses selected urban sprawl indicators in the cluster analysis. Results from the report investigated at NUTS 2 level complement the results of the cluster analysis of 385 cities and helped to understand causes and consequences of urban sprawl. The level of urban sprawl is largely a function of socio-economic and demographic drivers, and the geophysical context. The increase in urban sprawl has serious environmental, economic and social consequences; it affects natural resources and ecosystem services, and leads to higher costs for provisioning services, such as public transport, and lower social cohesion.

2.3.3 Adapting to climate change

Urban areas will generally experience the same exposures to climate change as surrounding regions. Figure 2.6 presents a graphical overview of how climate impacts affect living, working and moving in cities. However, the urban setting makes all the difference with regard to potential local impacts and urban adaptation is one key element in the preparation of European cities for the future climate (EEA, 2012, 2016b). The replacement of natural vegetation with artificial surfaces and buildings creates unique microclimates altering temperature, moisture, wind direction and rainfall patterns. Differences in urban design and management make cities vulnerable in different ways, even those situated in the same geographic region. Excessive amounts of rain water cannot drain into the ground where a high share of the city's area is imperviously sealed. As a consequence, floods can be triggered or reinforced. A high amount of artificial surfaces results in heat storage and increase of temperatures compared to the surrounding region.

The challenges of climate change require drastic changes in city and regional management, hence, innovative solutions are needed alongside traditional measures (Satterthwaite, 2006; Rosenzweig et al., 2010). Establishing strong spatial planning which stops placing homes, businesses and infrastructure into current but also future risk-prone areas or providing more room for rivers can be an effective and sustainable way to deal with risks complementary to building higher dikes. Keeping public space and buildings cool by using green roofs or walls and providing more shade, rather than air conditioning, saves energy and can make cities even more attractive compared to the surrounding region. Many cities have already taken action to adapt to climate change by e.g. participating in various city initiatives related to adaptation (such as the “Global Covenant of Mayors for Climate and Energy” or UNISDR’s “Making Cities Resilient”), putting a mitigation plan in place, or testing new nature-based solutions (EC and UN-Habitat, 2016). There are, however, many cities that do not possess any strategy. Successful urban adaptation requires actions from stakeholders at many levels (EEA, 2016b).

Figure 2.6 How climate impacts affect urban living, working and moving (EEA, 2016b)

	LIVING	WORKING	MOVING
HEAT	Decreased comfort Health risks Increased energy use for cooling, decreased for heating	Reduced labour productivity Increased energy use for cooling, decreased for heating	Discomfort on public transport Rail buckling Increased energy use for cooling, decreased for heating
FLOODS	Nuisance/health risks Damage to houses Power and water failures	Reduced accessibility Economic asset damage Power and water failures	Blocked roads and rail
WATER SCARCITY	Discomfort Health and safety risks	Reduced productivity Power and water failures	Shipping constraints
WILD FIRES	Health and safety risks Damage to houses	Damage to economic assets	Transport route blockage
STORMS	Nuisance/health risks Damage to houses Power and water failures	Economic asset damage Reduced accessibility Power and water failures	Blocked roads and rail

Note: The examples are not exhaustive and they may not be relevant for all cities.

2.4 Responses to urban challenges

2.4.1 Measures to improve quality of life

Developing more sustainable cities is not just about improving ‘grey’ and ‘green’ (ecological) urban infrastructures, it also relates to social aspects of city life, in particular to people’s satisfaction, experiences and perceptions of the quality of their everyday environments, including people’s health. Therefore, the approach on sustainability taken in this report has a more holistic approach.

Quality of life is a central issue for urban sustainability (EEA, 2009). It is not a simple function of material wealth, but it depends on all social, political and environmental factors that are important for the well-being of citizens. However, the concept is not easy to define or to measure. Quality of life includes personal factors which vary from person to person (e.g. values, expectations, social belonging, physical and mental health, life-phase) and objective characteristics of a place or a society (e.g. wealth, built environment, crime rates, pollution, social rights) that contribute to people’s judgement on their life. In short, the term can mean different things to different people. Generally, several major components make up the quality of life in a city (see Figure 2.7), such as (i) security, (ii) health, (iii) physical environment, (iv) natural resources, goods and services, (v) community development, and (vi) personal development.

Figure 2.7: Quality of life components

Source: adapted from (van Kamp et al., 2003)

2.4.2 Role of urban ecosystems

A city can be considered as an "urban ecosystem" with humans as one component (Pickett et al., 2016). Urban ecosystems are determinant for social well-being and health. Unhealthy urban ecosystems can lead to local and wider environmental degradation, social problems, economic decline, human health problems and further disconnection from nature.

Natural ecosystems, being one component of urban ecosystems, provide ecosystem services that benefit humans directly or indirectly (e.g. conserving biodiversity, protecting water resources, cleaning air, regulating microclimate, supplying fresh food, encouraging recreational activities, educating people about nature). They include different types of services that directly affect people (see Box 2.3). Urban ecosystems will contribute to face environmental issues in the coming decades and to adapt to critical conditions and disturbances (e.g. flood, adaptation to climate change).

Urban ecosystems are multifunctional. A piece of land can bring several functions at the same time: cultural functions (e.g. recreation, visual quality, cultural heritage, education), ecological functions (e.g. thermal regulation, carbon sequestration, water infiltration, biodiversity conservation, nutrient cycling, clean air) and production functions with market value (e.g. agricultural products, food, fibre, biofuel, and medicinal resources).

Box 2.3: Classes of ecosystem services according to the Common International Classification of Ecosystem Services (CICES)

Provisioning services: includes nutrition, materials and energy, such as biomass (e.g. food and fibre), water, and biomass-based and mechanical energy sources;

Regulation and maintenance services: includes the mediation of waste, toxics, nuisances, flows (e.g. bio-remediation, filtration, erosion control, or flood protection) and the maintenance of physical, chemical and biological conditions (e.g. pest and disease control or climate regulation);

Cultural services: the non-material benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation, and aesthetic experience as well as knowledge systems, social relations, and aesthetic values.

Source: (Haines-Young and Potschin, 2012)*, current classification for download at the CICES website (*[9]*)*

At the same time, they are complex, heterogeneous, and dynamic systems (Breuste et al., 2008). Urban green spaces are often small, fragmented and embedded in a built matrix. They are generally highly managed systems, heavily influenced by human activity and ecological functions are often highly interconnected with other functions (e.g. areas for recreational activities). Therefore, green infrastructure (GI), a network of green urban spaces planned and managed to provide benefits through multifunctionality, is crucial for urban sustainability (EC, 2012). GI provides cost-effective and flexible development options that can easily be retrofitted into the existing fabric of the city (EEA, 2015b). In addition, because of the interconnections between cities and the surrounding landscape and the blurring limits between urban and rural areas, a sustainable approach requires to consider the ecology of the landscape beyond the political administrative boundaries of the city (Wu, 2010).

Urban ecosystems are considered in good condition if the living conditions for humans and biodiversity are good (EC, 2016). This mainly means good quality of air, water and soil, a sustainable supply of ecosystem services, species and habitats in good conservation, a high level of urban species diversity and conservation.

2.4.3 Role of urban planning

Citizens' well-being is the focus of quality of life and health is the primary component of the well-being. Health is not simply the absence of disease, but a state of complete physical and mental well-being ([10]). It is linked to every aspect of life. In the urban context, the natural environment is a fundamental factor of health and well-being as well the physical environment (i.e. land use, transportation system, buildings and open spaces) and the social context (e.g. community). Cities are identified as one of the new priorities for the European Environment and Health Process (Kickbusch and Behrendt, 2013).

Environment does not only have a direct impact on health (e.g. bad air quality, contaminated water), but also indirect social and behavioural effects. Consequently, urban planning is increasingly recognised as a determinant factor ([11]) (WHO, 2015). The way it affects health and well-being has been analysed multiple times (Barton, 2009), (Tzoulas et al., 2007). For example, close, safe and walkable green urban areas contribute to increased physical activity, a cycle lanes network encourages the use of bicycles, and liveability of streets can improve communication between people (and therefore social cohesion) (Newman et al., 2016).

Given the complexity of cities, urban health is dependent on many interactions and it is difficult to isolate dependant and independent factors. Intra-urban diversity of the places and people is another factor of complexity. Therefore, urban planning for health is in general based on experimentation, for which the dialogue with stakeholders is essential. Hence, local governments can play a key role in shaping a good place to live for city's residents and developing accessible and well-maintained green

([9]) http://cices.eu/content/uploads/sites/8/2015/09/CICES-V4-3-_-17-01-13a.xlsx
([10]) 1946. Constitution of the World Health Organization WHO, New York.
http://www.who.int/governance/eb/who_constitution_en.pdf accessed 28/07/2016.
([11]) WHO European healthy cities programme.

areas within and around cities. They can influence urban morphology, which in the long run has impacts on air pollution, noise, GHG emissions and fuel consumption (EEA and FOEN, 2016).

2.4.4 The role of policies

Changing cities would have an impact on economy, environment and quality of life of the majority of Europeans. Global and EU policies have already defined ambitious goals and environmental targets that provide the frame for the transformation of urban areas in the coming decades. 2015 and 2016 have been a pivotal period for urban sustainable development at global and European levels. Several commitments should have a real impact on the livability of cities, their urban management, planning and governance. One of the key messages carried out by these global and European agendas is that goals and targets can be used as a driver to manage and govern cities in an integrated and sustainable way.

The following list provides an overview of the most important policies, agreements, declarations and agendas with a relevance for cities, starting on the general global level and continuing down to the more specific European level:

- The New Urban Agenda 'Quito declaration on sustainable cities and human settlements for all' ([12]) adopted at the United Nations Conference on Housing and Sustainable Urban Development (Habitat III held in October 2016) aims at making cities and human settlements more inclusive. The Agenda stresses that sustainability is a driver. For example, tackling air pollution is not only good for people's health, but also to reduce carbon emissions, to increase the use of renewable energy, to provide better and greener public transport, to sustainably manage natural resources, and to develop safe accessible and green public spaces, etc.
- Sustainable Development Goals ([13]): Cities are the only territorial entity with a dedicated SDG goal, i.e. n°11 'Make cities inclusive, safe, resilient and sustainable', but also other goals have direct links to cities (UN, 2015). It is a transformative agenda concerning many domains such as affordable housing, transport system, inclusive urbanization, protection of cultural and natural heritage, reduction of environmental impacts, resource efficiency, mitigation and adaptation to climate change, development of resilience to disasters.
- "The Future We Want": The Rio+20 assembly set the objective of 'a land degradation neutral world in the context of sustainable development' (UN, 2012). Urban sprawl resulting from uncontrolled planning is a major cause of land degradation. So, there is an urgent need of developing integrated urban planning.
- Paris agreement on Climate Change (COP 21) ([14]): The mitigation and adaptation objectives cannot be achieved without cities. On the one hand, residents of cities, especially the rich, are the largest contributors to climate change and will be required to adjust their current lifestyles. On the other hand, climate will affect most residents of cities, particularly the

([12]) https://habitat3.org/the-new-urban-agenda accessed 16 November 2016.

([13]) https://sustainabledevelopment.un.org/sdg11 accessed 16 November 2016.

([14]) http://unfccc.int/paris_agreement/items/9485.php accessed 20 July /2016 and http://unhabitat.org/cop21/ accessed 16 November 2016.

urban poor and vulnerable people. City's governance, dialogue with stakeholders, partnerships and spatial planning are the essential framework for achieving climate objective.

- EU2020 strategy ([15]) for becoming a smart, sustainable and inclusive economy is related to many urban issues. As motor of economy and innovation and home of the youngest population, cities play a key role in implementing EU policies regarding the seven EU 2020's flagship initiatives, in particular regarding innovation, resource efficiency, reduction of greenhouse gas emissions, low-carbon economy, education or the combat against poverty and social exclusion. Cities play a key role in the implementation of many European policies (waste water management, drinking water, air quality, resource efficiency, energy and climate, waste management, etc.).
- 'Living well, within the limits of our planet', the 7th Environment Action Programme to 2020 establishes priority objectives in line with the aforementioned EU 2020 Strategy and the long-term vision for 2050. The most important city-related priority objectives (PO) and targets are:
    - the preservation and enhancement of natural capital (PO 1): ecosystems provide essential goods and services for the economy prosperity and well-being of cities' residents (e.g. fertile soil for food production, good quality fresh water, clean air, climate regulation, flood regulation) (EEA, 2015a). The 2020 Biodiversity Strategy (EC, 2011c) defines actions to reverse the loss of biodiversity and the degradation of ecosystem services. Green infrastructure (EC, 2013) and nature-based solutions are emphasized to enhance ecological and climate resilience, to bring cost-effective solutions, including public health.
    - resource-efficient, green and competitive low-carbon economy (PO 2): the 'Roadmap to a Resource Efficient Europe' (EC, 2011d) gives orientations for the design and implementation of actions for transforming the economy. The objective is to deliver more with less resources. Nutrition, housing and mobility are the sectors responsible for major environmental impacts. Achieving PO 2 also requires the full implementation of the Climate and Energy Package, i.e. 20% cut in greenhouse gas emissions (from 1990 levels), 20% of EU energy from renewables, 20% improvement in energy efficiency (EEA, 2015d), as well moving forward with the Low-Carbon Economy Roadmap towards 2050 (EC, 2011b).
    - Reduction of environment-related pressures and risks to safeguard health and well-being (PO 3): water quality, air pollution levels, noise levels, soil contamination, exposition to hazardous substances are still problematic in some parts of Europe and can significantly affect human health. Many directives and regulations address directly or indirectly health and well-being issues;
    - Enhancing the sustainability of the Union's cities (PO 8): requires in particular to agree on a set of criteria to assess the environmental performance of cities, taking into account economic, social and territorial impacts. It also proposes to develop a common understanding of how to improve urban environments by focusing on objectives related to resource efficiency, low-carbon economy, sustainable urban land-use, sustainable urban mobility, urban biodiversity management, ecosystem resilience, water management, human health, public participation in decision-making and environmental education and awareness.

([15]) http://ec.europa.eu/europe2020/europe-2020-in-a-nutshell/flagship-initiatives/index_en.htm accessed 20/07/2016.

- Cohesion policy ([16]) (period 2014-2020) emphasizes the urban dimension. Already the territorial agenda of the EU 'Towards a more competitive and sustainable Europe of diverse Regions' (Informal Ministerial Meeting on Urban Development and Territorial Cohesion, 2007) introduced the idea of territorial cohesion and identified the issues faced by cities, towns and urban areas. The agenda for a reformed cohesion policy (Barca, 2009) argued that a place-based policy and multi-level governance might be a way to increase efficiency and to tackle persistent issues (e.g. social exclusion). The 2014-2020 period has put the urban dimension at the very heart of Cohesion Policy. At least 50% of the ERDF resources for this period will be invested in urban areas. Cities are empowered to implement integrated strategies for sustainable urban development.
- The Pact of Amsterdam: the Urban Agenda for EU (Informal Meeting of EU Ministers Responsible for urban matters, 2016), a non-binding ministerial declaration, aims to establish a more integrated and coordinated approach to EU policies with a possible impact on urban areas. The main objectives are to develop a more effective and coherent implementation of existing EU policies, to develop more supportive and user-friendly sources of funding for urban areas and to enhance the knowledge base on urban issues. Urban authorities (besides experts of the Commission, Member States, cities and existing networks) are involved in the design of policies through partnerships that will formulate an action plan for currently twelve Priority Themes (air quality, urban poverty, sustainable land use and nature-based solutions, climate adaptation, circular economy, urban mobility, housing, digital transition, energy transition, public procurement, jobs and skills, inclusion of migrants and refugees).

([16]) Priorities for 2014-2020 - http://ec.europa.eu/regional_policy/en/policy/how/priorities/ accessed 25/07/2016.

3 Similarities and diversity of European cities

There exist numerous factors of differences between cities, such as localisation, climate, demography, urban pattern and morphology, density, size, economy, management and planning, territorial identity and culture. Past policies on urban planning and actors, or dynamism of local stakeholders are also major factors that influence cities. Hence, each city is unique and has to find its own pathway towards sustainability given the main opportunities and challenges of the place. Some urban features cannot be changed at all and cities simply have to deal with them (e.g. climate, localisation). Others cannot be changed easily and rapidly. Typically, urban form and patterns of urban fabric are difficult to change. They are determined by topography, physical and structural elements, mainly buildings, transport infrastructure and green assets that have generally been shaped on the long run and result from the city-making over time (EEA, 2015e). At the same time, as a living organism, a city is transformed all the time as a result of individual or public actions.

The environmental performance of cities partly depends on factors that can be changed more easily by effective management and planning, often shorter-lasting or proximity elements that have less inertia over time. The longer-lasting elements of a city usually are structural elements that can only be changed slowly and can impede sustainable urban development (e.g. lock-in effects). Past planning decisions regarding ‘green’ or ‘grey’ infrastructures play an important role when analysing environmental performance of cities. Another constraint relates to those factors that act at scales above the city capability to influence like macroeconomic components linked to national and global trends or climate change.

3.1 Analytical challenges

Grouping challenge

Cities can be more or less similar. When looking at cities at a European perspective, some cities have enough properties in common to be considered as having roughly a comparable potential of transformation. This coarse assumption is acceptable at a European scale given the high number of cities and the lack of information on them.

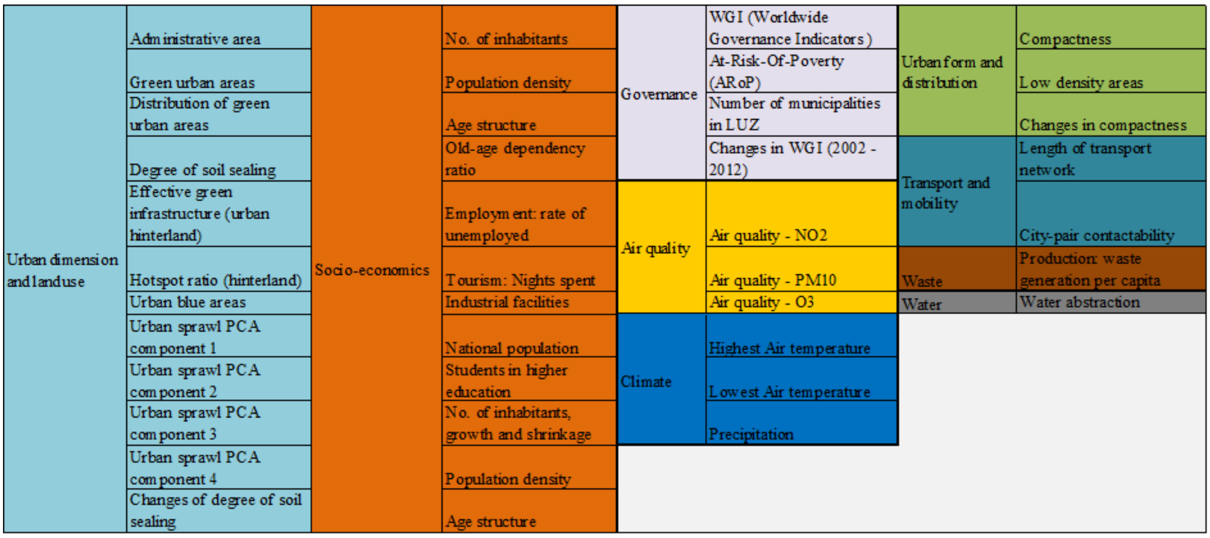
A typology in general is a system to put specific things into groups based on similarities. In this report, 385 cities have been broken down into six clusters or groups of cities (four bigger and 2 smaller clusters, one of the latter two being an outlier) and three sub-clusters for each big cluster. This (statistical) cluster analysis is based on 41 parameters covering a wide range of domains representing a majority of the characteristics that describe the urban system, such as urban dimension and land use, urban form and distribution, climate, air quality, water, waste, transport and mobility, governance, socio-economical and geographical context (see Figure 3.1 and further description of the parameters in Annex 1). To a certain extent, it is a data-driven study. Far from the initial ‘wish’ list, the final selection of data has pragmatically been led by their availability, reliability, quality and the time period (see discussion of the data challenge below).

The typology is understood as both quantitative and qualitative characterisation of cities, which should be structured in hierarchical systems providing a broad view on cities, their situation and basic functions, their individual performance and main activities, their threats and their most important changes (i.e. potential pressures and development paths).

Data challenge

The major difficulty of this approach was to find comparable and relevant data for the same time period and for a significant number of cities. As already alluded to before, the final selection was driven by data availability rather than by analysing all dimensions of urban sustainability. One consequence of this approach was the exclusion of noise data from the END directive, because about 30% of cities that reported data on noise used a different delineation than Urban Audit, and, consequently, the number of comparable cities would be significantly reduced. Likewise, energy data could not be included due to gaps in the coverage. However, given the large number of data and covered domains, this approach can be considered as a good approximation to analysing urban sustainability.

Figure 3.1: Classification of parameters and corresponding domains



The domains land use, urban form and socio-economics are represented with a large variety of different parameters, whereas other domains are under-represented with only a small number of available data (see Figure 3.1). The selected parameters include measured data, wherever available, proxy data and computed data.

The Urban Audit database and the Copernicus Urban Atlas are the main sources. They both cover the same number of cities and areas. 'Urban Audit' is a collection of quantitative information on the quality of life in European cities from Eurostat ([17]). Developed in the frame of Copernicus ([18]), a European system for monitoring the Earth, the 'Urban Atlas' provides a pan-European data set of land use and land cover data for Functional Urban Areas ([19]) (refer to Box 2.1). In 2006, Urban Audit and Urban Atlas included 321 cities from EU-27; in 2012, 697 Functional Urban Areas (most of EU-28 cities over 50,000 inhabitants) are covered. In accordance with the majority of the input data, the general reference year is 2012 whereas changes normally cover the period from 2006 to 2012.

([17]) http://ec.europa.eu/eurostat/web/cities/overview
([18]) http://land.copernicus.eu/ accessed 08/08/2016.
([19]) The Urban Atlas is a joint initiative of the European Commission Directorate-General for Regional and Urban Policy and the Directorate-General for Enterprise and Industry with the support of the European Space Agency and the European Environment Agency.

Box 3.1: Limit of the study: the case of air quality

The results are influenced by the availability of data and the applied method. Hence, it is important to well understand what the results exactly mean. For example, air quality is represented by data for three pollutants, i.e. particulate matter (PM_{10}), ozone (O_3) and nitrogen dioxide (NO_2), for which measurement data are available for a significant number of sampling points and cities. These three pollutants are determinants for health. According to different WHO studies (summarised in WHO, 2016), exposure to PM can cause or aggravate cardiovascular and lung diseases, heart attacks and arrhythmias. It can also affect the central nervous system, the reproductive system and cause cancer. Exposure to high O_3 concentrations can cause breathing problems, trigger asthma, reduce lung function and cause lung diseases. Exposure to NO_2 increases symptoms of bronchitis in asthmatic children and reduces lung function growth. The International Agency for Research on Cancer has classified air pollution in general, as well as PM as a separate component of air pollution mixtures, as carcinogenic (IARC, 2013).

However, the study is based only on urban background stations that are typically representative for the exposure of the general population over several square km. The monitoring is designed to the average exposure of air pollutants to citizens and vegetation within a given area. This means that the pollution levels can be considerably higher or lower at the local scale ([20]). The stations are usually representative for wider areas of at least several square kilometres. This means that a city characterised by a low level of background pollution can at the same time experience a high level of pollution at local level, for example in street canyons or in areas with high levels of congestion.

3.2 Clustering approach

Cluster analysis or clustering is “a statistical procedure that starts with a data set containing information about a sample of entities and attempts to reorganise these entities into relatively homogeneous groups” (Aldenderfer and Blashfield, 1984). The reorganisation of the elements is based on similarity, so clustering can be understood as the task of grouping a set of objects in such a way that objects in the same group (called cluster) are more similar (in some sense or another) to each other than to those in other groups (clusters) (Guo et al., 2002). Similarity is mostly determined by distances, based either on single or multiple dimensions. The targeted clustering (i.e. typology) of European cities was based on a large number of parameters (indicators) and, thus, multiple dimensions. As a consequence, a large number of cluster analysis methods are available, such as hierarchical clustering, k-means algorithms, etc. Although none of these methods have been accepted universally, the K-means algorithm is the most widespread and one of the simplest methods.

In order to conduct the cluster analysis, the data has been gap filled and descriptive statistics, including correlations between parameters, have been calculated. Then, the optimum number of clusters has been identified using dedicated statistical methods. Finally, an interactive combination of expert judgement and the results coming from statistical techniques were applied. The cluster dynamics obtained from the different clustering results (starting from 2 clusters up to 60 clusters) were observed, and analysed; eventually, working with six clusters was identified as optimum for the K-means clustering analysis in the framework of this study.

([20]) From « Guidance on the Commission Implementing Decision laying down rules for Directives 2004/107/EC and 2008/50/EC of the European Parliament and of the Council as regards the reciprocal exchange of information and reporting on ambient air (Decision 2011/850/EU) Version of 15 July 2013”, European Commission, DG, ENV 2013

In data mining, k-means clustering is a cluster analysis method which aims at partitioning n observations into k clusters in which each observation belongs to the cluster with the nearest mean (Aksoy, 2006). K-means clustering is an iterative algorithm and, in general, rather easy to implement and apply even on large data sets. Each of the cluster centres (centroids) and the distances of each of the cities from the centroids are automatically calculated. The characteristics of the cities which are the closest to the cluster centre can be considered as being the most representative for each of the clusters.

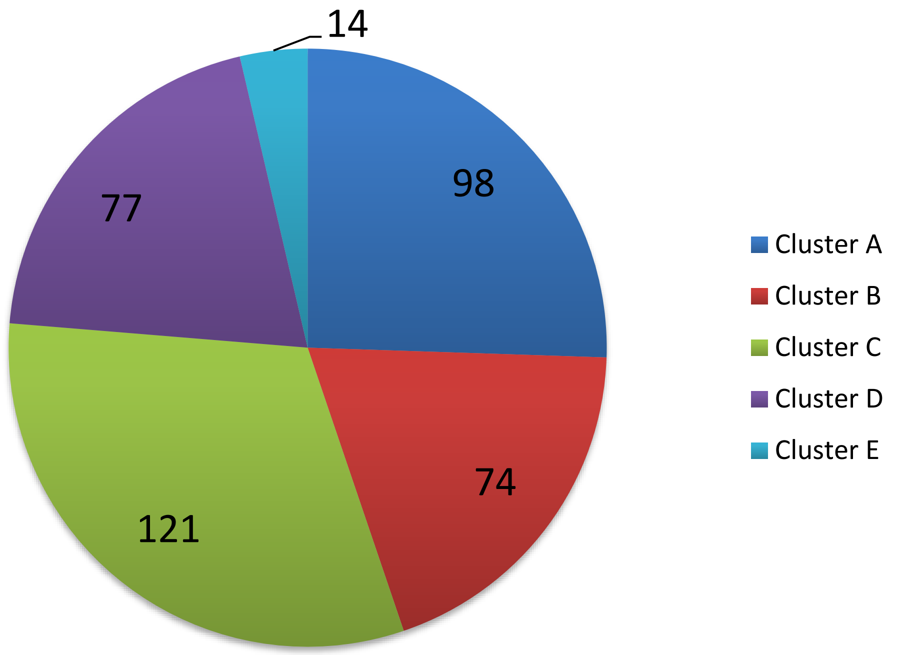
The cities that have the largest distances to the centres are called ”transition cities“ or “outliers”. Those cities might be defined as the cities that are ready to jump to another cluster based on their characteristics or appear alone in a 1-city cluster if we increase the number of the clusters. Both mild and extreme outliers could be observed in all of the clusters. London could even be considered an outlier cluster as it always ended up in a single-city cluster independent of the total number of clusters selected.

3.3 The clusters

Cluster analysis enables to compare cities by using all parameters at the same time. The methodology makes it possible to identify which parameters are of key relevance to distinguish between typologies and which parameters are less relevant. The performed cluster analysis has resulted in the definition of five clusters with distinct characteristics. London always appeared as a very distinctive city and, consequently, has been treated separately from the rest of clusters. The number of cities per cluster varies substantially and ranges from 14 cities (Cluster E) up to 121 cities in the largest Cluster C (see Figure 3.2).

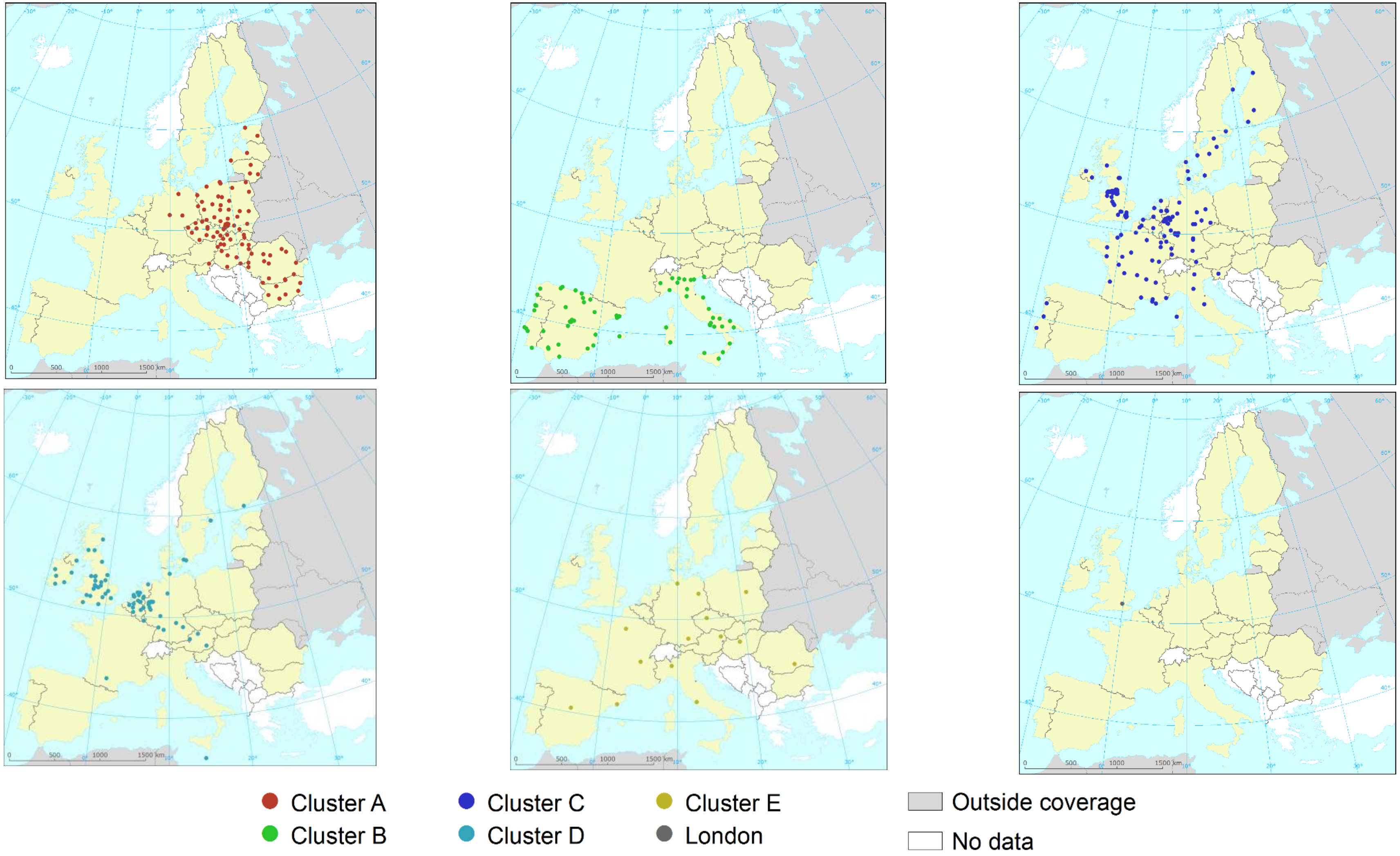
Within each cluster, one city is most representative for the cluster (the one closest to the average of all parameters in the cluster), whereas the so called “outliers” or more dissimilar ones are those that have a higher deviation from the average of the cluster for all parameters. The selected approach tried to take into account complexity and interactions. To better understand the characteristics of the bigger clusters, they were further subdivided into smaller groups using a combination of the most significant cluster-specific parameters and the highest and lowest average values for each of the clusters. The following chapters provide more detailed information on each of the clusters as well as observations and conclusions with respect to the analysis.

Figure 3.2: Number of cities per cluster



<u>Note:</u> The pie chart depicts the distribution of the cities for the five clusters. London as separate entity is missing in this overview.

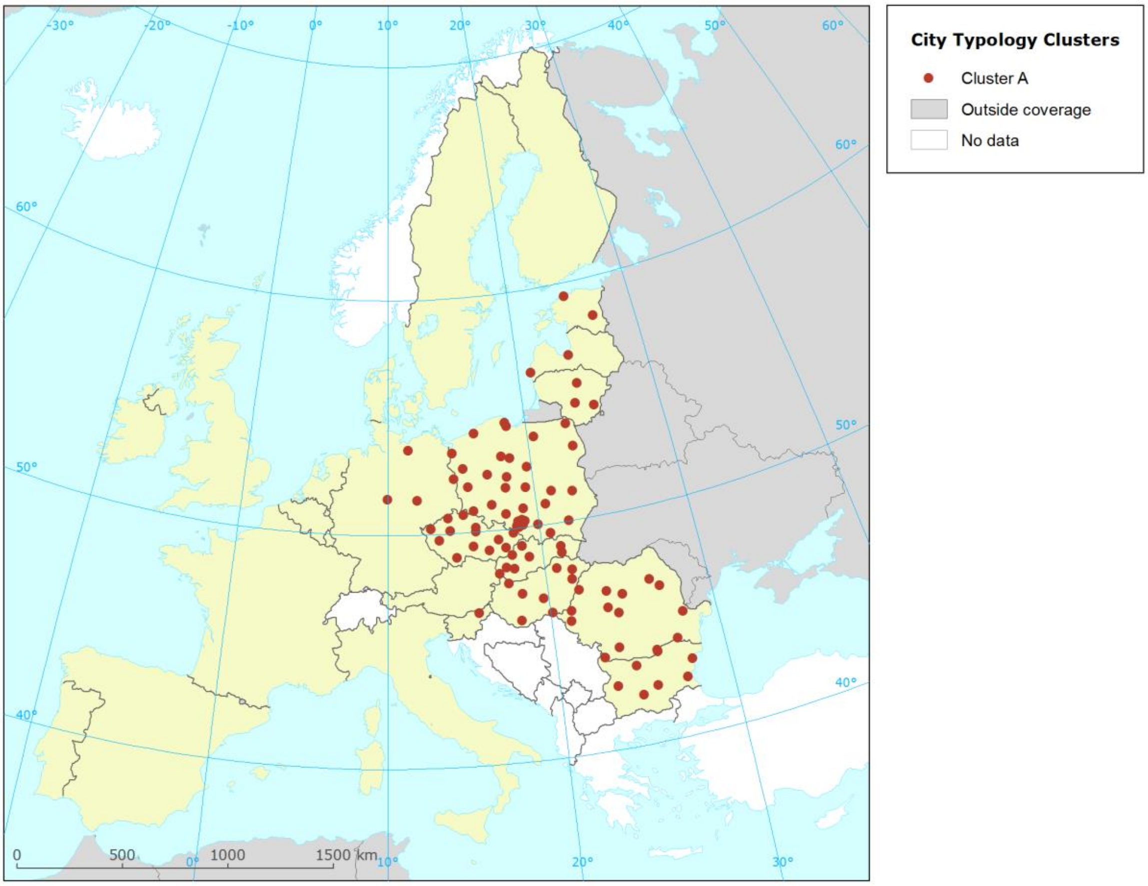
Map 3.1: Spatial distribution of the cities that are clustered according to their typologies



Finally, it needs to be mentioned that a list with all cities contained in the clusters are provided in the Annexes 4-8.

3.3.1 Cluster A

Map 3.2: Localisation of Cluster A cities (Source: EEA/ETC-ULS)



98 cities

(from Estonia, Latvia, Lithuania, Poland, Czech Republic, Slovakia, Slovenia, Hungary, Romania, Bulgaria, Germany)

Most representative city: Torun (PL)

Most dissimilar city: Calarasi (RO)

Significant characteristics:

- Low “lowest air temperature”
- Low “waste generation per capita”
- Low “World Governance Index/Government Effectiveness” (WGI/GE, aggregated index at country level)
- High/positive “changes in WGI/GE”

The first cluster comprises a group of 98 cities almost exclusively located in those countries who were members of the Soviet Union and Eastern Bloc before 1991: Estonia, Latvia, Lithuania, Poland, Czech Republic, Slovakia, Slovenia, Hungary, Romania and Bulgaria. The majority of the countries represented in this group joined the European Union in 2004. Three notable exceptions include Germany (but represented by only three cities in this cluster), who was one of the original EU members post-reunification, and Romania and Bulgaria, who joined in 2007. As a result, Cluster A contains in their large majority cities whose countries have had to deal with very unique governance and economic integration/transition challenges in the last 10 to 25 years.

Photo: Sofia (Bulgaria), © Tuncay Coskun/flickr.com

Cluster A includes a wide variety of cities (see the list of cities in Annex 4) in eleven countries with an average population of 206 800 inhabitants. The most significant indicator for this cluster is related to the World Governance Indicator (WGI) for Government Effectiveness. This indicator, which is provided at national level and captures perceptions of the quality of public and civil services and the degree of its independence from political pressures, as well as the quality of policy formulation and implementation, and the credibility of the government's commitment to such policies, has the lowest mean of all of the city typology clusters but also has a very dramatic range within the cluster ([21]): from -0.31 in Romania to 1.59 in Germany (it has to be noted, though, that only three German cities belong to Cluster A). However, despite having the lowest average Government Effectiveness rate, this is the only city typology cluster that has shown positive change over time, indicating that the overall quality of public services, civil service, and quality of urban management and governance has in general substantially improved since 2002. It is important to highlight that this indicator only reflects the context in which these cities are placed, in terms of governance, since the indicator is provided at country level.

In addition to the WGI-related conditions, cities in this cluster are significantly characterised by low minimum temperatures due to their continental climate caused by their geographic location. Cluster A cities also possess a low waste generation per capita. Moreover, cities in this cluster tend to have a low contactability, i.e. the lowest possibility to connect with other cities by air or rail and have a face to face meeting on the same day (return trips between 5:00 and 23:00). They also have the smallest transportation networks within the city. Many of them have relatively high rates of green urban areas within or around cities, an above-average distribution of green urban areas within the city and very low

([21]) For comparison purposes, the country with the highest WGI Government Effectiveness rate in the study is Finland with a score of 2.21.

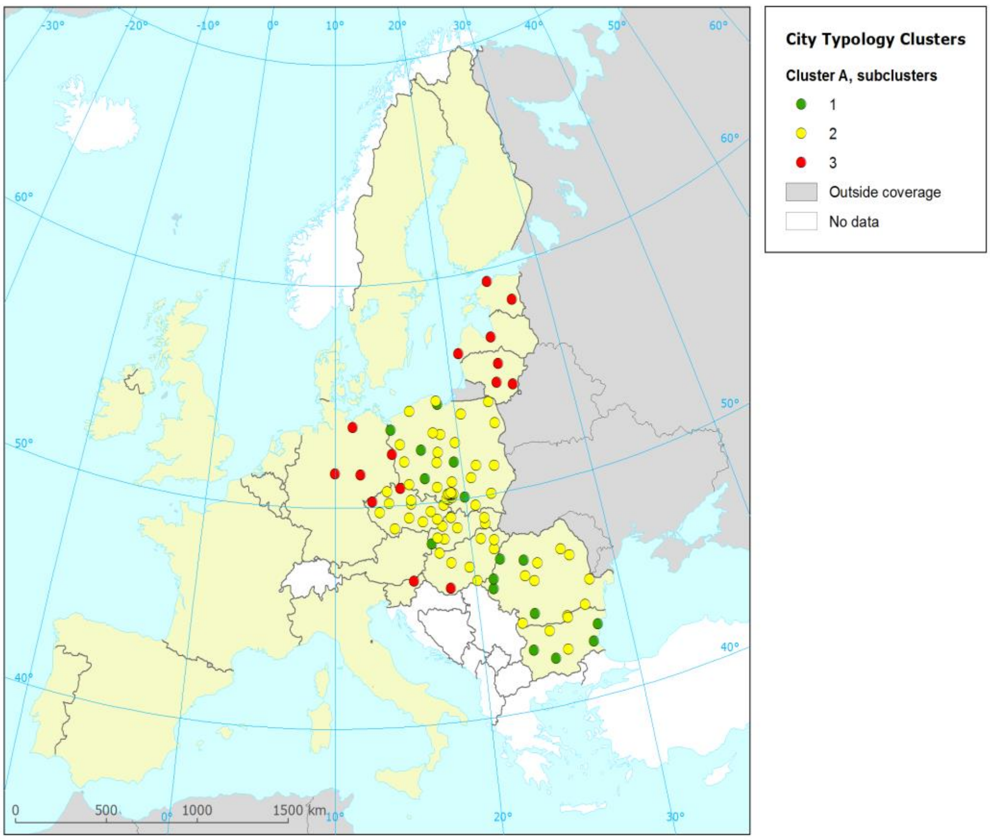
instances of urban encroachment into these areas. 37 % of the Cluster A cities possess a large proportion of urban forest (source: own calculations based on Urban Atlas data). However, although Cluster A cities are relatively "green", half of them are challenged with high air pollution rates, particularly with particulates (PM_{10}) close to EU annual limit value and above the WHO annual guideline value, which is more stringent.

Within-cluster variability: Cluster A sub-clusters

The 98 cities in the "Transition cities from eastern European enlargement countries" cluster were re-clustered into 3 smaller groups. The majority of this cluster is comprised of rural cities; the big cities were captured in the other two clusters that have different significant characteristics:

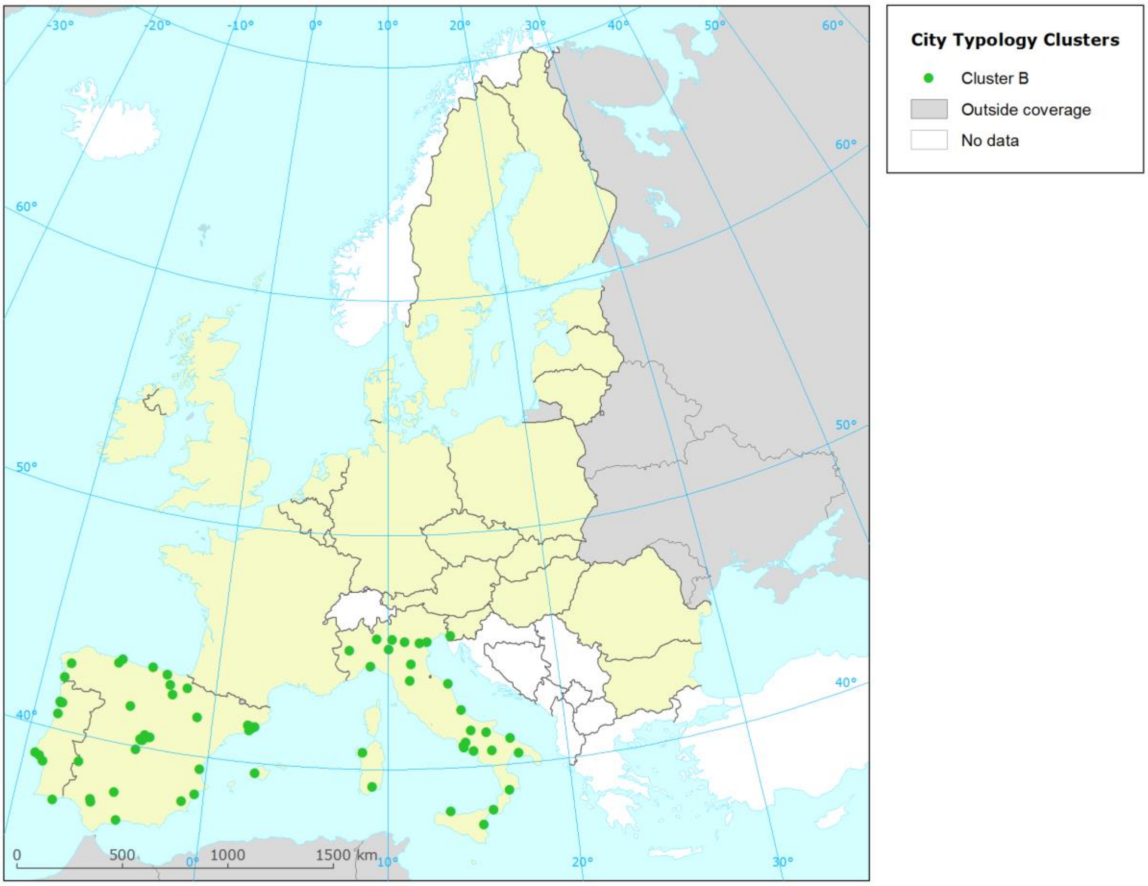
- Sub-cluster 1: 17 cities, majority of which could be catalogued as big cities (Sofia, Krakow, Bratislava, Varna, etc.). They show the highest number of inhabitants and length of transport network (above the Transition cities cluster´s average).
- Sub-cluster 2: 66 cities, mainly rural. They show the highest national population (98.8 %) and lowest urban sprawling values.
- Sub-cluster 3: 15 heterogeneous cities sharing the highest World Governance Indicator (WGI, coming from Germany, the Baltic countries, Czech Republic, Hungary and Slovenia), the highest tourism numbers, the lowest national population, the lowest age structure and the lowest particulate matters (PM_{10}) levels in overall clusters in this study.

Map 3.3: Localisation of cities in the sub-clusters of Cluster A (Source: EEA/ETC-ULS)



3.3.2 *Cluster B*

Map 3.4: Localisation of Cluster B cities (Source: EEA/ETC-ULS)



74 cities (from Spain, Italy, and Portugal)	Significant characteristics:
Most representative city: Salerno (IT) Most dissimilar cities: Potenza, Venezia (IT), L'Hospitalet de Llobregat (ES)	• Mediterranean climate (high "highest air temperature" and high "lowest air temperature") • High unemployment rate • Low/negative "changes in WGI/GE"

Cluster B captures 74 southern European cities (see list of cities in Annex 5) in three countries (Spain, Italy, and Portugal) that were significantly affected by the Global Financial Crisis in 2007, 2008 and 2009 ([22]).

([22]) It is rather likely that a large share of the Greek cities, that are now excluded due to a lack of available data, would also have fallen into this cluster as they share many of the characteristics of Spanish and Portuguese cities.

Photo: Malaga (Spain), © Lukmicity/pixabay.com

This city typology cluster is largely characterized by a generally very high unemployment rate (mean value of 19.3 %) ([23]) and the biggest drop in the countries' government effectiveness between 2002 and 2012, compared with other clusters. National governments in this cluster struggle to provide effective services and accountability. The WGI Government Effectiveness mean for the cluster is 0.84, which is slightly higher than those of Cluster A cities (0.59), but, unlike the cities in the East, the trend for Government Effectiveness has been significantly declining since 2002.

While not statistically significant for the city typology cluster analysis, the Cluster B cities nonetheless have the highest proportion of green infrastructure in the urban periphery and in the hinterland (42%) and the third highest average percentage of green areas in the city cores (63%). Cluster B cities tend to have the highest rates of ozone air pollution in Europe. Ozone levels tend to be particularly high in regions where large quantities of ozone emissions combine with stagnant meteorological conditions (high- or low-pressure systems, locations in valleys, etc.), high levels of solar radiation, and high temperatures during the summer (EEA, 2017). Because of their geographic location in southern European countries (around the Mediterranean Sea or along the coasts of the Atlantic Ocean), the cities of this cluster are the warmest cities in Europe, with the highest average high temperatures and the highest average low temperatures of all of the city typology clusters. The cities in Cluster B also have above-average background concentration of N02 and particulate matters (PM_{10}) air pollution, in 65% of cases above the target value for the protection of human health.

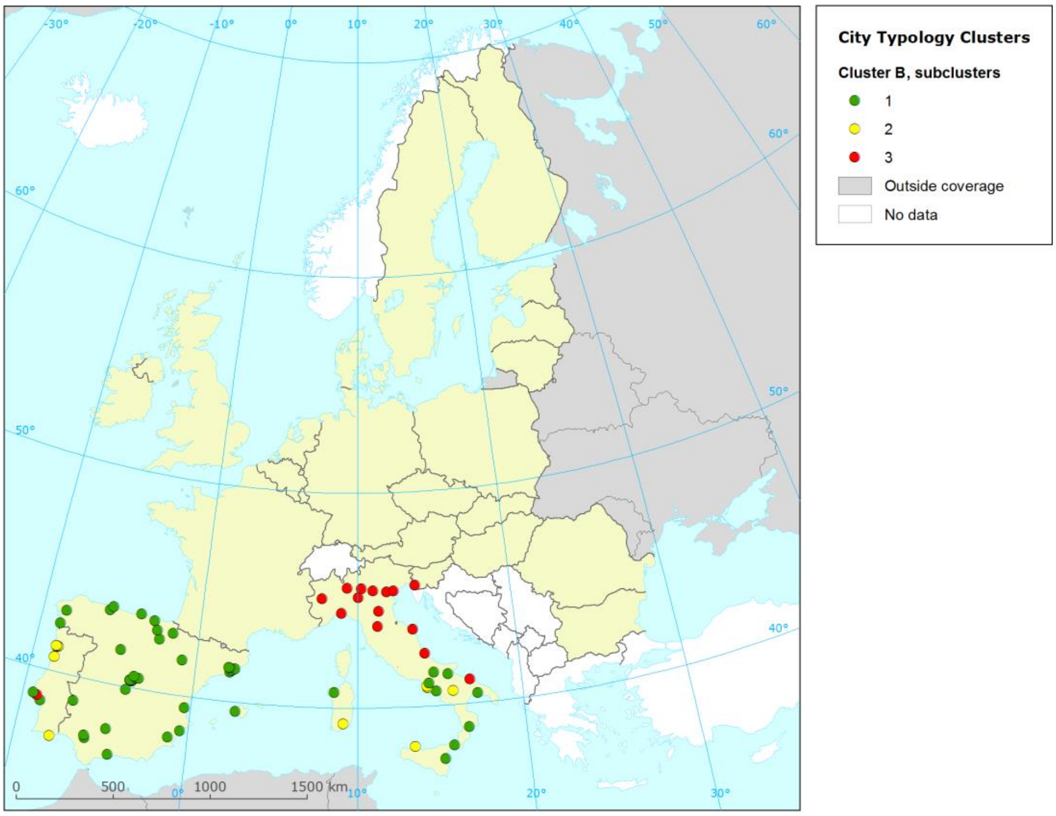
([23]) Years: Spain 2014, Italy and Portugal 2011.

Within-cluster variability: Cluster B sub-clusters

The re-clustering of these 74 cities reveals much clearer groupings, mainly shaped by unemployment rates and different urban sprawl characteristics:

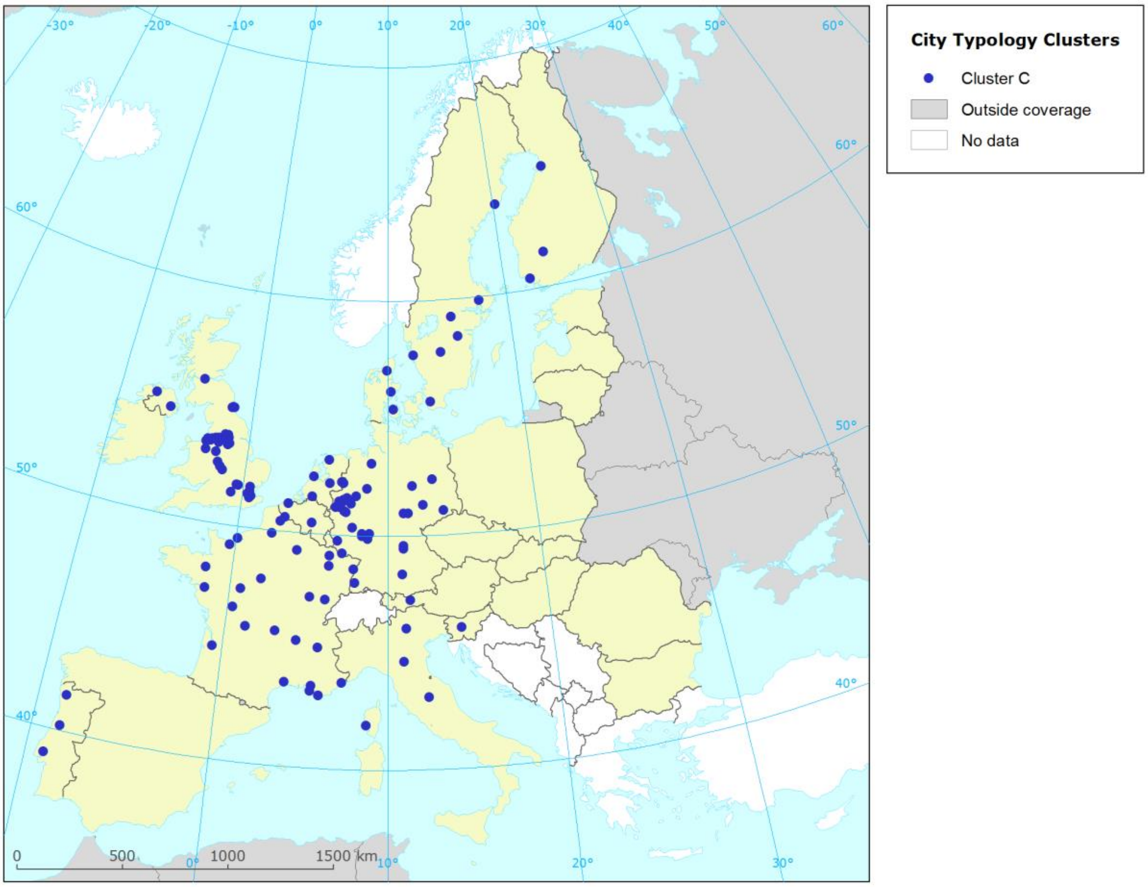
- Sub-cluster 1: 48 cities, including all the Spanish cities, some Portuguese and some from Southern Italy. These cities present the highest unemployment rates (ranging from 13.5% to 38.3%) in all clusters in this study and a low urban sprawl component 3 (sprawl exists, but people do not consume a high amount of surface).
- Sub-cluster 2: 11 cities from Portugal and Southern Italy. Their main difference relies on the urban sprawl pattern: highly dynamic urban areas with low dense developments.
- Sub-cluster 3: 15 cities that comprise Lisbon and cities located in Northern Italy. These cities are either industrialized or port cities; they are characterized by the lowest unemployment rates (8.8%) and the highest old-age dependency ratio (44.5%) in overall clusters in this study.

Map 3.5: Localisation of cities in the sub-clusters of Cluster B (Source: EEA/ETC-ULS)



3.3.3 Cluster C

Map 3.6: Localisation of Cluster C cities (Source: EEA/ETC-ULS)



121 cities (from mostly north-western European countries, exceptions Slovenia, Italy and Portugal)	Significant characteristics: • Low “degree of soil sealing” • Low “air quality – PM10” • High/positive “WGI/GE”
Most representative city: Bielefeld (DE) Most dissimilar cities: Umea, Linkoping, Uppsala (SE)	

Comprised of 121 cities (see list of cities in Annex 6), Cluster C is the largest and most heterogeneous of all of the clusters. The cities have no clear geographic pattern at the European scale and tend to be located in northern central Europe (France, Germany, Belgium, The Netherlands and the United Kingdom), but extend as far north as northern Finland and as far south as Portugal and northern Italy. However, there are some interesting geographic patterns that occur at the national level. For example, 90% of all French cities are in this cluster; only Paris, Lyon and Toulouse are excluded. Over half of all German cities (58%) and UK cities (56%) are in this cluster, as well as over 70% of Swedish, Norwegian, Danish and Finnish cities. The Scandinavian as well as the French cities do contain a substantial proportion of forest within their boundaries.

Photo: Freiburg (Germany), © James Russell/flickr.com

Populations of Cluster C cities range from 63 000 to 1.1 million. They are average to above-average performers in almost every way, but are statistically notable for two specific parameters: high Government Effectiveness (it needs to be reminded, though, that the WGI is given at national level) and the lowest average values of sealed surfaces (mean: 18 %). The latter is complemented by the highest average concentrations of green areas within the city administrative areas (67%). Notably, many of the cities in this cluster have large nature reserves, forests, or agricultural areas within their administrative boundaries, which slightly skew these figures.

The mean rate of Government Effectiveness (WGI/GE) is 1.52, but it varies by country, from 0.41 in Italy to 2.21 in Finland, the highest in Europe. Though the average rate is the third highest, it is skewed by the presence of a few cities in Italy. Italy has the lowest WGI/GE rate in Western Europe (0.41), and is also surpassed by some eastern European countries, like Hungary, Lithuania, Poland, and Slovakia. So, while the Cluster C cities in in the north will not likely have to overcome governance issues, the Italian ones will continue to have challenges with effective governance.

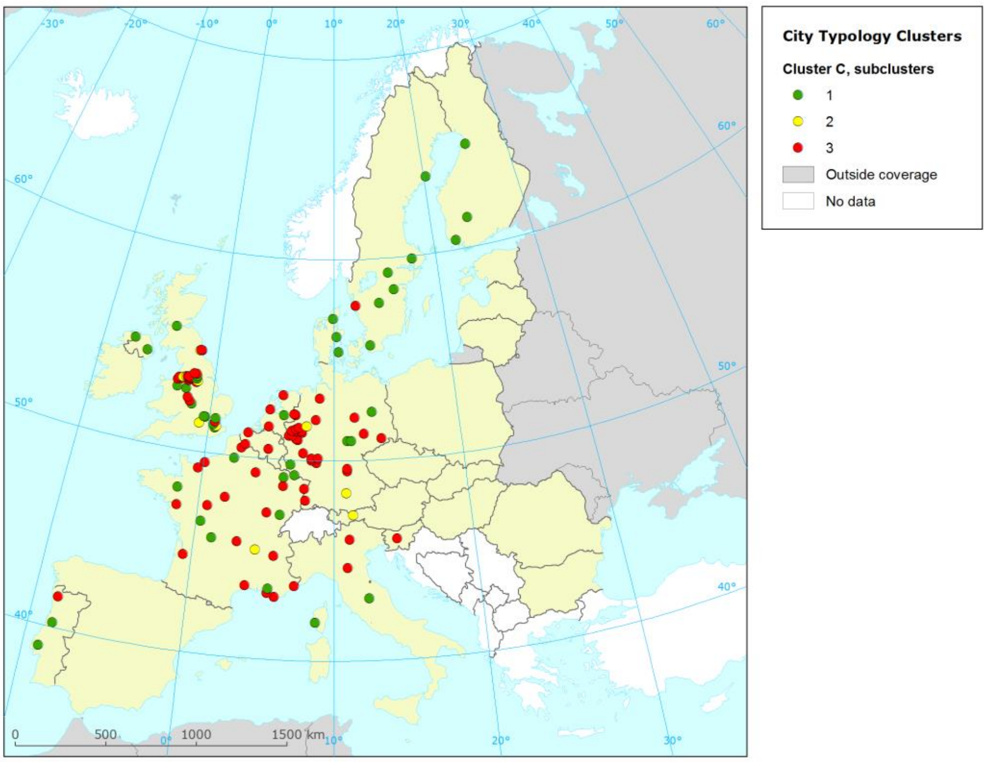
Next to a low degree of sealed surfaces and a high WGI/GE, cities in this cluster are also significantly characterised by low PM_{10} levels. Then, Cluster C cities have the lowest average population densities and their historic urban development patterns tend to reflect this (it is characterised by a sprawling structure and also a very low density with lots of dispersion). Some are knowledge centres with one or more respected universities (e.g., Freiburg, Germany; Sheffield, UK; Lille, France), but compared to other city typology clusters, they have the fewest average number of students in higher education. Moreover, the cities of this cluster are generally the ones with the highest rate of waste generation, that is, they are environmentally conscious (“green”) and at the same time very consumptive.

Within-cluster variability: Cluster C sub-clusters

A re-clustering was applied, as this cluster is the largest and most heterogeneous. No specific geographic concentration was detected and the results were two large clusters and a clearly smaller one:

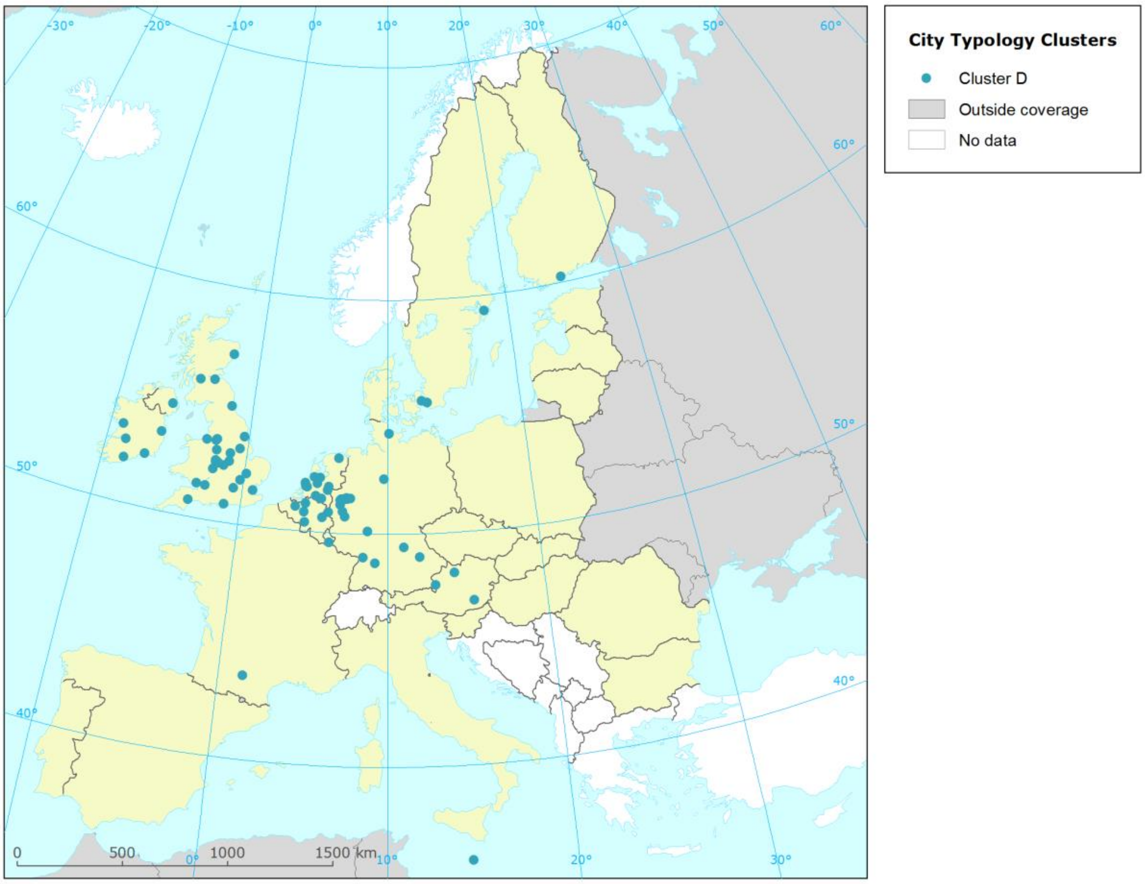
- Sub-cluster 1: Quite homogenous sub-cluster of 42 cities, all sharing a very small population density, very high green urban areas and very small degree of sealed soil. They are specified by the lowest values of population density, with a mean of 505.3 persons/km², the highest concentration of green urban areas (78.9 %) and the lowest degree of sealed soil (8.9 %) of all clusters in this study.
- Sub-cluster 2: 10 cities having in common the lowest changes in compactness (-0.04 %).
- Sub-cluster 3: 69 cities showing opposite values to sub-cluster 1, such as comparably lower levels of urban green areas (59.9 %), higher population density (1462.2/km²) and higher degree of soil sealing (22.9 %).

Map 3.7: Localisation of cities in the sub-clusters of Cluster C (Source: EEA/ETC-ULS)



3.3.4 Cluster D

Map 3.8: Localisation of Cluster D cities (Source: EEA/ETC-ULS)



<table>
<tr><td>77 cities

(mainly from 12 countries on an axis from Ireland to Austria, but also Sweden, Finland, France and Malta)</td><td rowspan="2"><u>Significant characteristics</u>:

• Low “green urban areas”
• High “compactness”
• High “changes age structure”</td></tr>
<tr><td><u>Most representative city</u>: Kiel (DE)

<u>Most dissimilar cities</u>: Almere (NL), Valletta (MT)</td></tr>
</table>

Comprising 77 cities in 12 countries (see the list of cities in Annex 8), Cluster D includes cities like Brussels, Amsterdam, Stockholm, Dusseldorf, Frankfurt, Toulouse, Helsinki, Dublin, Luxembourg, Edinburgh, Manchester and Liverpool. Most of the cities are clustered on a strong northwest-to-southeast axis from Ireland to Austria. The majority of the cities are in the UK (36 %), Germany (22%) and The Netherlands (15%) and tend to be situated on major rivers, harbours, or ports.

Photo: Bristol (United Kingdom), © Harshil Shah/flickr.com

The most striking characteristic of the cities of Cluster D is that it is the only cluster with cities whose populations are not aging. In general, their populations range from 46 700 to 1.1 million. Cluster D cities have the lowest percentage mean value of national population (Eurostat, 86.9 %,) ([24]), making them the most diverse city typology cluster.

Cities of this cluster are among the most compact and urbanised cities in Europe. Compactness values are the highest of all clusters (average of 0.63), whereas the share of green urban areas is very low (39 %). With this comes a high degree of soil sealing, covering the land with concrete and asphalt. However, the spectrum of urban green within the cluster is substantial: from 16 % in Rotterdam (The Netherlands) to 66 % in Malmö (Sweden). They also have the highest average distribution rate of urban green areas (25 m/ha), which could indicate an equitable, well-planned series of town greens, parks, and other green areas within the city core, rather than having large tracts of urban forest or agricultural lands within larger administrative areas. Indeed, Cluster D cities have the smallest average administrative areas of all of the city typology clusters.

They also have the highest mean rating of Government Effectiveness (WGI/GE) of all the clusters. This is attributed to all of the cities being located in politically stable northern European countries. Interestingly, like all of the other city typology clusters except “Transition cities from eastern European enlargement countries”, the perception of government effectiveness has been declining since 2002. The strongest declines were noted in Austria (-0.41), Belgium (-0.40), and Luxemburg (-0.40), but all of the countries experienced some decline in the perception of their effectiveness, except Malta (0.18) and Finland (0.05).

As it is the second fastest growing cluster, cities are challenged with urban sprawl in- and outside of the Urban Morphological Zones (UMZ). Currently, their average population density is substantially lower than that of Cluster E and Cluster B cities. This finding presents an opportunity to slow sprawl by

([24]) Between 2011 and 2014.

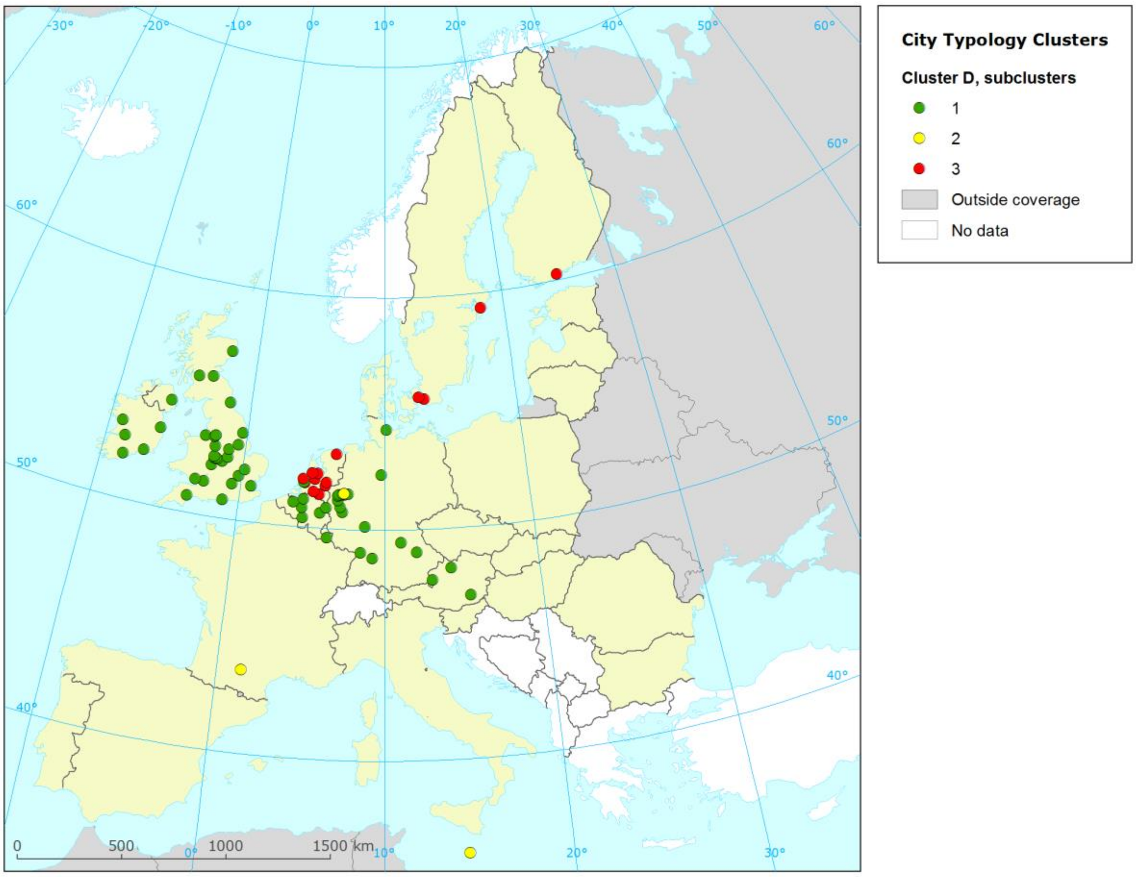
adopting policies that increase population density through infill development (i.e., brownfield development, strategic infill, etc.) and high-density redevelopment, instead of continuing to grow into the urban periphery (EEA, 2017).

Within-cluster variability: Cluster D sub-clusters

The re-clustering of Cluster D resulted in one large sub-cluster and two smaller ones, mainly structured on the basis of governance (WGI) and urban sprawl components:

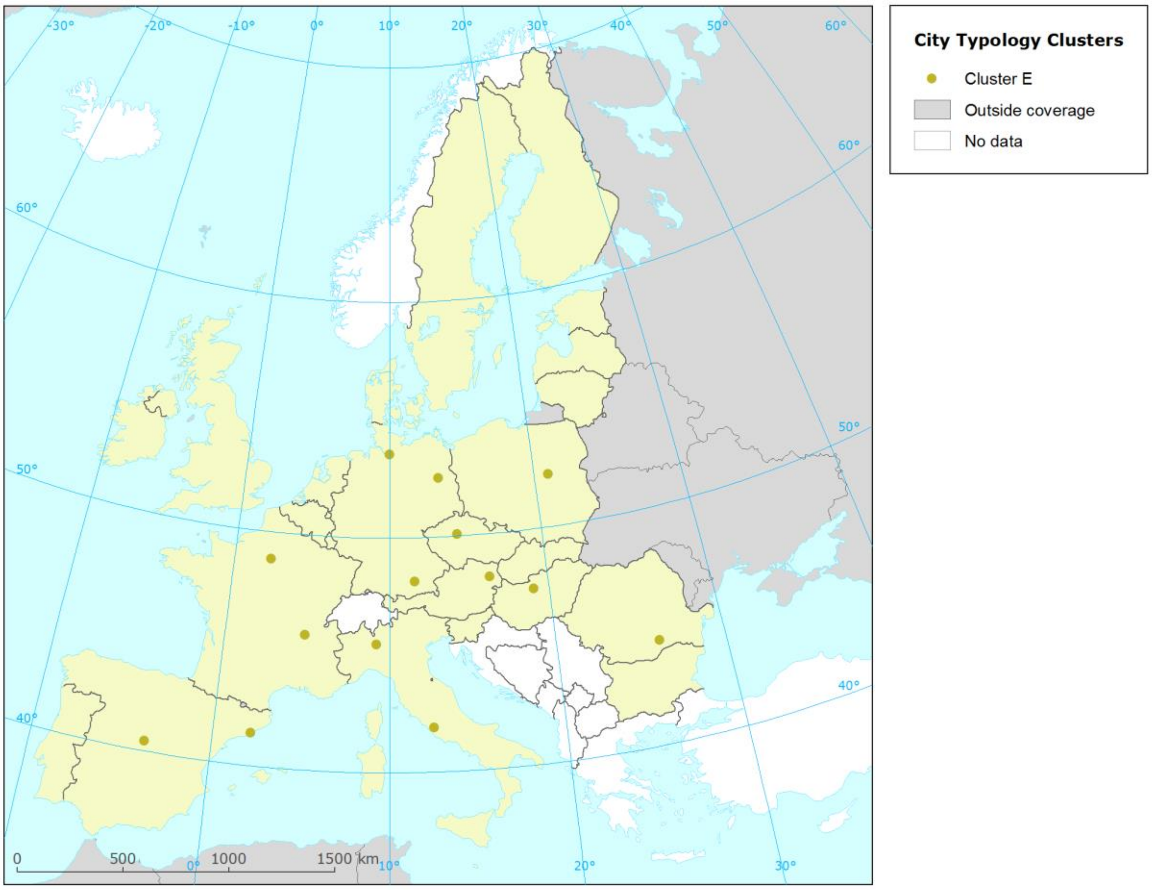
- Sub-cluster 1: 60 cities comprising all UK and Irish cities, among others. They share high levels of urban sprawl with low WGI.
- Sub-cluster 2: 3 cities (Herne, Toulouse and Valletta). They all have in common very high temperature, low precipitation and high hot-spot ratio.
- Sub-cluster 3: 14 cities mostly located in the Netherlands. They have the highest urban sprawl component 1, the highest WGI (1.9), highest levels of urban blue areas (9.7 %) of all clusters in this study and a lower old-age dependency ratio (20.3 %).

Map 3.9: Localisation of cities in the sub-clusters of Cluster D (Source: EEA/ETC-ULS)



3.3.5 Cluster E

Map 3.10: Localisation of Cluster E cities (Source: EEA/ETC-ULS)



<table>
<tr>
<td>14 cities

(Vienna, Prague, Berlin, Hamburg, Munich, Madrid, Barcelona, Paris, Lyon, Budapest, Rome, Milan, Warsaw and Bucharest)</td>
<td rowspan="2"><u>Significant characteristics</u>:

• High “administrative area”
• Low “green urban areas”
• High “degree of soil sealing”
• High “no. of inhabitants”
• High “population density”
• High “students in higher education”
• High “water abstraction”
• High “air quality – NO_2”
• High “length of transport network”
• High “city pair contactability”</td>
</tr>
<tr>
<td><u>Most representative city</u>: Budapest (HU)

<u>Most dissimilar city</u>: Rome (IT)</td>
</tr>
</table>

When one looks at Cluster E, one thinks “large”. Vienna, Prague, Berlin, Hamburg, Munich, Madrid, Barcelona, Paris, Lyon, Budapest, Rome, Milan, Warsaw and Bucharest: 14 cities in nine countries (see list of cities in Annex 7), all large cities or capitals with populations over 1.2 million people.

Photo: Paris (France), © Adrien Sifre/flickr.com

Cities in Cluster E are significant economic, political, education and cultural centres for their regions and for Europe. These highly connected cities have large administrative areas, large numbers of inhabitants and the highest population densities of all clusters, as well as large road and rail networks, and, subsequently, large problems with NO_2 air pollution. In fact, air pollution is one of the greatest challenges for these cities, since reported background NO_2 shows concentrations above the target value for the protection of human health. Particulate matter (PM_{10}) is also high, exceeding the WHO guidelines, although staying below the EU annual limit value.

Important economic centres, they have the lowest unemployment rates mean value (Eurostat, 9.17 %) ([25]) and are also attractive places for students. The percentage of urban green areas varies widely within this cluster, ranging from 22 % in Paris to over 68 % in Rome. Overall, the cities have a below-average mean of urban green areas (42 %) when compared to the other city typology clusters, but this rate is average for cities in the study with populations of over a million people. On the other hand, the cities in this cluster have the by far highest average degree of sealed surfaces of all clusters (43,4 %). Lastly, the average water abstraction rate is more than double as high as the one for the second-highest cluster (2201 million m^3).

3.3.6 London

The city of London, Europe's largest city, is also one of the most visited and celebrated cities in the world. A global financial, industrial and cultural centre, the city is considered to be diverse, young, connected, and growing – quickly! The London megacity ([26]) is big, with over 8.5 million people living in an administrative area that is almost seven times larger than the average of all the other cities in this study. Its density, economic opportunities, mobility options, and innovative local environmental policies (e.g., central city congestion pricing) have contributed to it being one of the most dynamic cities in the

([25]) Depending on the country the cities are located in: Vienna 2013, Prague, Budapest, Rome and Milan 2011, German and Spanish cities as well as Warsaw and Bucharest 2014, Paris and Lyon 2012.

([26]) Paris and its region with around 11 million of people is also a megacity. But Paris is not in the same cluster as London for different reasons. Firstly, the core city of Paris is smaller than the core city of London which covers a large area.

Secondly, the metropolitan area of Paris englobes many cities and covers a large urban area that is surrounded by agricultural land. The extension of the metropolitan area of London extends very far from the core city.

study. It is not surprising then that this global city is an outlier that does not fit into any of the previous clusters and is represented as its own cluster.

Photo: London (United Kingdom), © Mariusz Kluzniak/flickr.com

Effectively managing growth and urban sprawl has been, and will continue to be, one of London's greatest challenges. By 2024, London is expected to add an additional 1.1 million people ([27]), which may test the city's ability to adequately manage sprawl-related urban planning issues, like affordable housing, regional mobility, soil and agricultural lands conservation, and habitat / open space protection. According to our study, London has exhibited the highest trend for urban sprawl of all of the city typology cluster groups, showing development intensity patterns that are correlated with sprawl both inside and outside of the city limits. It has the highest rate of development encroachment into the hinterland and the lowest percentage of green infrastructure in the city's periphery (i.e. green spaces, forests and agricultural areas in the urban hinterland), primarily due to the sheer size of the administrative boundary of the city.

One of its relative weaknesses is its lack of green space in and around the city, when compared to the other city typology clusters. London is well-known for its high-quality city parks and green spaces and is often celebrated as being one of the greenest cities of its size, but it simply cannot compete with the other cities in the study. London has the lowest percentage of green urban areas in the city core (34 %) and the second lowest rate of distribution of green areas. The city is particularly noted for its high rate of soil sealing, where land is capped with impermeable surfaces, like concrete and asphalt. Linked with urban sprawl, soil sealing is an almost irreversible process and development potential inside urban areas should be used instead, through adaptive building reuse, brownfield mitigation, and development intensification along key transportation corridors and in centres ([28]).

([27]) Source: UK, Office for National Statistics, "Statistical bulletin: Subnational population projections for England: 2014-based projections"
([28]) http://ec.europa.eu/environment/soil/sealing_guidelines.htm

London has the second highest Government Effectiveness rate of all of the clusters and has shown no change from 2002-2012. However, the World Governance Indicator (WGI) for Government Effectiveness is measured at the national level and encompasses all of the United Kingdom, so it is not particularly representative of the city, whose governance structures may be managed differently from that of the state.

4 Conclusions

There is a need to better understand the complexity of the cities in order to identify the key elements that contribute, or are an obstacle, to its sustainable development. This report presents the outcomes of a multi-year activity aiming at developing a typology of cities as a tool to reduce this complexity. The pan-European study includes 385 cities, which are part of the Urban Audit database. For reasons of data availability, the study does not cover all domains of urban sustainability, but sheds light on several key environmental elements of it, such as land use, urban form, climate, water, waste, and air quality. In addition, socio-economic and governance-related parameters were included.

For the development and implementation of the city typology 41 parameters from nine thematic domains were grouped into five clusters using a statistical clustering approach. In accordance with the main clustering principles, the groups are created based on similarities, i.e. cities in one group are more similar to each other than to cities from other groups. The closer a city is to the statistical cluster centre, the more stable its position in the cluster; likewise, cities at the edges of clusters can be considered as transition cities that share characteristics of two or more clusters. In addition, this approach allows identifying the key factors that differentiate each cluster and also those factors that appear as relevant in more than one cluster. The main characteristics of each cluster are key for the interpretation of their situation. Looking at the results of the typology, it becomes clear that all five (or six, if London is counted) clusters show specificities that differentiate them from one another and allow creating an interesting picture of European cities.

First of all, London always appears as a stand-alone city that does not belong to any of the other clusters, irrespective of how many clusters were used during the calculation of the typology. This means that London possesses many strong characteristics that sets it apart from all other cities: size, number of inhabitants, urban sprawl problems, relatively few green spaces, high levels of soil sealing. Therefore, London is not considered to be a cluster, but can be counted as an outlier city when compared to all other clusters.

Two clusters have a very strong geographic pattern that is directly related to climatic, political and socio-economic impacts on those cities that shaped their urban development in the recent and more distant past. Cluster A is almost exclusively composed of cities from the former Eastern Bloc, i.e. the former socialist or communist countries in eastern Europe. In the past years, they all experienced a strong population loss and today consist of a young population with a very low share of foreign inhabitants. The common political past is obviously the main reason for them being in one cluster. Only the capital cities of four of those countries (i.e. Warsaw, Prague, Budapest and Bucharest) have managed to develop into economically attractive metropolitan cities and are therefore located in Cluster E.

The second cluster with a clear geographical pattern is Cluster B that consists of cities of three Mediterranean countries, Portugal, Spain and Italy. It needs to be reminded that it is rather likely that a large share of the Greek cities, which are now excluded due to a lack of available data, would also have fallen into this cluster as they share many of the characteristics of Spanish and Portuguese cities. Due to the urban development history, Mediterranean cities tend to be very compact and are very much characterised by their specific climatic conditions. However, it is likely that the most determinant factor for their grouping is the impact of the financial crisis of the years 2007 to 2009 on their inhabitants. The cities of this cluster have the highest unemployment rates, the strongest decrease in their government effectiveness and the highest old-age dependency, i.e. the highest proportions of older citizens. By consequence, they also possess the highest at-risk of-poverty rate.

While the largest Cluster C is the most heterogeneous one and does also not show a clear geographical pattern, it is the group with the highest share of green spaces, but at the same time experiencing a sprawling, low-density development pattern. On the other hand, Cluster D, which is also geographically heterogeneous, possesses the highest government effectiveness index and is the only cluster with cities which do not have an aging population. This is most likely due to their attractiveness as university and economically active cities. Finally, Cluster E consists of some of the biggest cities in Europe and shows the lowest unemployment and at-risk-of-poverty rates, so is a kind of antidote to the "Mediterranean cities with socio-economic challenges" cluster. With only 14 cities, it moreover could be considered a second-tier cluster to the London outlier as these cities also have very remarkable and similar characteristics that set them apart from the large majority of the cities, but group them into a distinct cluster.

Despite the data limitations, the results of the typology present a very relevant and applicable picture of European cities. They clearly demonstrate their commonalities and differences that are the result of differing development paths which are or were caused by mostly socio-economic drivers, such as the financial crisis. It is also helpful to identify the role of the historical development and also the inertia of the cities, in shaping the current state regarding their challenges to urban sustainability. Based on the analysis of the current status of cities with respect to their environmental sustainability, it will be important to monitor the development in the future and identify their trajectories. Although each city has its own challenges, it will make more sense to analyse them within and compared to their peers inside the groups. In addition, cities of the same group may be stimulated to collaborate on common projects. With a particular look at the specific challenges cities are facing (see chapter 2.3), the typology confirms that many European cities are confronted with air quality issues that require quick and sustainable attention. It should be noted that large number of cities are still experiencing background concentrations above the target value for the protection of human health (e.g. half of the Transition cities are challenged by PM_{10}, Mediterranean cities by NO_2, also metropolitan cities).

The development of a monitoring system will be part of the upcoming EEA activities with respect to creating a system to assess the evolution of the urban system. This development also needs to identify sources for missing or insufficient data from e.g. the noise, energy, waste, water, governance or socio-economic domains. During this study, gap filling using national sources was partly possible, but very time consuming. Enhancing the collaboration with Eurostat could be one solution; increasing the use of other existing data (such as reporting data from the Urban Waste Water Directive, noise and waste reporting mechanisms or big data in the fields of tourism or transport) another. Next to these mostly statistical data sources, spatial data, such as those coming from the Copernicus Programme, can help to provide land use/land cover-related time series data. In addition, the methodology to calculate and analyse the changes needs to be developed and tested. Concluding, this study provides extensive and relevant information for filling knowledge and information gaps on the environmental performance of cities on a European level using cluster analysis, typologies and indicators. Therefore, it contributes to both the 7th EAP priority objective 5 on the need for knowledge and information and priority objective 8 asking for the development of a set of indicators for urban sustainability. Because of several, to a large extent data-related issues, further research is needed. However, this study provides a sound basis for European analysis and follow-up work.

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Annex A1: List of parameters used for cluster analysis

Indicator Alias	Reference Area	Reference Year	Indicator Unit	Data Source
Administrative area/Core city area	core_city	2004	km²	LAU layer (EuroBoundary Map)
Green urban areas	core_city	2006	%	ETC-SIA (based on Urban Atlas 2006)
Distribution of green urban areas	core_city	2006	m/ha	ETC-ULS (based on Urban Atlas 2006)
Degree of soil sealing	core_city	2009	%	ETC-ULS (based on HRL Imperviousness)
Changes of S1-6	core_city	2006-2009	%	ETC-ULS (based on HRL Imperviousness)
Urban sprawl indicator, PCA component 1 (29)	LUZ/UMZ	2009	UPU/m2	ETC-ULS (based on HRL Imperviousness)
Urban sprawl indicator, PCA component 2	LUZ/UMZ	2009	UPU/m2	ETC-ULS (based on HRL Imperviousness)
Urban sprawl indicator, PCA component 3	LUZ/UMZ	2009	%	ETC-ULS (based on HRL Imperviousness)
Urban sprawl indicator, PCA component 4	LUZ/UMZ	2009	UPU/m2	ETC-ULS (based on HRL Imperviousness)
Effective green infrastructure (urban hinterland)	buffer rings around city	2006	%	ETC-ULS (based on CLC2006)
Hotspot ratio (hinterland)	buffer rings around city	2006	%	ETC-ULS (based on CLC2006)
Urban blue areas	core_city	2006	%	ETC-ULS (based on Urban Atlas 2006)
Compactness	core_city	2006	%	ETC-ULS (based on Urban Atlas boundaries)
Low sealed areas	core_city	2006	%	ETC-ULS (based on Urban Atlas 2006)
Changes in S2-1	core_city	2000-2006	%	ETC-ULS (based on Urban Atlas boundaries)
Highest Air temperature	core_city	2011	°C	Urban Audit
Lowest Air temperature	core_city	2011	°C	Urban Audit
Precipitation	core_city	2011	mm	Urban Audit

(29) Further explanation on the principal components below.

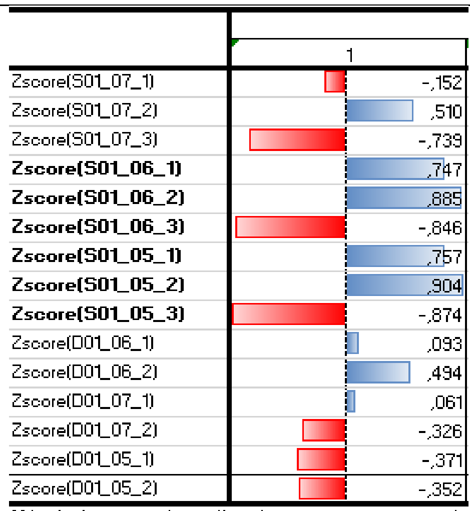
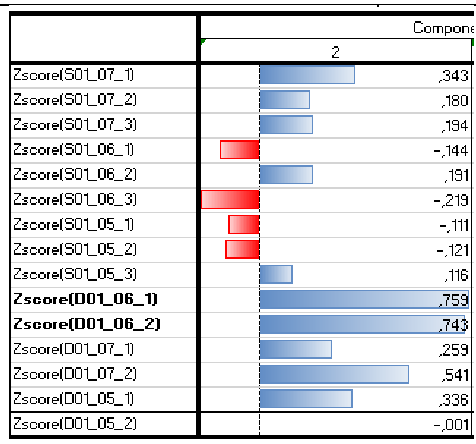
No. of inhabitants	core_city	2008-2015	persons	Urban Audit and local/national data
Population density	core_city	2008-2015	persons/km2	Urban Audit
Age structure	core_city	2008-2015	%	Urban Audit
Changes No. of inhabitants, growth and shrinkage	core_city	2006-2015	%	Urban Audit
Changes Population density	core_city	2008-2015	%	Urban Audit
Changes Age structure	core_city	2008-2015	absolute change	Urban Audit
Old-age dependency ratio	core_city	2008-2015	%	Urban Audit and Worldbank
Employment: rate of unemployed	core_city	2008-2015	rate	Urban Audit and local/national data
Tourism: Nights spent	NUTS3	2008-2014	%	Urban Audit and local/national data
Industrial facilities	core_city	2016	Number of the industrial facilities	Urban Audit
National population	core_city	2008-2015	%	Urban Audit and local/national data
Students in higher education	cities and greater cities	2009-2016	Number of students	Urban Audit (+ local/national data)
Waste generation per capita	core_city	AVG2007-2009	T/person	Urban Audit
Water abstraction	watershed	2002-2012	million m3	ETC-ULS (based on EEA Water Accounts)
Air quality - NO2	AirBase v9	2006	µg/m3	ETC-ULS (based on EEA AirBase)
Air quality - PM10	AirBase v9	2006	concentration with ug/cm3	ETC-ULS (based on EEA AirBase)
Air quality - O3	AirBase v9	2006	µg/m3	ETC-ULS (based on EEA AirBase)
Length of transport network	core_city	2006	km²	Eurostat: Networks
City-pair contactability	core_city	2009	Number of the cities	ESPON Database (FOCI Project)
WGI (Worldwide Governance Indicators)	NUTS0	2012	Index	Worldbank
Changes in S12-4 (2002 - 2012)	NUTS0	2002_2012	Index	ETC-ULS (based on Worldbank)
At-Risk-Of-Poverty (ARoP)	NUTS3	2008-2011	rate	ESPON Database (TIPSE Project)
Number of municipalities in LUZ	LUZ	2004	Number of the LAUs	ETC-ULS calculation (based on Urban Audit)

Because of the over representation of the urban sprawl indicators in an initial version of the database, a Principal Components Analysis was applied to reduce the 15 urban sprawl parameters (see tables in Annex 2 and Annex 3 below).

Annex A2: Urban sprawl indicators

Indicator	Description	Reference Area	Unit
S01_05_1	Dispersion inside UMZ (DIS)	LUZ/UMZ	UPU/m2
S01_05_2	Dispersion outside UMZ (DIS)	LUZ/UMZ	UPU/m2
S01_05_3	Difference of Dispersion (DIS)	LUZ/UMZ	%
S01_06_1	Urban permeation inside UMZ (UP)	LUZ/UMZ	UPU/m2
S01_06_2	Urban permeation outside (UP)	LUZ/UMZ	UPU/m2
S01_06_3	Difference of Urban permeation (UP)	LUZ/UMZ	%
S01_07_1	Land uptake per person inside UMZ (LUP)	LUZ/UMZ	m2
S01_07_2	Land uptake per person outside UMZ (LUP)	LUZ/UMZ	m2
S01_07_3	Difference of Land uptake per person (LUP)	LUZ/UMZ	%
D01_05_1	Change of Dispersion inside UMZ (DIS-DIF)	LUZ/UMZ	UPU/m2
D01_05_2	Change of Dispersion outside UMZ (DIS-DIF)	LUZ/UMZ	UPU/m2
D01_06_1	Change of Urban permeation inside UMZ (UP-DIF)	LUZ/UMZ	UPU/m2
D01_06_2	Change of Urban permeation outside UMZ (UP-DIF)	LUZ/UMZ	UPU/m2
D01_07_1	Change of Land uptake per person inside UMZ (LUP-DIF)	LUZ/UMZ	m2
D01_07_2	Change of Land uptake per person outside UMZ (LUP-DIF)	LUZ/UMZ	m2

Annex A3: Descriptions of the PCA components

PCA Component 1 "Sprawling cities"	1st component indicates high level of urban permeation and dispersion both inside and outside UMZ and the difference between inside and outside. To a lesser extent, it also indicates land take outside UMZ. Those two parameters are somewhat correlated as DIS is one of the two input variables in the formula for calculating UP (the other being percentage of built-up area PBA). In conclusion, this component clearly relates to sprawling cities whereby sprawl happens to a similar degree both inside and outside of the UMZ, so; high values for this component will be related to sprawled cities (all the relevant parameters could be interpreted in that direction).	 1 Zscore(S01_07_1) -,152 Zscore(S01_07_2) ,510 Zscore(S01_07_3) -,739 **Zscore(S01_06_1)** ,747 **Zscore(S01_06_2)** ,885 **Zscore(S01_06_3)** -,846 **Zscore(S01_05_1)** ,757 **Zscore(S01_05_2)** ,904 **Zscore(S01_05_3)** -,874 Zscore(D01_06_1) ,093 Zscore(D01_06_2) ,494 Zscore(D01_07_1) ,061 Zscore(D01_07_2) -,326 Zscore(D01_05_1) -,371 Zscore(D01_05_2) -,352
PCA Component 2 "Dynamic urban areas"	Component 2 relates to high increase of permeation inside and outside UMZ. Therefore, if this factor is relevant for a certain cluster, cities in that group will represent very dynamic urban areas (to increase the urban permeation I imagine that certain amount of land should have changed and also according to certain pattern). UP is determined as the product of DIS and PBA; by consequence, an increase in UP is either determined by an increase in DIS (which is obviously not relevant here) or PBA (which we have removed from the database and cannot analyse in this context). Positive changes in land uptake can also be recorded, but to a lesser degree; only the increase in LUP outside the UMZ could be relevant in my opinion. LUP is determined as the quotient of built-up area and the number of the sum of inhabitants and jobs. Therefore, we could also consider this to be a sign of sprawl.	 Compone 2 Zscore(S01_07_1) ,343 Zscore(S01_07_2) ,180 Zscore(S01_07_3) ,194 Zscore(S01_06_1) -,144 Zscore(S01_06_2) ,191 Zscore(S01_06_3) -,219 Zscore(S01_05_1) -,111 Zscore(S01_05_2) -,121 Zscore(S01_05_3) ,116 **Zscore(D01_06_1)** ,759 **Zscore(D01_06_2)** ,743 Zscore(D01_07_1) ,259 Zscore(D01_07_2) ,541 Zscore(D01_05_1) ,336 Zscore(D01_05_2) -,001
PCA Component 3 "Sprawling but not dense development where people consume lots of surface"	This component could be defined as high land uptake per capita in particular inside, but also outside of the UMZ. This component also reflects certain dynamic in the city although it could go into different directions (increasing dispersion or not, increasing permeation or not). The higher the values, the larger the built-up area per person. This also might be a sign	

	for a sprawling, not dense development where people consume a lot of surface.	
PCA Component 4 “Sprawling tendency outside the UMZ”	Component 4 is clearly and solely determined by high increase of dispersion inside and in particular outside of the UMZ, i.e. a sprawling tendency outside the UMZ.	

Annex A4: Cluster A - List of cities

HU008	Kecskemet		PL028	Koszalin
HU009	Szekesfehervar		PL019	Jelenia Gora
HU003	Nyiregyhaza		PL509	Tychy
HU006	Szeged		PL014	Olsztyn
HU002	Miskolc		PL027	Kalisz
HU005	Debrecen		PL018	Zielona Gora
HU007	Gyor		PL016	Opole
HU004	Pecs		PL026	Plock
DE031	Schwerin		PL017	Gorzow Wielkopolski
DE021	Gottingen		PL025	Radom
DE029	Frankfurt (Oder)		PL015	Rzeszow
DE018	Halle an der Saale		PL023	Zory
RO010	Targu Mures		PL024	Czestochowa
RO011	Piatra Neamt		PL013	Torun
RO014	Alba Iulia		PL012	Kielce
RO012	Calarasi		PL009	Lublin
RO003	Timisoara		PL011	Bialystok
RO008	Arad		PL504	Zabrze
RO009	Sibiu		PL008	Bydgoszcz
RO006	Oradea		PL007	Szczecin
RO007	Bacau		PL501	Gdynia
RO002	Cluj-Napoca		PL006	Gdansk
RO013	Giurgiu		PL503	Gliwice
RO005	Braila		PL002	Lodz
RO004	Craiova		PL003	Krakow
BG007	Vidin		PL022	Konin
BG005	Pleven		PL005	Poznan
BG006	Ruse		PL508	Rybnik
BG008	Stara Zagora		PL010	Katowice
BG003	Varna		PL515	Chorzow
BG004	Burgas		PL507	Ruda Slaska
BG002	Plovdiv		PL505	Bytom
BG001	Sofia		PL502	Sosnowiec
CZ014	Jihlava		PL004	Wroclaw
CZ013	Karlovy Vary		EE002	Tartu
CZ008	Ceske Budejovice		EE001	Tallinn
CZ006	Olomouc		SK003	Banska Bystrica
CZ007	Liberec		SK008	Trencin
CZ011	Zlin		SK007	Trnava
CZ010	Pardubice		SK006	Zilina
CZ005	Usti nad Labem		SK002	Kosice
CZ012	Kladno		SK005	Presov
CZ009	Hradec Kralove		SK001	Bratislava
CZ003	Ostrava		SK004	Nitra

CZ002	Brno		LV002	Liepaja
CZ004	Plzen		LV001	Riga
SI002	Maribor		LT003	Panevezys
PL021	Suwalki		LT002	Kaunas
PL020	Nowy Sacz		LT001	Vilnius

Annex A5: Cluster B - List of cities

ES011	Santiago de Compostela	IT017	Ancona
ES535	Alcobendas	IT019	Pescara
ES015	Santander	IT032	Salerno
ES016	Toledo	IT015	Trieste
ES014	Pamplona/Iruna	IT025	Reggio di Calabria
ES509	Fuenlabrada	IT026	Sassari
ES012	Vitoria/Gasteiz	IT027	Cagliari
ES504	Mostoles	IT022	Taranto
ES526	Santa Coloma de Gramenet	IT517	Giugliano in Campania
ES507	Sabadell	IT031	Foggia
ES530	Mataro	IT012	Verona
ES022	Vigo	IT007	Firenze
ES010	Palma de Mallorca	IT008	Bari
ES019	Bilbao	IT009	Bologna
ES025	Santa Cruz de Tenerife	IT028	Padova
ES524	San Cristobal de la Laguna	IT021	Caserta
ES023	Gijon	IT011	Venezia
ES503	Badalona	IT006	Genova
ES018	Logrono	IT029	Brescia
ES512	Terrassa	IT010	Catania
ES013	Oviedo	IT013	Cremona
ES006	Malaga	IT003	Napoli
ES009	Valladolid	IT004	Torino
ES021	Alicante/Alacant	IT510	Monza
ES020	Cordoba	IT005	Palermo
ES007	Murcia	PT009	Faro
ES531	Dos Hermanas	PT006	Setubal
ES004	Sevilla	PT503	Matosinhos
ES003	Valencia	PT501	Sintra
ES024	L'Hospitalet de Llobregat	PT504	Gondomar
ES017	Badajoz	PT502	Vila Nova de Gaia
ES534	Torrejon de Ardoz	PT002	Porto
ES511	Alcala de Henares	PT008	Aveiro
ES513	Leganes	PT001	Lisbon
ES518	Getafe		
ES517	Alcorcon		
ES005	Zaragoza		
IT020	Campobasso		
IT023	Potenza		
IT024	Catanzaro		

Annex A6: Cluster C - List of cities

AT005	Innsbruck	FR021	Poitiers
BE007	Namur	FR019	Orleans
BE006	Brugge	FR035	Tours
IT014	Trento	FR023	Caen
IT016	Perugia	FR017	Metz
IT030	Modena	FR016	Nancy
UK015	Derry	FR032	Toulon
UK573	Bracknell Forest	FR011	Saint-Etienne
UK554	Maidstone	FR026	Grenoble
UK538	Basildon	FR008	Nantes
UK529	North Tyneside	FR203	Marseille
UK030	Wirral	FR207	Lens - Lievin
UK556	Dacorum	FR007	Bordeaux
UK544	Chelmsford	FR006	Strasbourg
UK564	Warwick	FR009	Lille
UK563	St Albans	FR010	Montpellier
UK534	Bury	FR205	Nice
UK547	South Tyneside	FR202	Aix-en-Provence
UK513	Medway	NL014	Apeldoorn
UK022	Wrexham	NL012	Breda
UK020	Gravesham	NL015	Leeuwarden
UK565	Newcastle-under-Lyme	NL517	Hengelo
UK505	Wigan	SE005	Umea
UK530	Gateshead	NL502	Zaanstad
UK523	Tameside	NL008	Enschede
UK526	Rochdale	PT508	Vila Franca de Xira
UK537	St. Helens	PT003	Braga
UK511	Bolton	PT005	Coimbra
UK521	Oldham	DE030	Weimar
UK507	Stockport	DE026	Trier
UK010	Sheffield	DE545	Erlangen
UK005	Bradford	DE042	Koblenz
UK519	Barnsley	DE041	Potsdam
UK514	Rotherham	DE019	Magdeburg
UK512	Walsall	DE032	Erfurt
UK574	Lisburn	DE025	Darmstadt
UK502	North Lanarkshire	DE027	Freiburg im Breisgau
UK527	Solihull	DE037	Mainz
UK503	Wakefield	DE009	Dresden
UK003	Leeds	DE033	Augsburg
UK508	Sefton	DE036	Monchengladbach
FR027	Ajaccio	DE020	Wiesbaden
FR012	Le Havre	DE017	Bielefeld
FR024	Limoges	DE008	Leipzig

FR018	Reims	DE531	Offenbach am Main
FR013	Rennes	DE538	Furth
FR025	Besancon	DE040	Saarbrucken
FR022	Clermont-Ferrand	DE511	Hagen
FR020	Dijon	DE514	Hamm
FR014	Amiens	DE012	Bremen
DE519	Leverkusen	DE022	Mulheim a.d.Ruhr
DE543	Witten	SE008	Orebro
DE023	Moers	SE002	Goteborg
DE541	Bergisch Gladbach	SE004	Jonkoping
DE525	Recklinghausen	FI004	Oulu / Uleaborg
DE528	Bottrop	FI003	Turku / Abo
DE521	Neuss	FI002	Tampere / Tammerfors
DK003	Odense	SI001	Ljubljana
DK002	Arhus		
DK004	Aalborg		
SE504	Lund		
SE007	Linkoping		
SE006	Uppsala		

Annex A7: Cluster D - List of cities

AT004	Salzburg	DE028	Regensburg
AT003	Linz	DE039	Kiel
AT002	Graz	DE034	Bonn
BE004	Charleroi	DE035	Karlsruhe
BE005	Liege	DE014	Nurnberg
BE002	Antwerpen	DE007	Stuttgart
BE001	Bruxelles / Brussel	DE013	Hannover
BE003	Gent	DE006	Essen
LU001	Luxembourg	DE503	Gelsenkirchen
UK021	Stevenage	DE515	Herne
UK017	Cambridge	DE004	Koln
UK018	Exeter	DE011	Dusseldorf
UK024	Worcester	DE015	Bochum
UK019	Lincoln	DE010	Dortmund
UK025	Coventry	DE509	Oberhausen
UK011	Bristol	DE501	Duisburg
UK541	Southend-on-Sea	DE005	Frankfurt am Main
UK016	Aberdeen	DK001	Kobenhavn
UK567	Slough	IE004	Galway
UK026	Kingston-upon-Hull	IE003	Limerick
UK023	Portsmouth	IE002	Cork
UK013	Newcastle upon Tyne	IE005	Waterford
UK014	Leicester	IE001	Dublin
UK027	Stoke-on-trent	SE003	Malmo
UK009	Cardiff	SE001	Stockholm
UK522	Salford	FI001	Helsinki / Helsingfors
UK007	Edinburgh	MT001	Valletta
UK029	Nottingham	NL011	Almere
UK524	Trafford	NL006	Tilburg
UK008	Manchester	NL007	Groningen
UK012	Belfast	NL005	Eindhoven
UK509	Sandwell	NL010	Heerlen
UK504	Dudley	NL009	Arnhem
UK028	Wolverhampton	NL013	Nijmegen
UK002	Birmingham	NL001	's-Gravenhage
UK006	Liverpool	NL518	Schiedam
UK004	Glasgow	NL003	Rotterdam
FR004	Toulouse	NL002	Amsterdam
		NL004	Utrecht

Annex A8: Cluster E - List of cities

ES001	Madrid
ES002	Barcelona
AT001	Wien
HU001	Budapest
IT002	Milano
IT001	Roma
FR001	Paris
FR003	Lyon
DE001	Berlin
DE003	Munchen
DE002	Hamburg
RO001	Bucuresti
CZ001	Praha
PL001	Warszawa

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