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How are cities planning to respond to climate change? Assessment of local climate plans from 885 cities in the EU-28

Diana Reckien [a, *], Monica Salvia [b], Oliver Heidrich [c], Jon Marco Church [d], Filomena Pietrapertosa [b], Sonia De Gregorio-Hurtado [e], Valentina D'Alonzo [f, g], Aoife Foley [h], Sofia G. Simoes [i], Eliška Krkoška Lorencová [j], Hans Orru [k, l], Kati Orru [m], Anja Wejs [n, o], Johannes Flacke [a], Marta Olazabal [p], Davide Geneletti [f], Efrén Feliu [q], Sergiu Vasilie [r], Cristiana Nador [s], Anna Krook-Riekkola [t], Marko Matosović [u], Paris A. Fokaides [v], Byron I. Ioannou [v], Alexandros Flamos [w], Niki-Artemis Spyridaki [w], Mario V. Balzan [x], Orsolya Fülöp [y], Ivan Paspaldzhiev [z], Stelios Grafakos [aa], Richard Dawson [c]

[a] Faculty of Geo-Information Science and Earth Observation, University of Twente, PO Box 217, 7500 AE Enschede, The Netherlands
[b] Institute of Methodologies for Environmental Analysis, National Research Council of Italy, (CNR-IMAA), C. da S. Loja, 85050 Tito Scalo PZ, Italy
[c] School of Engineering, Tyndall Centre for Climate Change Research, Newcastle University, Newcastle Upon Tyne, NE1 7RU, United Kingdom
[d] Université de Reims, 57 Rue Pierre Taittinger, 51571 Reims Cedex, France
[e] School of Architecture, Department of Urban and Spatial Planning, Universidad Politécnica de Madrid, Avenida de Juan de Herrera, 4, 28040 Madrid, Spain
[f] Department of Civil, Environmental and Mechanical Engineering, University of Trento, Via Mesiano 77 38123 Trento, Italy
[g] Institute for Renewable Energy, Eurac Research, A.Volta Straße - Via A.Volta 13A 39100 Bozen/Bolzano, Italy
[h] University Belfast, School of Mechanical & Aerospace Engineering, Ashby Building, Stranmillis Road, Belfast BT9 5AH, United Kingdom
[i] Center for Environmental and Sustainability Research (CENSE), NOVA School for Science and Technology, NOVA University Lisbon, 2829-516 Caparica, Portugal
[j] Global Change Research Institute of the Czech Academy of Sciences, Bělidla 986/4a, 603 00 Brno, Czech Republic
[k] Faculty of Medicine, University of Tartu, Ravila 19, 51007 Tartu, Estonia
[l] Faculty of Medicine, Umea University, Umeå Universitet, 901 87 Umea, Sweden
[m] Faculty of Social Sciences, University of Tartu, Lossi 36, 50090 Tartu, Estonia
[n] NIRAS A/S, Østre Havnegade 12, 9000 Aalborg, Denmark
[o] Department of Planning, Aalborg University, Rendsburggade 14, 9000 Aalborg, Denmark
[p] Basque Centre for Climate Change (BC3), Parque Científico UPV/EHU, Edificio Sede 1, Planta 1, Barrio Sarriena, s/n, 48940 Leioa, Spain
[q] TECNALIA. Energy and Environment Division, Parque Tecnológico de Bizkaia, c/ Geldo, 48160 Derio, Spain
[r] Denkstatt Romania SRL, Str. Madrid nr.22, 300391 Timisoara, Romania
[s] Vrije Universiteit Amsterdam, De Boelelaan 1105, 1081 HV Amsterdam, The Netherlands
[t] Luleå University of Technology (LTU), Energy Science Unit, SE- 971 87 Luleå, Sweden
[u] Energy Institute Hrvoje Požar, Savska cesta 163, 10001 Zagreb, Croatia
[v] School of Engineering, Frederick University, 7, Frederickou Str., 1036 Nicosia, Cyprus
[w] Department of Industrial Management & Technology, University of Piraeus (UNIPI), 80, Karaoli & Dimitriou street, 18534 Piraeus, Greece
[x] Institute of Applied Sciences, Malta College of Arts, Science and Technology, Paola, PLA9032, Malta
[y] Energiaklub Climate Policy Institute, 1056 Budapest Szerb U. 17-19, Hungary
[z] Denkstatt Bulgaria Ltd., 115 Arsenalski blvd ent. 1, fl. 5, app. 7, 1421 Sofia, Bulgaria
[aa] Institute for Housing and Urban Development Studies (IHS), Erasmus University Rotterdam (EUR), 3062 PA, Rotterdam, The Netherlands

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ABSTRACT

The Paris Agreement aims to limit global mean temperature rise this century to well below 2 °C above pre-industrial levels. This target has wide-ranging implications for Europe and its cities, which are the source of substantial greenhouse gas emissions. This paper reports the state of local planning for climate change by collecting and analysing information about local climate mitigation and adaptation plans

* Corresponding author. Climate Change at the Faculty of Geo-Information Science and Earth Observation (ITC), University of Twente, PO Box 217, 7500 AE Enschede, The Netherlands.
E-mail addresses: dianareckien@gmail.com, d.reckien@utwente.nl (D. Reckien).

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across 885 urban areas of the EU-28. A typology and framework for analysis was developed that classifies local climate plans in terms of their alignment with spatial (local, national and international) and other climate related policies. Out of eight types of local climate plans identified in total we document three types of stand-alone local climate plans classified as type A1 (autonomously produced plans), A2 (plans produced to comply with national regulations) or A3 (plans developed for international climate networks). There is wide variation among countries in the prevalence of local climate plans, with generally more plans developed by central and northern European cities. Approximately 66% of EU cities have a type A1, A2, or A3 mitigation plan, 26% an adaptation plan, and 17% a joint adaptation and mitigation plan, while about 33% lack any form of stand-alone local climate plan (i.e. what we classify as A1, A2, A3 plans). Mitigation plans are more numerous than adaptation plans, but planning for mitigation does not always precede planning for adaptation. Our analysis reveals that city size, national legislation, and international networks can influence the development of local climate plans. We found that size does matter as about 80% of the cities with above 500,000 inhabitants have a comprehensive and stand-alone mitigation and/or an adaptation plan (A1). Cities in four countries with national climate legislation (A2), i.e. Denmark, France, Slovakia and the United Kingdom, are nearly twice as likely to produce local mitigation plans, and five times more likely to produce local adaptation plans, compared to cities in countries without such legislation. A1 and A2 mitigation plans are particularly numerous in Denmark, Poland, Germany, and Finland; while A1 and A2 adaptation plans are prevalent in Denmark, Finland, UK and France. The integration of adaptation and mitigation is country-specific and can mainly be observed in two countries where local climate plans are compulsory, i.e. France and the UK. Finally, local climate plans produced for international climate networks (A3) are mostly found in the many countries where autonomous (type A1) plans are less common. This is the most comprehensive analysis of local climate planning to date. The findings are of international importance as they will inform and support decision-making towards climate planning and policy development at national, EU and global level being based on the most comprehensive and up-to-date knowledge of local climate planning available to date.

Abbreviations

CO_2	Carbon Dioxide
EC	European Commission
EU	European Union
GDP	Gross Domestic Product
GHG	Greenhouse gases
LCP	Local Climate Plan
SECAP	Sustainable Energy and Climate Action Plan
UA	Urban Audit
UK	United Kingdom
UN	United Nations

1. Introduction

Tackling climate change is a priority for the European Union (EU), which has set ambitious short and long-term emissions reduction targets, i.e. to reduce greenhouse gases (GHG) emissions by 20% by 2020, 40% by 2030 and 80% by 2080 compared to 1990 levels (European Commission, 2011). Meeting these targets will increase the likelihood that the aims of the Paris Agreement under the United Nations Framework Convention on Climate Change (UNFCCC, 2015) can be met. The central aim of the Paris Agreement is to keep global temperature rise this century well below 2 °C above pre-industrial levels, and to pursue efforts to limit the temperature increase even further, to 1.5 °C. Furthermore, the agreement aims to strengthen the ability of countries to deal with the impacts of climate change.

Cities[1] are crucial actors in climate change mitigation and adaptation efforts (Kousky and Schneider, 2003; Rosenzweig et al., 2010). This is particularly the case in Europe, where approximately 74%[2] of the population lives in urban areas. However, how and why cities engage in climate policy is a matter of current debate (Castán Broto, 2017; De Gregorio Hurtado et al., 2014, 2015; Heidrich et al., 2016; Olazabal et al., 2014; Reckien et al., 2015) and the effect of (binding and non-binding) national or international policies on the local level is not well understood (Kelemen, 2010). Engagement of European cities in climate mitigation and adaptation efforts has been partially assessed (Flacke and Reckien, 2014; Reckien et al., 2014a). However, the risk of climate-related impacts combined with vulnerability and exposure of human and natural systems requires a response to climate change, in terms of both mitigation (to address the causes of climate change) and adaptation (to deal with the consequences of a changed climate), across all European cities.

Cities can play a key role in developing and implementing climate change programs because they are located at the interface of local action and national and international level climate change adaptation and mitigation commitments (Heidrich et al., 2016). Moreover the synergies and trade-offs that exist between mitigation and adaptation (Landauer et al., 2015) are especially felt by cities (IPCC, 2015). Castán Broto (2017) argues that cities play a pivotal role in transnational climate change governance in three ways: firstly, cities support processes of learning and exchange between local governments and other sub-national organizations. Secondly, they gather local resources and knowledge in order to implement specific schemes. Thirdly, by raising the profile of cities in international agendas they evoke the interest of political and business actors. In order to excel in this pivotal role, cities need to design and implement local climate plans (LCPs). In this study, LCPs are considered as planning documents prepared at the city level

[1] referring to all local authorities with urban characteristics, i.e. urban areas, towns, and cities.

[2] http://www.statista.com/statistics/270860/urbanization-by-continent/(last accessed 19 December 2017).

that contain policies that are relevant to climate change adaptation and/or mitigation (see also the methods section below and Supplementary Information).

The climate governance at the national level in each Member State influences the development and implementation of climate plans at the lower administrative levels, including LCPs (Heidrich et al., 2016; De Gregorio Hurtado et al., 2015). However, in countries where national climate policies are lacking or weak cities align themselves to international climate networks (Heidrich et al., 2016; Reckien et al., 2014b; Villarroel Walker et al., 2017). The largest climate networks in Europe are the EU Covenant of Mayors and the UN Compact of Mayors, although other international, national or sub-national/regional networks have also been formed to support the diffusion of international best practices and to help cities share climate change planning related knowledge. Bauer and Steurer (2014) argue that regional climate change networks help prepare policy systems for innovation by spreading information on the magnitude and timing of climate impacts and identifying potential response options. However, the influence of networks, relative to that of local and national governance, is only beginning to be explored (De Gregorio Hurtado et al., 2015; Reckien et al., 2015). Another influential factor is proximity to a country that is actively addressing climate change. Neighbouring such a country seems to spur on to tighten one's own mitigation policies (Biesenbender and Tosun, 2014; Tompkins and Amundsen, 2008).

Moreover, European LCPs have been positively associated with the size of a city, gross domestic product (GDP) per capita and with adaptive capacity, i.e. with institutional capability and economic strength (Reckien et al., 2015). By contrast, cities with high unemployment rates, but also warmer summers, close proximity to the coast, and hence increased projected exposure to future climate impacts have significantly fewer LCPs (Reckien et al., 2015). Lack of resources, inadequate capacity in terms of preparedness, and low levels of competence and political salience rank as the principal barriers to local climate planning across EU countries, especially in lower income EU countries (Massey et al., 2014). Lack of political commitment, associated with inertia towards the integration of climate action in local policies, is a further barrier in many cities that needs to be addressed by specific research. Climate change planning in European cities is therefore often determined by local institutional capacity rather than by a proactive response to anticipated future needs (Reckien et al., 2015).

European national and local government climate change policies have prioritised mitigation over adaptation (Reckien et al., 2014a). This preference might be motivated by other benefits of mitigation (Puppim de Oliveira et al., 2013), such as economic savings and improved energy security, in addition to reduced emissions (Bulkeley and Kern, 2006; Heidrich and Tiwary, 2013; Hunt and Watkiss, 2011; Kousky and Schneider, 2003; Villarroel Walker et al., 2017; Wende et al., 2012). Similarly, adaptation in cities is seldom carried out systematically with measures across several sectors (Wamsler et al., 2013). Adaptation implementation often depends on alignment with other programmes (e.g. health) that are designed to address non-climate related problems as well.

In this study we use the term 'city' to refer broadly to all local authorities with urban characteristics, i.e. urban areas, towns, and cities. Specifically, the study analyses the LCPs of 885 Urban Audit (UA) cities across the EU-28 countries. Data on UA cities is available in the Eurostat repository, based on information collected and provided by the National Statistical Institutes, the Directorate-General for Regional and Urban Policy and Eurostat. We first develop a typology of LCPs in Europe. We then identify and review existing LCPs, focusing on stand-alone, comprehensive LCPs that were developed with climate change mitigation and/or adaptation as the main motivation. The study addresses two principal research questions:

- What are the emerging patterns of LCPs' distribution across the EU-28?
- How can the overall pattern be explained, i.e. what is the relative influence of local, national or international policies and networks on the development of LCPs?

The focus of the work is on the distribution of stand-alone LCPs and the factors driving their development. In contrast to stand-alone LCPs, the mainstreaming of climate issues in other policies or climate related plans is not considered here. This, together with the quality of LCPs and their content are subject to future research.

A previous study, conducted on a smaller sample of 200 cities across 11 EU Member States revealed a large variation in climate change response, which was most noticeable on a north–south axis (Reckien et al., 2014a). A follow-up investigation (Heidrich et al., 2016) already discussed the respective roles of national legislation and international networks in motivating the development and implementation of local climate strategies on that smaller sample. A related study also examined the potential of specific institutional, environmental and socio-economic urban characteristics to act as drivers of, or barriers to climate action (Reckien et al., 2015). The analysis presented here represents a significant advance on these studies, in the number of cities analysed and the breadth of information considered, paving the way for more detailed consideration of the engagement and preparedness of European cities in response to climate change.

2. Methodology and methods

2.1. The sample of cities

The analysis is based on the entire sample of 885 UA core cities in the EU-28, and uses some of the data provided in the UA database,[3] which is now called "Statistics on European cities". The UA city sample currently contains 885 core cities and 22 greater cities or larger urban zones across the EU-28, plus a number of cities in Iceland, Norway, Switzerland and Turkey. The more than 900 cities in the EU-28 together represent 25% of the EU's population. The UA defines a city as a local administration unit (LAU) where the majority of the population lives in an urban centre of at least approximately 50,000 inhabitants. However, as explained below, to ensure representativeness within countries and across the EU-28, the UA also includes some smaller urban centres with less the 50,000 inhabitants. The UA adopted the following criteria in order to ensure a balanced and regionally representative sample (see Fig. 1): cities in each country should represent about 20% of the population in the country, have a good geographical distribution (at least one city from each NUT3 Region), and vary in size to include large and small cities (including some urban centres with less than 50,000 inhabitants).

The UA is run by the European Commission and Eurostat (2017) and has been developed in cooperation with the national statistical offices to compare data across European urban areas. Datasets include statistical information on individual cities and on their commuting zones (called 'Functional Urban Areas'). The topics and datasets that are reported by the database are wide ranging and include, for example, demography, housing, health, environment, and education. The database is a very useful resource for climate

[3] http://ec.europa.eu/eurostat/statistics-explained/index.php/Statistics_on_European_cities (last accessed: 26 May 2017); http://ec.europa.eu/eurostat/web/cities/data/database (last accessed 19th December 2017).

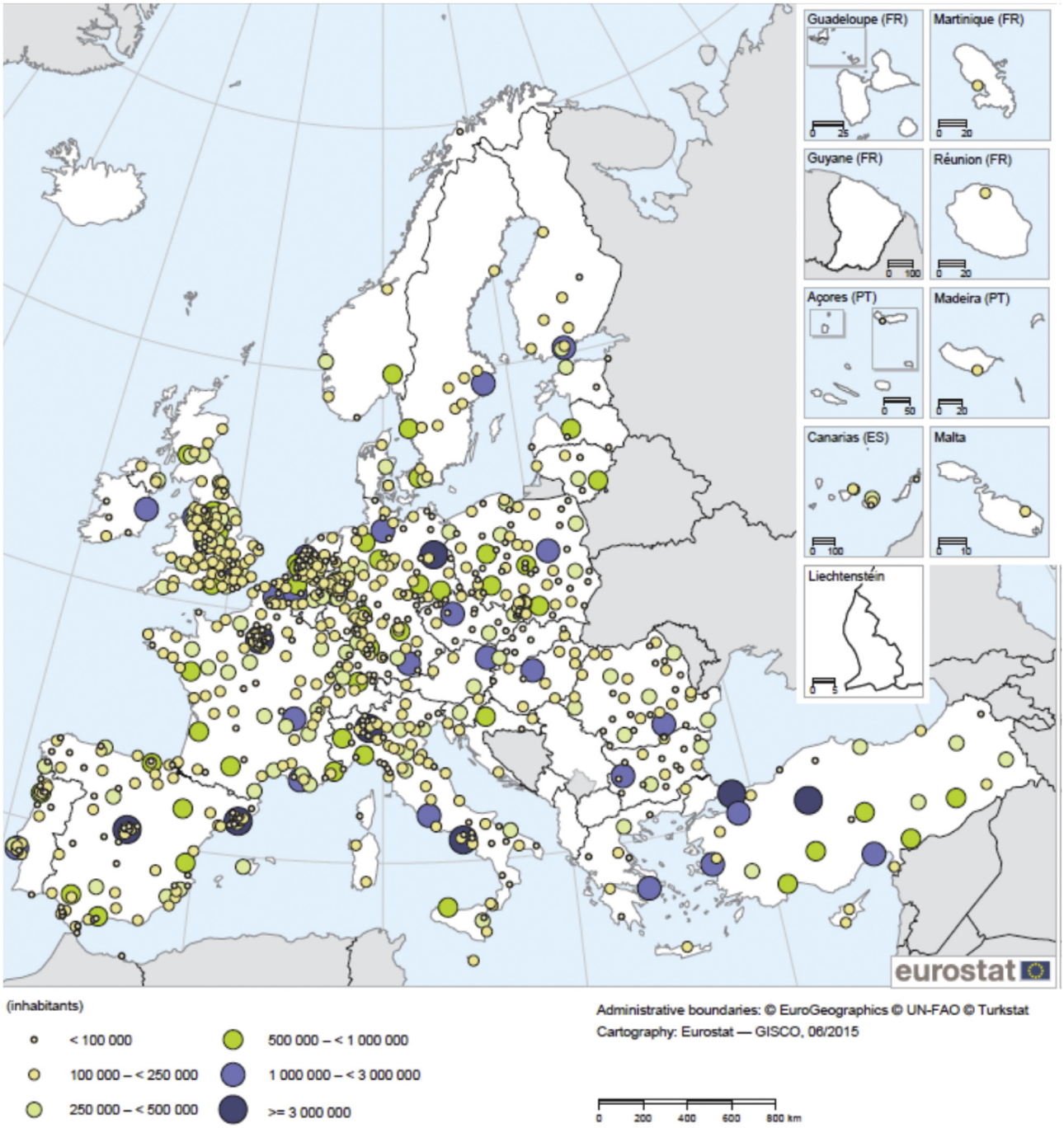

Fig. 1. Map of the location of Eurostat Urban Audit cities, showing resident populations as of 1st January 2012. Source: Eurostat (2015).

change policy makers and urban planners alike (Seto et al., 2014). For more details on the methodology, definition and classifications used in the analysis see Supplementary Information and Eurostat (2004).

2.2. Typology of local climate plans

The LCPs of European cities are drafted and published in a variety of forms, and vary in terms of detail, structure and scope. Some of the plans are comprehensive stand-alone documents, such as comprehensive adaptation or mitigation plans. Other LCPs are integrated into another document such as a sustainability plan, resilience plan, or Local Agenda 21, and these sometimes integrate adaptation and mitigation. Increasingly, aspects of climate change are also covered by spatial development plans; sectoral plans, e.g. air quality plans or emergency response plans (for heat waves, flooding, or energy shortages); and plans prepared for other purposes but which are nevertheless relevant to climate change.

Due to the multitude of planning constellations and types of LCPs available we developed a typology of LCPs that also serves as a framework for analysis. It is based on two dimensions: the alignment with spatial (local, national and international) policies and level of integration with other local policy documents (Table 1). This study only considers plans with a clear focus on climate change and those developed for an entire urban area as stand-alone documents, i.e. those defined as type A1, A2, and A3 plans according to

Table 1
Typology of Local Climate Plans (LCPs). This study only comprises LCPs with a clear focus on climate change and those developed for the entire urban region, i.e. plans of type A1, A2, and A3.

Spatial dimension	Integration with or placement within the existing local policy documents					
Type	Comprehensive and stand-alone (A)	Mainstreamed and inclusive (B)	Partial GHG sources and impacts, stand-alone (C)	Operational (D)	Related (E)	Areal (F)
Autonomous (1)	A1 - Local Climate Plan of the urban authority/ administration that comprehensively (multiple sectors) addresses climate change. The plan does not rely on support from international networks or funding agencies, and are described in a stand-alone document. 'Adaptation' or 'mitigation' should be mentioned in the title (e.g. Local Climate Mitigation Plan, Local Climate Adaptation Plan) or identified in the preface/ introduction as the main motivation for developing the plan.	B - Climate change aspects included in another municipal plan, e.g. sustainability plan, resilience plan, development/master plan, core strategy.	C – Local Climate Plan, addressing partial aspects of climate change in stand-alone documents, relating to particular sectors, such as energy, or particular impacts (such as heat waves, flooding, etc.).	D - Local Climate Plan for parts of the municipal operations, such as universities, schools, housing associations, hospitals, e.g. site- and operation-specific carbon management plans in the UK.	E – Plan with relevance to the climate issue but without a clear focus and no single section dedicated to climate change, e.g. urban development plan, municipal emergency response plan, disaster risk reduction plan, civil protection plan.	F – Local Climate Action Plan for part of a city/ urban area.
National regulation (2)	A2 - Local Climate Plan produced in response to requirements of national legislation, and published as a stand-alone document.					
Internationally induced (3)	A3 - Local Climate Plan developed under the auspices of international urban climate networks, such as the EU Covenant of Mayors and UN Compact of Mayors, e.g. Sustainable Energy and Climate Action Plan (SECAP), Sustainable Energy Action Plans (SEAP), etc.					

the typology set out in Table 1.

Types A1 and A2: In this category we included LCPs relevant for the entire urban area that mention 'climate' or 'climate change' in the title or, in the introduction, and identify responding to climate change as main motivation for producing the plan. These plans were detected using common search engines, entering search terms such as 'climate change mitigation planning' and 'climate change adaptation planning' (see Supplementary Information). In addition, we reviewed websites of municipal authorities, focusing on those departments that might cover climate action (e.g., planning, energy, sustainable development).

Type A3: In absence of type A1/A2 LCPs we checked for plans that have been developed under the auspices of international climate networks (in particular the EU Covenant of Mayors and the UN Compact of Mayors). We extracted and noted the presence of a Sustainable Energy Action Plan (SEAP) (for mitigation), or a Sustainable Energy and Climate Action Plan (SECAP) (combining mitigation and adaptation), developed for the Covenant of Mayors.

2.3. Selection of local climate plans for the Urban Audit cities sample

For each country, a team of authors (with native or full professional language proficiency) compiled a database of local climate (mitigation and adaptation) plans through a combination of desk/ web review and occasionally direct contact with local authorities. We took advantage opportunities to obtain the information we needed online and only contacted the respective city representative(s) in cases where further information and/or clarification were needed. In all cases the respective plan or policy had to be, or to be made available to us. A more comprehensive version of the analysis guidelines can be found in the Supplementary Information.

The information extracted was entered into a database, where the name of the mitigation and adaptation strategy, the web link, and the date of search was recorded, along with comments on particularities of each city. The relevant documents where downloaded and saved.

The LCP may either be officially adopted by the municipal government, or simply acknowledged and noted; it may be binding or non-binding. The database includes draft and finalized plans as well as current and past strategies, i.e. including those with a timeframe that had already expired (e.g. 2010–2016). We included draft documents because we assume that the planning process is just as important as the plan itself (Heidrich et al., 2013; Millard-Ball, 2013) and that a draft plan can already produce effects such as awareness raising and capacity building.

The size of a municipality or local area differs across Europe and this has implications for what counts as local climate plan. For example, in France, municipalities are small compared to other countries. This motivated the transfer of the competence for LCPs from municipalities to city-regions (larger urban areas) as part of the territorial reform enacted in 2015. We recorded both municipal

Table 2
Number of autonomous mitigation, adaptation and joint plans in Urban Audit Cities in 24 EU countries where the development of LCPs is not compulsory (A1). Key: Dark grey is > 66.7%, light grey is > 33.3% and <=66.7%.

A1	UA Cities	Mitigation plans		Adaptation plans		Joint plans		No plans	
	N	*N*	%	*N*	%	*N*	%	*N*	%
Austria	6	2	**33.3**					4	**66.7**
Belgium	11	5	**45.5**	1	**9.1**	1	**9.1**	6	**54.5**
Bulgaria	18							18	**100.0**
Croatia	5			1	**20.0**			4	**80.0**
Cyprus	2							2	**100.0**
Czech Republic	18	1	**5.6**	1	**5.6**			17	**94.4**
Estonia	3							3	**100.0**
Finland	9	7	**77.8**	7	**77.8**	7	**77.8**	2	**22.2**
Germany	125	101	**80.8**	31	**24.8**	4	**3.2**	21	**16.8**
Greece	9							9	**100.0**
Hungary	10							10	**100.0**
Ireland	5	4	**80.0**	1	**20.0**	1	**20.0**	1	**20.0**
Italy	76			2	**2.6**			74	**97.4**
Latvia	4							4	**100.0**
Lithuania	6							6	**100.0**
Luxemburg	1							1	**100.0**
Malta	1							1	**100.0**
Netherlands	51	15	**29.4**	1	**2.0**			35	**68.6**
Poland	68	66	**97.1**	2	**2.9**	1	**1.5**	2	**2.9**
Portugal	25	1	**4.0**	6	**24.0**			18	**72.0**
Romania	35	1	**2.9**	4	**11.4**	1	**2.9**	31	**88.6**
Slovenia	2							2	**100.0**
Spain	109	11	**10.1**	8	**7.3**	4	**3.7**	98	**89.9**
Sweden	13	10	**76.9**	4	**30.8**			2	**15.4**
EU-24	**612**	**224**	**36.6**	**69**	**11.3**	**19**	**3.1**	**372**	**60.8**

plans and plans of city-regions as LCPs in the French case, as many cities are still in the process of transferring the competence from one level to the other. A similar issue relates to cities in Ireland and the UK, where one city can make up multiple local authorities (Heidrich et al., 2013). In these cases, we reported plans for local authorities within a city (e.g. London).

Type A1 and A2 LCPs were searched for between November 2016 and January 2017. Subsequently, in May 2017, information on type A3 climate plans developed under the auspices of international urban networks (e.g. Covenant of Mayors for Climate and Energy, Compact of Mayors) was retrieved from the organizations' websites.

3. Results

This section summarizes our findings and provides a comprehensive overview of the current state of development of LCPs across the EU-28. As mentioned above, we report only on LCPs of types A1, A2, and A3, as defined in Table 1, in order to focus on cities with stand-alone plans that comprehensively address climate change.

3.1. Type A1: autonomous and comprehensive LCPs

National governments in 24 of the EU-28 countries do not require the preparation of LCPs. In these countries, LCP development is the result of local level engagement and action. Table 2 shows the large disparities in the prevalence of LCPs across these 24 European countries.

Overall, approximately 37% of the cities in this sample have an A1 mitigation plan. They are particularly numerous in Poland, Germany, Ireland, Finland and Sweden, where more than two-thirds of cities have a mitigation plan.

Across the EU-24 sample, about 11% of cities have an A1 adaptation plan; thus overall there are far fewer adaptation plans than mitigation plans. Finland is a forerunner in this respect, with most cities having an adaptation plan. Less than one-third of cities have adaptation plans in 12 other countries, while adaptation plans are non-existent in the remaining 11 countries. The fact that mitigation plans are far more numerous than adaptation plans might suggest that mitigation planning precedes adaptation planning. However, there are some cities with an adaptation plan but no mitigation plan. These include, for example, Zagreb (Croatia) and Bologna and Ancona (Italy).

Some of the plans address mitigation and adaptation issues in the same document. This is the case in most Finnish cities, but also in some Irish cities. However, overall only 3% of type A1 LCPs in Europe are joint plans.

Overall, 10 of the 24 countries that do not require LCPs do not have any cities with local A1 mitigation or adaptation plans. The countries concerned, apart from two small countries with a single UA city (Luxembourg and Malta), are located in the south, south-east and north-east of Europe.

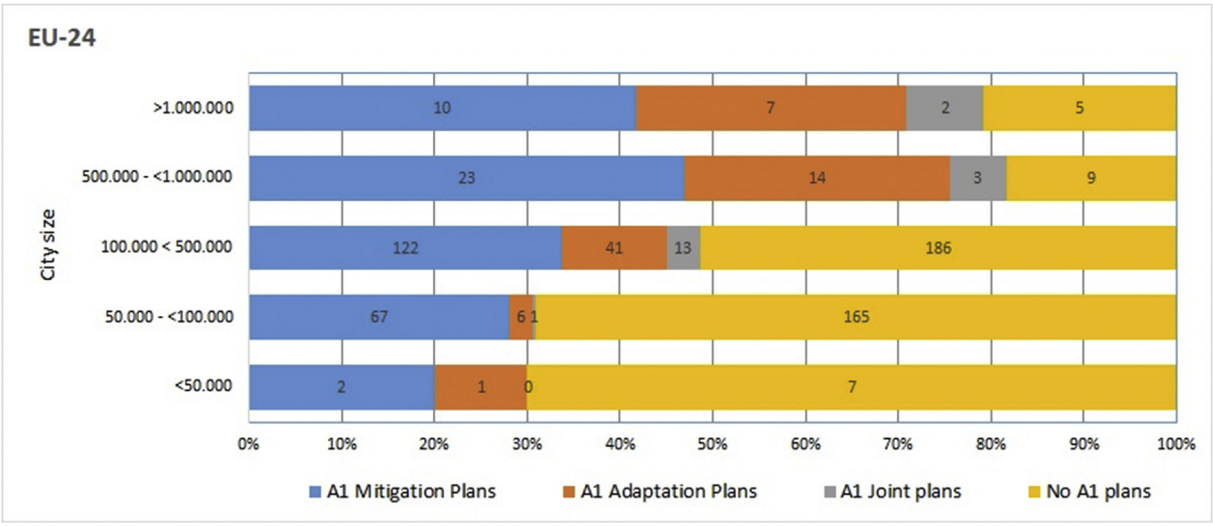

Fig. 2. Distribution of LCPs across city size in the 24 countries without a national obligation to develop plans. (A1) Data on number of inhabitants relate to the total population on the 1st of January for the latest year available (2008–2016).

Fig. 2 shows how the LCPs in countries without national legislation requiring the development of LCPs are distributed across city size. The proportion of cities with an A1 mitigation plan and/or an A1 adaptation plan increases in line with their size. Around 80% of cities with more than 500,000 inhabitants have a mitigation and/or adaptation plan. Fig. 2 shows that some of the smallest urban centres, with less than 50,000 inhabitants, are also addressing the challenges of climate change; however the data in that category is far from representative, because of the small sample size. Joint plans are more likely to be developed in large cities but not exclusive to them, suggesting a relation to economic or institutional capacity.

3.2. Type A2: Nationally required and regulated LCPs

While many national governments provide some policy guidance to local authorities on the production and design of LCPs, their content and legal status is usually left to the discretion of local authorities. Only 4 countries, Denmark (DK), France (FR), Slovakia (SK) and the United Kingdom (UK), have made the adoption of LCPs compulsory, determining their legal status and providing guidance on the development and content of plans.

Since 2008, local planning authorities in the UK have a statutory duty to include "policies designed to secure that the development and use of land in the local planning authority's area contribute to the mitigation of, and adaptation to, climate change" in their local planning documents.[4] The legislation demands the inclusion of climate change issues in general local planning documents addressing both mitigation and adaptation. The regulation applies to local planning authorities of all sizes.

In 2010, France made it compulsory for municipalities to adopt LCPs. The French local authorities are required to produce a Local Climate-Air-Energy Plan (*Plan Climat Air Energie Territorial*), which is a stand-alone document. It must include sections on mitigation and adaptation, but most often the focus is mitigation and particularly the link between energy policy, air quality and GHG emissions. However, these regulations only apply to areas with a certain number of inhabitants. Initially, LCPs were compulsory for municipalities of more than 50,000 inhabitants, but the scope of the regulations was expanded to cover smaller-sized urban areas in 2016. Since then LCPs have been obligatory for municipalities with more than 20,000 inhabitants.

In Slovakia, local authorities are obliged to develop an Action Plan for Sustainable Energy (e.g. *Akčný plán trvalo udržateľnej energie mesta Nitra do roku 2020*), which are strategic framework documents related to climate change mitigation. The requirement to develop these plans is set out in the National Energy Policy and the National Framework and Energy Strategy of the Slovak Republic, which relate in turn to obligations stemming from EU directives 2006/32/EC (relating to energy end-use efficiency and energy services), 2012/27/EU (relating to energy efficiency), and 2003/87/EC (relating to emissions trading). Cities are required to take measures to improve the efficiency of public services and to influence energy consumption by key stakeholders and end users.

In Denmark, only local climate change adaptation plans are legally required, whereas mitigation plans are voluntary. However, mitigation LCPs are indirectly demanded as a component of mandatory municipal heat supply plans, which are required by law and aim to reduce the energy sector's dependence on fossil fuels (§1 in the Danish Heat Supply Law [LBK no. 523]).[5] Mitigation is dealt with by the Danish Climate Law [LOV no. 716], which came into force in 2014 and whose goal is for Denmark to become a 'low emission society' in 2050.[6] Regarding adaptation, in 2013, the then Environment Minister Ida Auken made it mandatory for Danish municipalities to include climate change adaptation into municipal spatial plans—a requirement integrated into the Danish planning law since February 2018. Accordingly, municipalities are required to identify local areas that may be exposed to flooding and erosion as a result of climate change and designate these areas as such in the municipal spatial plans. If urban developments are planned in these designated areas, the municipalities have to ensure the implementation of preventive measures. Moreover, Denmark is among the few countries with a Ministry of Climate, which was created in the wake of the UNFCCC Conference in Copenhagen in 2009.

Table 3 shows the number of mitigation, adaptation and joint LCPs produced in the UA cities of Denmark, France, Slovakia and the

[4] UK. *Planning and Compulsory Purchase Act*, section 19, subsection 1A, 2008.

[5] https://www.retsinformation.dk/forms/R0710.aspx?id=190081; (last accessed 19 December 2017).

[6] https://www.retsinformation.dk/forms/R0710.aspx?id=163875; (last accessed 19 December 2017).

Table 3
Number of mitigation, adaptation and joint plans in four countries where LCPs are compulsory (A2) compared with other countries. The table shows all plans, i.e. including those that were developed before there was a legal requirement for the development of Local Climate Plans. Key: Dark grey is > 66.7%, light grey is > 33.3% and <=66.7%.

A2	UA Cities	Mitigation plans		Adaptation plans		Joint plans		No plans	
	N	*N*	%	*N*	%	*N*	%	*N*	%
Denmark (A2)	4	4	100.0	4	100.0				
France (A2)	98	74	75.5	54	55.1	53	54.1	24	24.5
Slovakia (A2)	8	6	75.0	1	12.5			1	12.5
United Kingdom (A2)	163	90	55.2	95	58.3	72	44.2	63	38.7
4 countries (A2)	**273**	**174**	**63.7**	**154**	**56.4**	**125**	**45.8**	**88**	**32.2**
24 countries (A1)	**612**	**224**	**36.6**	**69**	**11.3**	**19**	**3.1**	**372**	**60.8**
28 countries (A1 + A2)	**885**	**398**	**45.0**	**223**	**25.2**	**144**	**16.3**	**460**	**52.0**

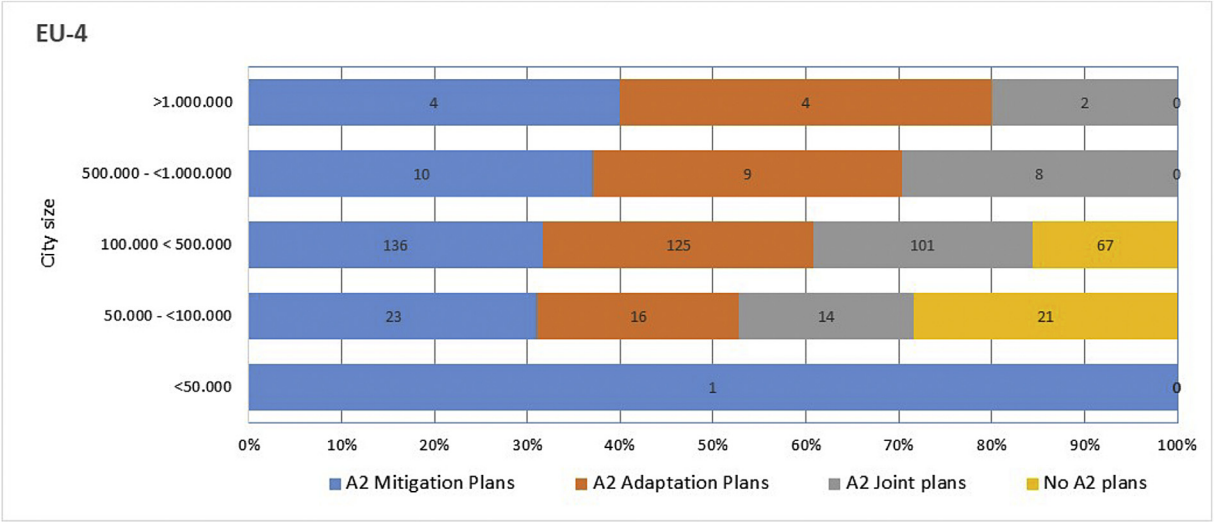

Fig. 3. Distribution of LCPs across city size in countries with a national obligation to develop plans. (A2) Data on number of inhabitants relate to the total population on the 1st of January for the latest year available (2008–2016).

UK, and the total number of plans for these four countries compared with the prevalence of LCPs in other countries. Some basic analyses show that cities with a national obligation to develop LCPs are approximately 1.8 times more likely to have a mitigation plan and about 5.0 times more likely to have an adaptation plan—although this is also influenced by the length of time the regulation has been in force. Moreover, our sample indicates that the large majority of all joint mitigation and adaptation plans (86.8%) in the EU were produced in cities of two countries (France and the UK) with national climate legislation that require and provide guidance for the development of LCPs. However, compliance with the legislation is not universal: one in four cities in France and one in three in the UK do not possess a LCP of type A2 and thus may not be complying with national legislation.

Fig. 3 shows the distribution of type A2 LCPs across city size in the four countries where they are compulsory. The data reveals the same pattern as for autonomously produced (type A1) LCPs in other countries. Larger cities are more likely to have an LCP than smaller cities and compliance rates are 100% in cities with more than 500,000 inhabitants.

3.3. Type A3: plans of international climate networks

International climate networks are initiatives that play an important role in boosting development of urban local climate plans (Heidrich et al., 2016; Reckien et al., 2014b). While there are also regional and national climate networks in many countries, the EU Covenant of Mayors for Climate and Energy and the UN Compact of Mayors are the most important initiatives at the international level.

The Covenant of Mayors brings together some 7000 local and regional authorities voluntarily committed to implementing EU climate and energy objectives on their territory. It was launched by the European Commission (EC) after the adoption of the 2020 EU Climate and Energy Package in 2008, with the aim of endorsing and supporting the efforts of local authorities to reduce GHG emissions and implement sustainable energy policies. The Covenant of Mayors asks signatories to prepare so-called Sustainable Energy Action Plans (SEAPs). These are envisaged as roadmaps, charting the paths of EU cities towards the goal of reducing carbon dioxide (CO_2) emissions by 20% by 2020. For adaptation, a similar network initiative—Mayors Adapt—was launched in 2014, inviting cities to make political commitments and take action to prepare for the impacts of climate change. At the end of 2015, both initiatives merged under the new integrated Covenant of Mayors for Climate & Energy. The new Covenant of Mayors asks signatories to prepare Sustainable Energy and Climate Action Plans (SECAPs), containing a commitment to the EU 2030 objectives to reduce CO_2 emissions by

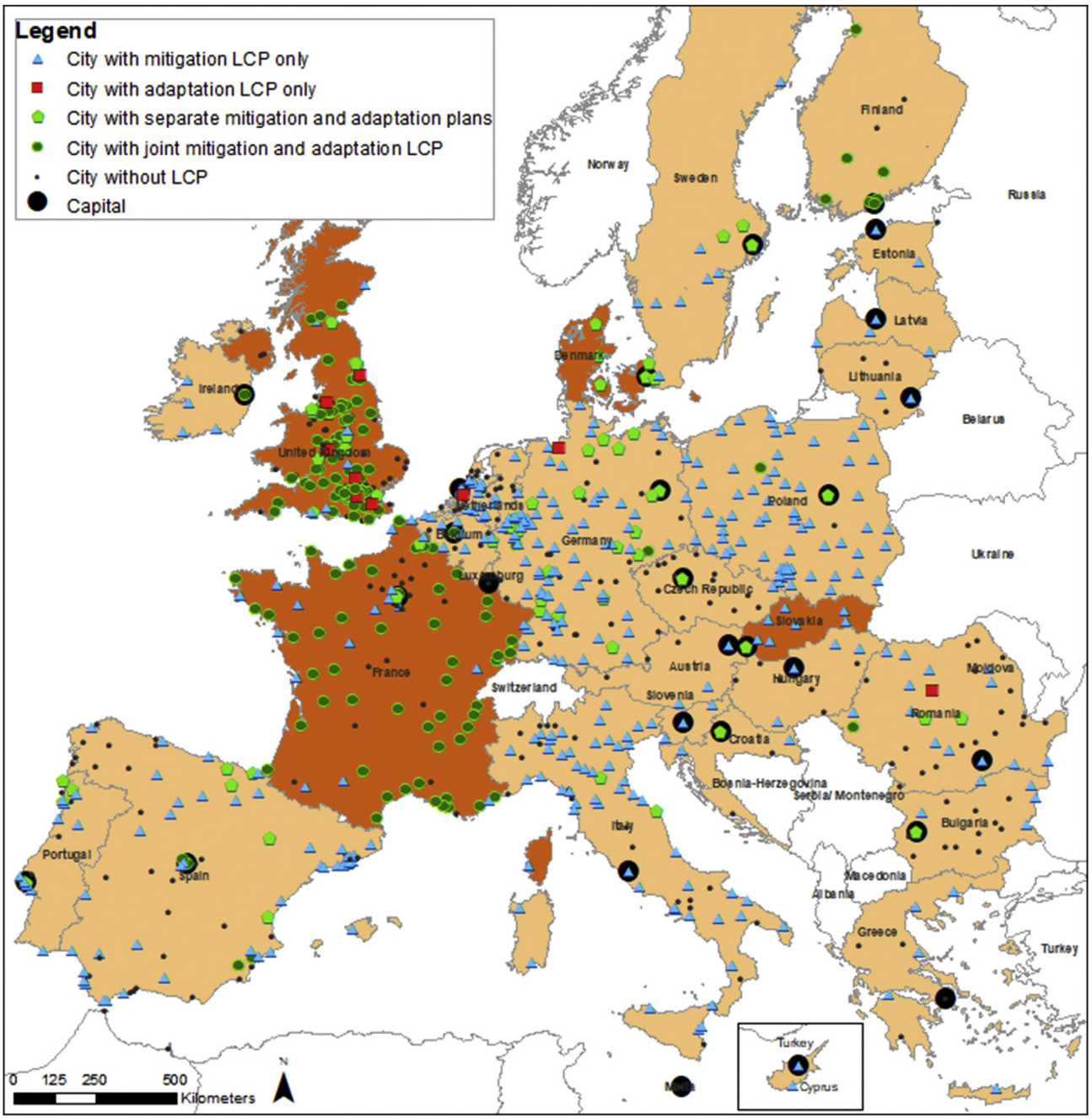

Fig. 4. Status of local climate policies and plans of Type A1 and A2 across 885 cities in the European Union. Countries in beige do not require their local governments to develop Local Climate Plans; countries in dark orange make it compulsory for cities and larger local governments to develop either Local Climate Mitigation Plans (Slovakia) or Local Climate Adaptation Plans (Denmark) or both (France, UK). Overseas territories are not shown for the sake of clarity of the cities and countries on the mainland. Fort-de-France on Martinique (France), Santa Cruz de Tenerife (Spain) and San Cristóbal de la Laguna (Spain) on Tenerife have "a mitigation LCP only". Funchal on Madeira (Portugal) is a "city with separate mitigation and adaptation LCPs". (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

at least 40% and adopting an integrated approach towards climate change mitigation and adaptation.[7]

The Compact of Mayors is an international initiative launched in 2014 at the United Nations (UN) Climate Summit by the UN Secretary General and UN Habitat in collaboration with the C40 Cities Climate Leadership Group (C40), the Local Governments for Sustainability (ICLEI), and the United Cities and Local Governments (UCLG) (C40 ICLEI, 2012). As part of their commitment, cities agree to perform a series of key activities on mitigation and adaptation, including carrying out an inventory, creating targets and metrics, and establishing a local climate action and adaptation plan.[8]

Both initiatives have been successful in encouraging cities to address the challenge of climate change. The EU Covenant of

[7] http://www.covenantofmayors.eu/about/covenant-of-mayors_en.html; (last accessed 19 December 2017).

[8] https://www.compactofmayors.org/resources/; (last accessed 19 December 2017).

Table 4
Number of UA cities in the EU-28 signatory to the Covenant of Mayors (CoM, 2020 goal), Covenant of Mayors for Climate and Energy (CoM, 2030 goal), and the Compact of Mayors (A3), with average stage in each process. Last update CoM: 22.05.2017, Compact: 20.02.2017. Key: Dark grey is >66.7%, light grey is >33.3% and ≤ 66.7%; Mit. = Mitigation; Ada. = Adaptation; w/o = without.

	UA Cities	CoM Signatories		CoM Signatories with SEAP (All A3)		CoM Signatories with SEAP (A3) w/o type A1/A2 Mit. LCP		CoM Signatories with SECAP (All A3)		CoM Signatories with SECAP (A3) w/o type A1/ A2 Ada. LCP		Adapt Commitment (A3)		Average Covenant stage	Compact member		Average Compact Stage (Badge)
	N	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%		*N*	%	
Austria	6	2	33.3	2	33.3	1	16.7	0	0.0	0	0.0	1	16.7	2.0	0	0.0	0
Belgium	11	9	81.8	8	72.7	3	27.3	1	9.1	0	0.0	4	36.4	2.3	1	9.1	1
Bulgaria	18	5	27.8	5	27.8	5	27.8	0	0.0	1	5.5	1	5.6	2.2	3	16.7	1
Croatia	5	3	60.0	3	60.0	3	60.0	0	0.0	0	0.0	1	20.0	3.0	1	20.0	1
Cyprus	2	2	100.0	2	100.0	2	100.0	0	0.0	0	0.0	0	0.0	2.5	1	50.0	1
Czech Republic	18	3	16.7	1	5.6	1	5.6	0	0.0	0	0.0	2	11.1	1.7	0	0.0	0
Denmark	4	4	100.0	4	100.0	0	0.0	0	0.0	0	0.0	1	25.0	2.0	1	25.0	4
Estonia	3	2	66.7	2	66.7	2	66.7	0	0.0	0	0.0	1	33.3	2.5	0	0.0	0
Finland	9	8	88.9	7	77.8	0	0.0	0	0.0	0	0.0	2	22.2	2.5	3	33.3	1
France	98	32	32.6	30	30.6	0	0.0	3	3.1	0	0.0	4	4.1	2.1	5	5.1	1
Germany	125	37	29.6	35	28.0	2	1.6	3	2.4	0	0.0	14	11.2	2.4	6	4.8	1.5
Greece	9	5	55.6	4	44.4	5	55.6	0	0.0	0	0.0	1	11.1	2.6	1	11.1	2
Hungary	10	5	50.0	4	40.0	4	40.0	0	0.0	0	0.0	1	10.0	1.8	2	20.0	1
Ireland	5	4	80.0	3	60.0	1	20.0	1	20.0	0	0.0	3	60.0	2.3	0	0.0	0
Italy	76	58	76.3	56	73.7	56	73.7	0	0.0	0	0.0	15	19.7	2.4	5	6.6	1
Latvia	4	4	100.0	3	75.0	4	100.0	0	0.0	0	0.0	1	25.0	2.5	1	25.0	1
Lithuania	6	2	33.3	2	33.3	2	33.3	0	0.0	0	0.0	0	0.0	3.0	0	0.0	0
Luxemburg	1	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0.0	0	0.0	0
Malta	1	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0.0	0	0.0	0
Netherlands	51	15	29.4	15	29.4	6	11.8	0	0.0	0	0.0	2	3.9	2.1	2	3.9	4
Poland	68	9	13.2	7	10.3	1	1.5	0	0.0	0	0.0	2	2.9	2.2	5	7.4	1.2
Portugal	25	17	68.0	17	68.0	15	60.0	1	4.0	0	0.0	5	20.0	2.8	5	20.0	2.2
Romania	35	22	62.9	18	51.4	16	45.7	0	0.0	0	0.0	3	8.6	2.0	1	2.9	1
Slovakia	8	4	50.0	2	25.0	2	25.0	0	0.0	0	0.0	3	37.5	1.5	0	0.0	0
Slovenia	2	2	100.0	2	100.0	2	100.0	0	0.0	0	0.0	0	0.0	2.0	2	100.0	1
Spain	109	66	60.6	64	58.7	49	45.0	1	0.9	1	1.0	20	18.3	2.4	10	9.2	2.2
Sweden	13	10	76.9	10	76.9	3	23.1	0	0.0	1	7.7	2	15.4	2.6	5	38.5	1.6
UK	163	26	16.0	26	16.0	3	1.8	0	0.0	0	0.0	4	2.5	2.3	8	4.9	2.4
EU-28	885	356	40.2	333	37.6	188	21.2	10	1.1	3	0.3	93	10.5	2.1	68	7.7	1.6

Mayors has been very successful in Europe and the UN Compact of Mayors successfully engaged many cities throughout the world. A Global Covenant of Mayors for Climate and Energy was launched in June 2016[9] aimed at linking the two initiatives to generate synergies and avoid duplication, especially among EU local authorities.

In this section we present findings on participation in the Covenant of Mayors and Compact of Mayors, by UA cities in EU-28 countries. Table 4 shows that 356 or 40% out of 885 UA cities are signatories of the Covenant of Mayors. Among them, 333 cities (38%) have a SEAP, 10 cities (1%) have a SECAP and 93 cities (10.5%) have an adaptation commitment (some of them as SECAP). The status of all cities in the Covenant process is on average 2.1 (stage 1 - signature, stage 2 - action plan submitted, stage 3 - results monitored), showing that most cities have submitted an action plan and some already monitor their results. Countries where, on average, cities have reached the highest stage in the Covenant of Mayors process include Croatia, Lithuania and Portugal.

Table 4 also shows that 8% of the UA cities in our sample are members in the Compact of Mayors. They are on average at stage 1.6 in the process (stage 1- register commitment, stage 2 - take inventory, stage 3 - set reduction targets, stage 4 - create plan(s) to address climate mitigation and/or adaptation), signifying that many cities of the Compact network are still at stage 1 and have not yet carried out an inventory.

Comparing this with Table 2 we conclude that cities in countries where autonomous (type A2) plans are less common are more likely to produce internationally accredited plans, whereas cities in countries where autonomous plans are more common tend to engage less in international networks.

Table 5 summarizes the statistics and shows that A1 and A2 LCPs are slightly more numerous (total 398 for mitigation and 223 for adaptation) than A3 LCPs (total 333 for mitigation and 103 for adaptation). It further shows that 66.2% of EU UA cities have either an A1, A2, or A3 mitigation LCP, 25.5% have an adaptation LCP, 16.4% have joint LCPs; and 32.5% have no type A1, A2 or A3 LCP.

The findings regarding the distribution of type A1, A2 and A3 LCPs across countries and European regions are summarised in Fig. 4. Cities in eastern and southern Europe have fewer mitigation and adaptation LCPs, whereas most central and northern European cities have a LCP. The prevalence of types of LCPs is often clustered in countries.

4. Discussion and conclusion

Our dataset includes 885 cities in all 28 EU countries, and is the first to provide a detailed database of local climate action. It is thus much more comprehensive and representative than previous similar studies. It contributes towards establishing patterns of local climate action and assessing the effectiveness of action by cities in support of EU policy targets geared towards combating climate change and meeting the objectives of the Paris Agreement. Data collected for this study was last updated in January 2017 (with some exceptions, e.g. climate networks). This allowed plans developed in the wake and immediately after the 2015 UNFCCC

[9] http://europa.eu/rapid/press-release_IP-16-2247_en.htm; (last accessed 19 December 2017).

Table 5
Number of mitigation, adaptation and joint plans of Type A1, A2, and A3. Please note that we count the existence of a SECAP and Adapt Commitment as A3 adaptation LCP, because no more detailed information was available. Key: w/o = without.

A1/ A2/ A3	UA Cities	Mitigation plans		Adaptation plans		Joint plans		No plans	
	N	*N*	%	*N*	%	*N*	%	*N*	%
A1 plans (24 countries)	612	224	36.6	69	11.3	19	3.1	372	60.8
A2 plans (4 countries)	273	174	63.7	154	56.4	125	45.8	88	32.2
A3 plans in cities w/o A1/ A2 plans (28 countries)	460	188	40.9	3	0.0	1	0.0	288	62.6
All A3 plans, i.e. in cities with or without A1/ A2 plans (28 countries)	885	333	37.6	103	11.6	10	1.1	552	62.4
All cities with A1, A2 or A3 plans (sum of lines 1-3)	**885**	**586**	**66.2**	**226**	**25.5**	**145**	**16.4**	**288**	**32.5**

Conference in Paris, which saw a significant increase of climate action at all levels, to be included.

This paper has presented the data and provided an initial analysis. We intend to update this work at regular intervals to map, observe and compare the evolution of local climate planning over time. This will continuously inform decision making and thinking by stakeholders at all levels and across sectors.

4.1. Methodological challenges and insights

1) **The accessibility of LCPs can be challenging, especially for medium and small-sized cities.** In a few cases, there was some evidence of the existence of LCPs, but no copy of the plan available. While we are sure to have found the vast majority of LCPs for our sample, some LCPs might exist that are not publicly available on the webpages of the municipalities concerned.
2) **The use of the typology across countries proved challenging.** Despite the co-development of the typology and analytical framework by members of the research team, a framework that clearly distinguished comprehensive, mainstreamed, partial and related plans, the application of the framework to the different national situations proved difficult at times. For example, it was difficult to know which plan came first when cities had both an A1/A2 and A3 plan. We recorded most of them as A1/A2, unless it was absolutely clear that the plan was developed initially for the Covenant of Mayors. Similarly, it was sometimes difficult to distinguish between types of plans considered in this paper (A1, A2 and A3) and plans assigned to the other categories (i.e. B, C, D, E, and F) that were excluded from our analysis. For example, the distinction between A3 plans and Local Energy Plans (type 3) is not always straightforward. It should also be noted that, while the typology might suggest a hierarchy (of commitment or effectiveness) from A down to F, this was not intended and the typology should not be interpreted in this way. The typology distinguishes among different approaches adopted by cities in addressing the challenge of climate change but does not imply that one approach is 'better' than others. For example, type B plans can be more successful than type A plans in addressing and implementing climate change issues in the real world, by mainstreaming climate change-related issues in other local policy processes. The classification of plans was also made more difficult by the fact that mitigation and adaptation are not always dealt with at the same level of detail, depth, or length. Moreover, while in some countries there is a recent trend towards including LCPs into broader sustainability plans (as in the Netherlands), in other countries an opposite trend can be observed (as in France, where local Agenda 21s are being transformed into more technical and narrow LCPs). In this paper, we did not include sustainability plans or local Agenda 21s. As a result we may have underestimated the level of climate engagement in European cities.
3) **Evolving local governance structures complicated the analysis.** Local government reforms can have a significant impact on local climate planning, when competences are moved from one level to the other. For instance, when France merged a large number of smaller municipal authorities into larger 'inter-municipal' ones, competence for development of LCPs moved 'up' to the higher level. By contrast, Italy has transformed its provinces, which were previously responsible for most urban planning, into large inter-municipal authorities. In some cases, this made existing plans obsolete, thus creating a legal 'in-betweenness' that we found difficult to characterise. In this assessment, we included the lowest-level plans (e.g. municipal over inter-municipal), unless more recent higher-level plans existed in a context of territorial reform. Furthermore, lower-level plans interact with higher-level plans in the respective spatial planning systems. This is particularly salient in the case of water and climate plans and adaptation plans in general, which usually cover larger areas, such as in the Netherlands, Finland, and Italy. To maintain consistency we therefore also included plans for metropolitan regions (larger urban areas including a number of municipalities that are part of the UA). For example, the metropolitan region of Helsinki has a plan that also covers the adjacent UA cities of Esbo, Vanda and Lahtis. It should also be mentioned that the restriction to UA cities introduces a distortion of representability. In some countries (e.g. Portugal where UA cities cover only 8% of municipalities), urban centres outside the UA may have LCPs that were not recorded in this study.

4.2. Interpretation of the findings

1) **The drivers of LCPs in countries without national legislation to develop LCPs need further exploration—in many of those countries more than 2/3 of cities have LCPs.** Some countries stood out as having a large proportion (two-thirds or more) of UA cities with autonomously developed (type A1) mitigation plans. These included Poland (97.8% coverage), Germany (80.8%), Ireland (80.0), Finland (77.8%) and Sweden (76.9%). This prevalence of LCPs could be due to several factors, such as the

level of climate awareness, the presence of local expertise, the level of administrative decentralization, the presence of institutional capacity or political commitment, the impact of political parties and the amount of funding available. Further research is needed to elucidate which factors contribute the most and how they interact with each other and other factors.

2) **The existence of national regulation has a significant impact on local climate planning.** Cities in Denmark, France, Slovakia and the UK, where LCPs are compulsory, are about 1.8 times more likely to have a mitigation plan, and 5.0 times more likely to have an adaptation plan than cities in other countries—although this is also influenced by the length of time the regulation has been in place. The case of Denmark, where all four UA cities have both mitigation plans and adaptation plans, is particularly interesting. Moreover, our sample indicates that almost all joint mitigation and adaptation plans (86.2% of the total joint plans) were produced in France and the UK. It seems that, without national regulation, local authorities are reluctant or do not have the capacity to produce joint plans. It is worth highlighting that French and British cities represent about 30% of all UA cities and are therefore particularly well-represented in the sample.
3) **There are countries where a significant number of LCPs were developed under the auspices of Covenant of Mayors.** These included, most notably, Cyprus, Denmark, Slovenia, Latvia (100.0% of UA cities), Finland (88.9%), Belgium (81.8%), Ireland (80.0%), Sweden (76.9%), Italy (76.3%), Estonia (66.7%), Portugal (64.0%), Romania (62.9%) and Spain (60.6%). Within our sample, the EU Covenant of Mayors has five times as many signatories as the UN Compact of Mayors. No country has a significant number of members of Mayors Adapt. In the light of these results, we conclude that, in countries where autonomous (type A1) LCPs are rare and cities are not required by national legislation to develop plans, international networks such as the Covenant of Mayors help raise awareness, build capacity and, often through EU-funded projects, provide the expertise and the funding necessary to develop LCPs. The cases of Spain and Italy are particularly interesting, as the number of Spanish and Italian signatories is particularly high. They represent more than one-third (35.0%) of the signatories of the Covenant of Mayors in our sample (and more than three-quarters (76.7%) of the total signatories to the Covenant of Mayors at the time of writing). However, UA cities are probably not a representative sample of local authorities that are signatory to the Covenant of Mayors, considering that the UA contains only few urban areas with less than 50,000 inhabitants, while local authorities of all sizes can sign the Covenant. This is the case for Malta, where several smaller cities that make up part of the Valletta UA city have submitted action plans to the Covenant of Mayors for Climate and Energy but these do not cover the entire UA city. Actions promoted by the Covenant of Mayors also differ from the plans considered in this study in other ways: the Covenant of Mayors is mostly focused on what the local authority owns, rather than the city as a whole; the timeframe is often different; and plans can cover administrative areas with populations ranging from a few hundred people to several million. This means that, while our sample can be considered as representative of European cities, defined as urban centres with (in most cases) more than 50,000 inhabitants, it is not fully representative of the signatories of the Covenant. Future research should assess how promotion of climate plans by the Covenant of Mayors interacts with other factors driving the development of LCPs in European cities.

This is the most comprehensive analysis of local climate planning to date. However, we acknowledge the limitations of a study on the existence of LCPs for climate mitigation and adaptation achievements. Although our sample includes LCPs that have been adopted years ago and could therefore potentially prove successful implementation the analysis of planning and policy documents cannot. It is yet to determine whether and to what extent cities in Europe are acting on and moving towards adaptation and mitigation goals. Our sample allows for larger objectivity than previous studies, although, as mentioned above, it may still underestimate climate engagement in smaller cities and of other types than standalone, comprehensive LCPs.

4.3. Final conclusions

Our analysis of 885 cities across the 28 European countries has shown that approximately 66% of the EU UA cities have either an A1, A2, or A3 mitigation LCP; that 26% have an adaptation LCP; 16% are joint LCPs; and about 33% of cities have neither an A1, nor an A2 or an A3 LCP.

Although far more numerous, mitigation plans do not always precede adaptation plans, which is different from the conclusions of earlier assessments (Reckien et al., 2014a; b). There is large diversity in the proportions of cities with different types of plans across the EU, with generally more plans in central and northern EU countries, which agrees with the results of previous studies. City size, international climate networks and national regulation are influential parameters in driving the development of LCPs. About 80% of the cities with more than 500,000 inhabitants have an A1 or A2 mitigation and/or an adaptation plan. We also found that the EU Covenant of Mayors has an important role to play in encouraging smaller cities, notably in Italy and Spain, but also in many other countries, to engage in climate action. Overall, though, LCPs developed independently (type A1) as well as in response to national legislation (type A2) are more numerous in European countries than LCPs developed as part of international climate networks (type A3). The prevalence of LCPs is greater in countries that require local authorities to develop LCPs than in those that do not, by a factor of 1.8 for mitigation and a factor of 5.0 for adaptation.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.jclepro.2018.03.220.

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