European
Commission

Covenant of Mayors: 2023 assessment

15 years of climate action at local level in Europe

Melica, G., Treville, A., Franco De Los Rios, C., Todeschi, V., Baldi, M.G., Bezerra, P., Davide, M., Hernandez Moral, G., Palermo, V., Pittalis, M., Bastos, J., Monforti-Ferrario, F., Barbosa, P., Bertoldi, P.

2024

Joint
Research
Centre

How to cite this report: European Commission, Joint Research Centre, Melica, G., Treville, A., Franco De Los Rios, C., Todeschi, V., Baldi, M.G., Bezerra, P., Davide, M., Hernandez Moral, G., Palermo, V., Pittalis, M., Bastos, J., Monforti-Ferrario, F., Barbosa, P. and Bertoldi, P., *Covenant of Mayors: 2023 assessment*, Publications Office of the European Union, Luxembourg, 2024, https://data.europa.eu/doi/10.2760/835080, JRC137368.

Contents

Abstract

Cities and local authorities are key players in addressing climate change. Since 2008, the European Commission (EC) endorses and supports their efforts through the Covenant of Mayors for Climate and Energy (CoM) and notably through the provision of capacity building, technical assistance, sharing of best practices and peer learning opportunities. The initiative helps consolidate practices to monitor and report on energy consumption and greenhouse gas (GHG) emissions as well as on risks and vulnerabilities at the local level, enabling decision makers to identify priority sectors, set emission reduction targets and adaptation goals and plan relevant measures.

This report provides a scientific assessment of the CoM pillars of climate change mitigation and adaptation, focusing on Europe. It describes the Covenant community, the plans submitted by signatories, examines actions and measures and gives an overview on the progress made.

The key findings on mitigation show that the overall commitment to reducing GHG emissions by 1 631 signatories in EU-27 is 55.2 % by 2030 compared to baseline emissions. Looking only at 676 action plans accompanied by at least one monitoring report, a 48 % reduction by 2030 is forecasted, while the targeted mean reduction is 56 %. This insight suggests that greater effort is necessary for signatories to advance in the implementation of their action plans and achieve the emission reduction targets they have set.

On adaptation, the report shows that several vulnerable population groups including the elderly, persons with chronic diseases, low-income households, and persons living in sub-standard housing, are exposed to climate hazards. Signatories report high-risk hazards (such as extreme heat, droughts & water scarcity, heavy precipitation and floods & sea level rise) that affect 65.3 million people.

Acknowledgements

Executive summary

The Global Covenant of Mayors for Climate and Energy counts more than 11 300 cities and local governments from Europe and its neighbouring countries. This report presents an analysis of the political commitments made by those signatories. Subsequently it delves into a subset of about 1 800 action plans from European signatories targeting 2030 or later years and presents key figures on overall ambition, emissions by sector and scope, most reported hazards and vulnerable sectors, and planned policies and measures. Finally, based on about 670 action plans accompanied by a monitoring emission inventories it forecasts emissions in 2030.

Policy context

Cities and local authorities are crucial actors in the fight against climate change. This was acknowledged by the European Commission back in 2008, when the Covenant of Mayors (EU CoM) was launched with a main focus on abating energy-related emissions and targeting cities and local authorities from the EU. Since then, the EU CoM has grown in scope and in geographical coverage: the integration of the adaptation pillar in 2015 and the merger with the Compact of Mayors in 2017 originated the Global Covenant of Mayors for Climate and Energy (GCoM), the world's largest coalition of cities and local governments voluntarily committed to fight climate change. The EU CoM and the GCoM continue to feature high in the EU policy agenda on climate and energy, and are explicitly mentioned in the European Green Deal communication, in the Climate Pact communication and in the new EU strategy on adaptation to climate change.

In Europe, the Covenant originally required cities to commit to a minimum 20% GHG emission reduction target by 2020. In 2015, the minimum commitment was increased to 40% GHG emission reduction by 2030[1], aligned with the EU 2030 climate and energy targets. In 2021, the EU CoM stepped up its ambition in line with the EU goal to achieve climate neutrality by 2050 and strengthened the energy poverty dimension. In 2022, the reporting template on energy poverty was also launched.

15 years after the launch of the EU CoM, cities and local authorities are increasingly recognised by the EC as key partners to engage with to fight climate change and ensure a just transition, also thanks to their proximity to citizens – including the most vulnerable ones – and to local stakeholders.

Key conclusions

The GCoM supports signatories' efforts through provision of guidance, technical support, sharing of best practices and peer learning opportunities. At the same time, it helps consolidate practices to monitor and report on energy consumption and GHG emissions as well as risks and vulnerabilities at the local level, allowing decision makers to identify priority sectors, set emission reduction targets and adaptation goals, and plan relevant measures.

A very high number of GCoM signatories comes from the EU-27 or from other regions where the EU has been supporting the Covenant of Mayors since 2011 (notably Eastern Partnerships countries).

Most cities and local authorities remain committed only to 2020 mitigation targets and have not yet integrated a commitment to adaptation or renewed their pledges to 2030 or 2050.

As a result, the majority of submitted action plans has a focus on climate mitigation only and a time horizon limited to 2020. However, while committed signatories and adaptation action plans are less numerous than mitigation ones, figures are constantly growing.

Many Covenant signatories are late on their action plans' implementation reports, in particular on quantitative reports that are needed to monitor the achieved emission reduction. This might be due to delays with action plans' implementation or to challenges in complying with the reporting timeline and requirements.

In terms of emission reduction ambition, we note that Covenant signatories collectively aim to higher emission reductions than the minimum targets set by the initiative for 2030. Interim emission reduction achievements, calculated for EU-27 signatories with a 2030 mitigation commitment and at least one monitoring report, reveal a gap compared to their collective emission reduction target by 2030.

In terms of adaptation, we observe that Covenant signatories are developing a thorough understanding of their climate risks and vulnerabilities. However, they are facing challenges in setting measurable goals prioritizing

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[1] For cities from Eastern Partnership countries the minimum emission reduction target is 30% by 2030.

the hazards and impacted sectors to address. Consequently, the large number of planned actions are not directly linked to defined goals, making it challenging for signatories to measure their progress on adaptation.

In light of the increased ambition of the EU CoM soliciting signatories to reach climate neutrality by 2050 in line with the goals set in the European Climate Law, signatories should be encouraged to renew their commitments beyond 2020. Reinforced support may be necessary to help signatories implement their mitigation and adaptation actions, and report regularly on their action plans.

Main findings

The majority of Covenant signatories (55 %, covering 35.5 % of the CoM population[2]) remains committed only to the 2020 mitigation targets, while 44 % (representing about 61 % of the CoM population) committed to a 2030 or 2050 mitigation target combined with adaptation. The remaining 1 % has a commitment to adaptation only or to adaptation combined with a 2020 mitigation target.

Looking at the pillars addressed, 74.9 % of the submitted action plans cover only mitigation and just 24.7 % address both mitigation and adaptation, however the number of action plans with a commitment to a 2030 or 2050 mitigation target and to adaptation is constantly growing.

Looking at the 1 698 plans with a 2030 time horizon, we can see that 59 % chose the minimum 40 % target set for EU signatories, while about one fourth selected a more ambitious target, yet not as ambitious as the 55 % headline target set by the EU for 2030. About 4 % of the signatories set a target lower than 40 %, which is allowed to CoM signatories outside the EU.

Looking only at signatories from EU-27, the overall committed reduction is 55.2 % by 2030 (compared to a baseline level of 469.1 Mt CO_2-eq). Reported emissions in baseline emission inventories are dominated by energy use, while emissions associated with waste treatment account for a minor share in the inventories.

Analysing a subset of 676 action plans in the EU-27 targeting 2030, accompanied by at least one monitoring emission inventory, a 48 % reduction by 2030 is forecasted, while the targeted mean reduction is 56 %. This insight suggests that greater effort is necessary for signatories to advance in the implementation of their action plans and achieve the emission reduction targets they have set.

Looking at the adaptation information coming from 1 816 action plans, several vulnerable population groups – including the elderly, persons living with chronic diseases, low-income households, and persons living in sub-standard housing – are exposed to climate hazards. Signatories report high-risk hazards – such as extreme heat, droughts & water scarcity, wild fires, and heavy precipitation – that affect 65.3 million people. The following sectors are the most reported by signatories in their action plans as vulnerable to the identified climate hazards: agriculture & forestry, environment & biodiversity, civil protection & emergency, and health.

However, adaptation action is growing: there are more than 20 170 reported actions so far and figures are increasing. While there is still a gap between identified risks & vulnerabilities and action taken, 57 % of signatories reporting at least one high-risk hazard are also reporting already at least one matching action to address it.

Related and future JRC work

This report is part of a series of JRC reports assessing the CoM status in order to track the overall progress of the initiative based on action plans and monitoring reports transmitted by Global Covenant cities to the European Commission through the MyCovenant reporting platform (Cerutti et al., 2013), (A. Kona et al., 2016), (A. Kona et al., 2017), (P. Bertoldi et al., 2020), (Melica, et al., 2022), (Franco, et al., 2022), (Melica, et al., 2022b), (Franco , et al., 2023) or through offline reporting tools (Palermo, et al., 2022).

Specific aspects of the Covenant are also explored in dedicated studies (e.g. multi-level governance models in the Covenant (Melica et al., 2018); review of reporting platforms (Bertoldi, Kona, Rivas, & Dallemand, 2018); projections towards Paris Agreement targets (A. Kona, Bertoldi, Monforti-Ferrario, Rivas, & Dallemand, 2018); methods on indirect emission accounting (A. Kona, Bertoldi, & Kılkış, 2019); climate mitigation policies (Palermo, Bertoldi, Apostolou, Kona, & Rivas, 2020); impacts of mitigation actions on air quality (Monforti-Ferrario et al, 2018; Peduzzi, et al., 2020); key factors enabling higher climate ambition (Rivas, Urraca, Bertoldi, & Thiel, 2021); and predictors of GHG emissions in cities (Franco, et al., 2022b; Franco, et al., 2023)).

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[2] CoM population refers to the people living in a city or local authority that signed up to the CoM.

Quick guide

This report provides a scientific assessment of the EU CoM and the GCoM by looking at data reported by signatories through the MyCovenant reporting platform until end of March 2023 and/or through the CDP-ICLEI Track reporting platform until December 2022. The assessment is based on climate change mitigation and adaptation plans and monitoring reports, examines planned and implemented policies and gives an overview on the progress achieved.

1 Introduction

Fifteen years after the launch of the European Covenant of Mayors initiative, cities and local authorities are increasingly looked at as crucial players in the fight against climate change, in the European Union and all over the world. There is general consensus that the involvement of different levels of government and multiple actors in addressing the climate challenge is necessary for the world to deliver on the 1.5°C limit on global temperature rise.

In December 2023, the COP 28 Presidency launched the "Coalition for High Ambition Multilevel Partnerships" (CHAMP) for Climate Action, to encourage national governments to enhance cooperation with subnational governments the development and implementation of climate strategies, notably the updated Nationally Determined Contributions (NDCs), in time for COP30 in 2025.

The European Union (EU) has committed to becoming the world's first climate-neutral continent by 2050[3,4,5]. The package of proposals put forward by the European Commission (EC) in 2021[6] in various domains to deliver on the 55% emission reduction by 2030 have all been adopted or agreed by the co-legislators. Among them, the following are particularly relevant for local governments, providing a clearer framework for decision-makers and for investors:

— the Energy Efficiency Directive[7] has established a target to improve energy efficiency by 11.7% by 2030 and requires Member States to ensure that regional and local authorities prepare local heating and cooling plans at least in municipalities having a total population higher than 45 000.

— the Renewable Energy Directive[8] raised the binding target for 2030 from 32% to a minimum of 42.5%, with the ambition to reach 45%. It also increased sector-specific targets for renewables in heating and cooling, transport, industry, buildings and district heating/cooling, while promoting electric vehicles and smart recharging.

— the Energy Performance of Buildings Directive requires that all new public buildings shall be zero-emission by 2028 and all new buildings by 2030. It extends from the central government to all levels of public administration the obligation for Member States to renovate each year at least 3% of total floor area of buildings owned by the public administration.

While cities involved in the Global Covenant of Mayors are increasing their ambition towards climate neutrality by 2050 (or even by 2030, as in the EU 100 Climate Neutral and Smart Cities Mission), the effects of climate change are already tangible all over the world. 2023 is confirmed as the hottest year on record, with an intensely hot summer, and extreme heat and wildfires affecting many parts of Europe[9]. Other areas of the continent suffered from major flooding events, and precipitations patterns showed significant anomalies in the number of wet days and in the average precipitation rate on wet days.

Acknowledging that the impacts of climate change are already occurring today, the EU strategy on adaptation to climate change[10] aims to make adaptation smarter, swifter and more systemic and to increase support for international climate resilience. In this regard, it intends to support the further development and implementation of adaptation strategies and plans at all levels of governance and aims to spread adaptation awareness to

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[3]　COM(2019) 640 final. COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE EUROPEAN COUNCIL, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS The European Green Deal

[4]　COM(2020) 788 final. COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS European Climate Pact

[5]　Regulation (EU) 2021/1119 of the European Parliament and of the Council of 30 June 2021 establishing the framework for achieving climate neutrality and amending Regulations (EC) No 401/2009 and (EU) 2018/1999 ('European Climate Law')

[6]　COM(2021) 550 final. COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS 'Fit for 55': delivering the EU's 2030 Climate Target on the way to climate neutrality

[7]　DIRECTIVE (EU) 2023/1791 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 13 September 2023 on energy efficiency and amending Regulation (EU) 2023/955 (recast)

[8]　DIRECTIVE (EU) 2023/2413 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 18 October 2023 amending Directive (EU) 2018/2001, Regulation (EU) 2018/1999 and Directive 98/70/EC as regards the promotion of energy from renewable sources, and repealing Council Directive (EU) 2015/652

[9]　See e.g., Copernicus press release "2023 is the hottest year on record", https://climate.copernicus.eu/copernicus-2023-hottest-year-record

[10]　COM(2021) 82 final. COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS Forging a climate-resilient Europe - the new EU Strategy on Adaptation to Climate Change

every single local authority, company and household[11]. The Adaptation Mission contributes to putting the EU's adaptation strategy in practice by supporting EU regions, cities and local authorities in their efforts to build resilience against the impacts of climate change.[12]

In this context, local involvement and public participation are key points of attention for the EU: Member States are required to establish multilevel climate and energy dialogues involving local authorities as well as other stakeholders to engage and discuss the achievement of the EU climate neutrality objective. The importance of transnational networks of cities and local authorities to stimulate the development of renewable energy and energy efficiency is acknowledged at EU level.

Being the level of governance closest to citizens, cities and local authorities may influence and take action on several sectors: through local energy and climate plans, they can contribute to the implementation of EU energy and climate policies. For example, they can get involved in renewable energy communities or accelerate permitting procedures for renewable energy installations, they can improve the efficiency of their own buildings and raise citizens' awareness of building energy renovation options, they can promote sustainable mobility options and create more liveable cities. To increase the resilience of their territories, they can implement nature-based solutions in their own buildings and public infrastructure, as well as embed high-performance resiliency standards in city planning and building codes; additionally, they can promote climate awareness and disaster risk preparedness within their employees as well as with citizens and businesses.

The EU Covenant of Mayors (EU CoM) and the Global Covenant of Mayors (GCoM) have been instrumental in spreading awareness on climate change among local governments and in providing methodologies and approaches to develop local climate and energy plans. For more than a decade now, cities and local authorities have been setting GHG emission reduction targets and adopted plans to tackle the key emitting sectors in their territories. More recently, they started to set adaptation goals and to adopt plans addressing the climate hazards, exposure and vulnerabilities in their territories. The energy poverty dimension is also gaining increasing importance, in order to achieve a just transition that leaves no one behind.

1.1 The Covenant of Mayors: history, commitments and reporting requirements

The EU CoM was launched by the EC in 2008 with a target for participating cities to reduce GHG emissions in their territories by at least 20% by 2020 through the development and implementation of a Sustainable Energy Action Plan (SEAP). The initiative was very well received by cities and local governments all over the EU and beyond, with thousands of signatories of all sizes, backgrounds and levels of experience joining enthusiastically, and with regional and national authorities endorsing and supporting their efforts.

In 2014, based on the experience of the Covenant of Mayors and acknowledging the vulnerability of urban areas to the unavoidable impacts of climate change, the EC launched Mayors Adapt, a similar voluntary initiative with a focus on climate adaptation in cities.

The Covenant of Mayors and Mayors Adapt then merged in 2015, resulting in the Covenant of Mayors for Climate & Energy, which set a new target in line with the EU headline target of 40% GHG emission reduction by 2030 and integrated the adaptation pillar.

In 2017, the Covenant of Mayors for Climate and Energy and the Compact of Mayors joined forces becoming the GCoM, currently the world's largest coalition of cities and local governments voluntarily committed to fighting climate change.

As a result of the EU's commitment to reducing its net GHG emissions by at least 55% by 2030 and becoming climate neutral by 2050, , the EU chapter of the GCoM initiative announced in April 2021 its renewed ambition[13], with participating cities pledging to the goal of climate neutrality by 2050 and to tackling in an integrated manner the three pillars of the initiative:

— climate mitigation;

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[11] Among the actions from the EU Strategy of particular relevance to CoM signatories:
 - increase funding opportunities to implement adaptation actions at the local scale;
 - improve monitoring frameworks, develop indicators, and record data on climate-related losses (i.e., EU Risk Data Hub);
 - create a "policy support facility" (CoM EU) to further support local and regional governments for a more systemic adaptation;
 - further promote nature-based solutions for adaptation (biodiversity co-benefits)
 - promote a socially-just transition, recognizing the higher impact of climate risks on vulnerable population groups, and avoiding reinforcing inequalities.
[12] As of December 2023, 311 EU regions and local authorities signed the Mission Charter. Many of them are GCoM signatories.
[13] https://eumayors.eu/index.php?option=com_attachments&task=download&id=1017

— climate adaptation;

— energy poverty.

The key document to translate into climate action the vision of local authorities for both mitigation and adaptation to climate change in the EU CoM is the Sustainable Energy and Climate Action Plan (SECAP). Detailed methodological guidance on how to develop a SECAP (Bertoldi, P., 2018), as well as guidelines on how to report the SECAP through the MyCovenant reporting platform (Covenant of Mayors Office, 2020) covering both mitigation and adaptation are publicly available free of charge. The energy poverty pillar reporting framework for EU signatories has been launched (Covenant of Mayors Office, 2022). Some key requirements of the initiative are briefly illustrated hereafter.

Within two years from signing up for the initiative, local authorities have to approve and submit a SECAP. The SECAP is the key document through which the Covenant signatory presents its vision and target, together with the measures to be implemented to achieve its climate mitigation target and adaptation goals. The SECAP covers the geographical area under the jurisdiction of the local authority and includes actions by both public and private sectors.

With regards to the mitigation pillar, the SECAP has to contain the results of the baseline GHG emission inventory, a GHG emission reduction target based on the country's or region's Nationally Determined Contribution (NDC) to the United Nations Framework Convention on Climate Change (UNFCCC) and a clear outline of the actions (including at least three key actions) that the local authority intends to take in order to reduce its GHG emissions. The SECAP may as well cover a longer period, in which case it is advised that the plan contains intermediate targets and goals for the year 2030.

With regards to the adaptation pillar, the SECAP includes the assessment of climate risks and vulnerabilities within the territory, at least one adaptation goal and a set of actions (including at least three key actions) to increase the resilience of the local authority sectors and vulnerable groups.

As far as energy poverty is concerned, cities are required to carry out an assessment based on a proposed list of indicators, to set a goal and to plan relevant actions. Given that the reporting requirements on energy poverty are more recent, until the end of 2024 a transition period applies, during which there are no mandatory data reporting requirements for signatories.

In January 2020, the SECAP template and related reporting guidelines were updated according to the Common Reporting Framework (CRF)[14] defined in the context of the GCoM. In 2023, the GCoM CRF was updated to include, next to the comprehensive reporting level, a simplified reporting level that provides greater flexibility, notably for cities with low data capacity.

A city or local authority willing to join the GCoM shall sign a commitment letter and send it to the regional/national Covenant responsible for their country.

Signatories are required to report specific data and information on emission inventories and action plans, reflecting the content of the action plan formally approved by the local council, through one of the two officially recognised reporting platforms:

— MyCovenant[15]

— CDP-ICLEI Track[16]

MyCovenant is also used by several regional Covenants (notably the European one) to manage signatories' commitments, regardless of the platform each city reports to. This report is based on data submitted through either of the two platforms and is structured as follows. Section 2 provides an overview of signatories, submitted action plans and monitoring reports, from the following regions:

— European Union (EU-27)

— Europe non-EU (incl. EFTA, Western Balkans + Türkiye, and United Kingdom)

— Eastern Partnership - CoM East

— Southern Partnership - CoM South / Clima-MED

— Central Asia

Sections 3 to 7 provide a more in depth analysis of data from action plans and monitoring reports for the EU-27 and for Europe non-EU, in particular: section 3 describes the approach and methodology on climate change mitigation, section 4 illustrates results on mitigation, section 5 describes the approach and methodology on climate change adaptation, section 6 illustrates results on adaptation, while section 7 draws conclusions. Action plans and monitoring reports from signatories in Eastern Partnership (CoM East), Southern Partnership (CoM South / Clima-MED) and Central Asia are not analysed in this report as they follow a slightly different approach and are the subject of separate, regional studies.

Box 1. Covenant of Mayors: from pledges to actions

Mayors who join the Covenant commit to take the lead and enhance the transparency and accountability of local climate and energy policies by:

1. Setting ambitious and quantified GHG emission reduction targets, adaptation goals and energy poverty goals;

2. Measuring their GHG emission level in a base year according to a common methodological approach;

3. Assessing climate risks and vulnerabilities in their territories;

4. Assessing energy poverty in their territories;

5. Defining a strategy and concrete actions to mitigate and adapt to climate change, and to tackle energy poverty;

6. Approving and making their action plan publicly available;

7. Regular reporting (both qualitatively and quantitatively) on the implementation of their action plan;

8. Sharing their vision, results, experience and know-how with fellow local and regional authorities within the EU and beyond through direct cooperation and peer-to-peer exchange.

1.2 The role of the Joint Research Centre in the Covenant of Mayors

The Joint Research Centre (JRC) of the EC was entrusted since the launch of the initiative with the role of providing scientific, methodological and technical support to the EU CoM initiative to ensure its coherence with EU climate and energy policies as well as its scientific credibility.

One of the key tasks of the JRC is to assist signatories with the preparation and implementation of their action plans through the development of methodological guidebooks. With the extension of the CoM beyond the EU, the JRC has been responsible for adapting the CoM EU methodology to the environmental, economic and political conditions of other world regions (e.g. Eastern Partnership countries, (Kona A. , et al., 2018). Southern Partnership countries (Rivas, et al., 2018), Sub-Saharan Africa (Palermo, et al., 2019)). In this process, the JRC works closely with the consortium operating the EU Covenant of Mayors Office[17], with the Global Covenant of Mayors' Secretariat[18] as well as with other offices managing regional Covenants[19,20,21] with the goal of ensuring the feasibility of these methodologies. The JRC also contributes to the definition and regular update of the reporting framework.

The JRC is responsible for the evaluation of submitted action plans and the provision of feedback to signatories[22], with the objectives of verifying the compliance of the plan with the Covenant commitments, principles and methodological approaches, as well as of assessing the credibility of the action plan in relation to the set targets and goals. Through its feedback, the JRC may provide further guidance and suggestions to CoM signatories for the potential improvement of their plans. The JRC is also responsible for regularly publishing datasets of submitted action plans and monitoring reports as open data[23].

Finally, given the policy relevance of the initiative, the JRC prepares scientific publications on its outcomes and its impacts on local and EU policies in order to evaluate the policies adopted by local governments and their

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[17] https://eumayors.eu/about/support-the-community/office.html
[18] https://www.globalcovenantofmayors.org/about/
[19] http://com-east.eu/en/
[20] https://www.com-med.org/en/
[21] https://comssa.org/en/
[22] Only to signatories from Europe, Eastern Partnership, Southern Partnership, and Sub-Saharan Africa.
[23] https://data.jrc.cec.eu.int/collection/id-00172 ; https://data.jrc.cec.eu.int/collection/id-00354

path towards the targets. Since 2013, the JRC has published a series of assessment reports on the Covenant of Mayors status (Cerutti et al., 2013), (Kona et al., 2016), (Kona et al., 2017), (Bertoldi et al., 2020), (Melica et al., 2022), (Franco et al., 2022), (Palermo et al., 2022), (Melica, et al., 2022b) (Franco , et al., 2023) in order to track the overall progress of the initiative on the basis of action plans and monitoring reports transmitted by Covenant cities to the EC.

In the context of the GCoM, the JRC collaborates with partners and other research institutions for aggregation reports[24] and co-chairs the GCoM technical working group (TWG) on data. This TWG cooperates with cities and city networks to develop an efficient and robust assessment, planning, reporting and monitoring framework by ensuring that the global initiative benefits to the maximum extent from the work, knowledge and resources placed over the years. A key output of the TWG on data has been the GCoM Common Reporting Framework (CRF)[25] (GCoM, 2018), which ensures compatible and comparable reporting approaches for signatories worldwide, and its updated version introducing a simplified reporting level (GCoM, 2023).

Specific aspects of the Covenant are also explored in dedicated studies, e.g., multi-level governance models in the Covenant (Melica et al., 2018); review of reporting platforms (Bertoldi, Kona, Rivas, & Dallemand, 2018); projections towards Paris Agreement targets (Kona A. , Bertoldi, Monforti Ferrario, Rivas, & Dallemand, 2018); methods on indirect emission accounting (Kona, Bertoldi, & Kılkış, 2019); climate mitigation policies (Palermo, Bertoldi, Apostolou, Kona, & Rivas, 2020); impacts of mitigation actions on air quality (Monforti-Ferrario et al, 2018; Peduzzi et al., 2020), key factors enabling higher climate ambition (Rivas, Urraca, Bertoldi, & Thiel, 2021), key predictors of greenhouse gas emissions for cities (Franco, et al., 2022b) (Franco, et al., 2023).

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2 Dataset construction and cleaning

Quantitative information analyses contained in this report are based on the GCoM MyCovenant dataset (Baldi, et al., 2023) and the CDP-ICLEI Track 2018-2022 Full cities datasets. From the latter, only cities belonging to the GCoM initiative were included in the analysis, as not all cities reporting to CDP are GCoM signatories. MyCovenant is also the platform used by some regional Covenants (notably the European one) to manage signatories, and therefore should provides a complete overview of committed cities and local authorities.

The overall data include the emission inventories, the GHG emission reduction targets, the climate risk and vulnerability information, the adaptation goals, and the planned mitigation, adaptation and energy poverty actions. Given that reporting on energy poverty will only become mandatory as of 1st January 2025, the data on this pillar are rather limited and only concern energy poverty actions, hence this report does not analyse them.

Assuring a good level of data quality has always been a challenging task: indeed, under the CoM framework, local governments voluntarily report their own data which naturally contains different sources of uncertainty. Such sources are of varied nature, for example biased estimations, evident errors with respect to the CoM reporting framework, missing information or lack of coherence (see Rivas et al. 2021). From all the possible drawbacks coming from the signatories' reported data, the JRC has acted mainly upon correcting evident mistakes, aiming at harnessing the quality of the available information on the cities' commitments, action plans and emissions inventories. In consequence, after the JRC-harnessing process, a structured collection of action plans and monitoring reports from MyCovenant reporting platform is available in the GCoM MyCovenant datasets[26]. Along with the GCoM datasets, the CDP-ICLEI Full cities datasets provide the information used for this report.

The general methodology for extracting and harnessing the reference GCoM datasets from the full set of raw submissions consists of two parts, namely data extraction and data cleaning. The first part, described in the following Section 2.1, refers to the extraction and management of the data from the full MyCovenant set of submissions. The second part, which will be described in Section 3.2, takes more in-depth analysis, screening and cleaning the data from unexplainable-outlier observations in both GCoM and CDP data sources.

2.1 MyCovenant data management

For the present report, all the data is extracted from a 'frozen' version of the MyCovenant PostgreSQL database as of end of March 2023. The signatories and the action plans are selected according to the following main criteria:

— Signatories with initiative status corresponding to 'published' (i.e., active, compliant with the reporting requirements) or 'on-hold' (i.e., active, but suspended due to non-compliance)

— Action plans with submission status 'submitted' or 'resubmitted'.

Different signatory profiles were excluded, notably: if they had initiative status corresponding to 'unpublished' (i.e., signatories that never concluded the registration process: 135 profiles) or 'under evaluation' (i.e., not yet formally confirmed as signatories: 260 profiles). Besides, action plans with submission status 'under completion' (i.e., not submitted) were also excluded (3 880 plans).

Along the extraction process from MyCovenant, an important challenge consisted of linking each action plan with its commitments. A careful examination had to be performed, plan by plan, considering the date of submission of the plan, the level of completeness of the templates related to the plan, and most importantly, the presence of a reduction target[27].

The overall procedure was carried out in different stages. On a first stage, the raw data extraction was performed. Then, on a second stage, the available data was integrated into structured tables, adding extra information such as the GCoM identification codes for each organisation-signatory in the GCoM platform. On a third stage, the main information quality-harnessing procedure was performed, as it will be explained in the Mitigation (3.2.1) and Adaptation (5.2) sections. Finally, the new cleaned and structured tables were submitted

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[26] https://data.jrc.ec.europa.eu/collection/id-00354

[27] The presence of adaptation goals was not considered among the completeness criteria, since it was an optional information and its requirements in the reporting template was only introduced in 2020. However, the presence of at least one reported climate hazard was considered among the completeness criteria for adaptation plans. See also Section 5.2.

for publication (Baldi et al., 2023), following the FAIR (Findability, Accessibility, Interoperability, and Reusability) guiding principles for scientific data management and stewardship (Wilkinson et al., 2016).

2.2 Signatories and commitments

At the cut-off date for the analysis (end of March 2023), there was a total of 11 367 cities and local governments registered as CoM signatories through MyCovenant, covering a total population of 370.8 million inhabitants, as shown in Table 1[28]. Some of these cities and local governments have committed to submitting a joint action plan (i.e., a plan covering a group of local authorities) instead of an individual plan, notably in EU and in South Mediterranean countries; thus, the number of expected action plans that should be submitted by those 11 367 signatories is 10 184.

An overview of signatories from different world regions is presented in Figure 1.[29.]

Table 1. Overview of signatories and expected Action Plans.

Region	No. of cities and local governments committed to the CoM	No. of expected Action Plans, taking into account joint commitments	No. of inhabitants
Europe – EU-27	10 414	9 241	240 371 464
Europe - EFTA	31	31	3 044 113
Europe – Non-EU	62	62	25 432 100
Eastern Europe – CoM East	545	545	33 773 690
Southern Mediterranean – CoM South	147	137	15 235 593
Western Balkans and Türkiye	153	153	50 502 698
Central Asia	15	15	2 945 955
Total	11 367	10 184	370 838 898

Source: JRC elaboration based on GCoM data

As shown in Table 1, most of the signatories (10 414) come from the EU-27, covering 240.3 million inhabitants, followed by the Eastern Partnership countries (545 signatories, 33.8 million inhabitants), Western Balkans and Turkey (153 signatories, 50.5 million inhabitants), Southern Partnership countries (147 signatories, 15.2 million inhabitants), Europe – non-EU and EFTA (93 signatories, 28.5 million inhabitants). A smaller number of signatories come from Central Asia (15 signatories, 2.9 million inhabitants).

The maps in Figure 2 illustrate in greater details EU-27 signatories: Figure 2 (a) shows the signatories in different colours based on population ranges, while Figure 2 (b) presents for each member state the share of signatories per population range, showing that in Austria, Czechia, Hungary, Italy, Malta, Slovakia and Spain more than half of the signatories are local authorities with less than 5 000 inhabitants.

Figure 3 shows the share of population covered by the CoM per EU Member State. It is observed that the CoM has a better population coverage in Mediterranean countries as well as in Belgium, probably because a similar framework supporting climate action in cities was not in place before the Covenant.

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[28] 12 European cities reporting to GCoM through CDP-ICLEI Track did not register their commitment to the European Covenant through MyCovenant and therefore are not included in the analysis presented in section 2.2.

[29] Signatories from Sub-Saharan Africa (CoM-SSA) use an offline reporting tool, tailor-made to the regional priorities. Therefore, signatories from CoM-SSA are not included in the analysis underpinning this report.

Figure 1. Overview of signatories registered through the MyCovenant reporting platform
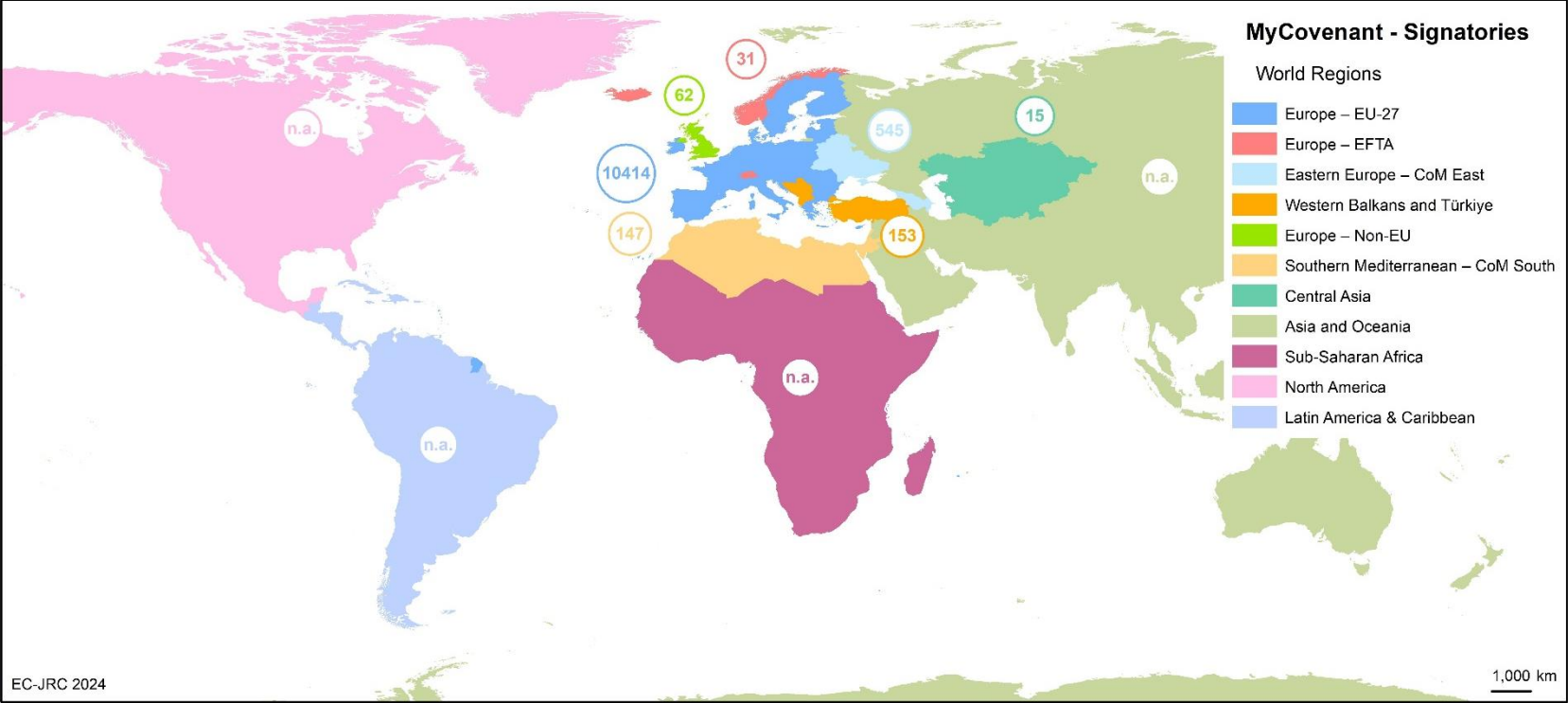
Source: JRC elaboration based on GCoM data

Figure 2. Signatories from EU-27, by population range (a) and share of signatories by population range per Member State (b). In the Nomenclature of Territorial Units for Statistics (NUTS) classification, NUTS2 indicates the basic regions for the application of regional policies.

(a)

(b)
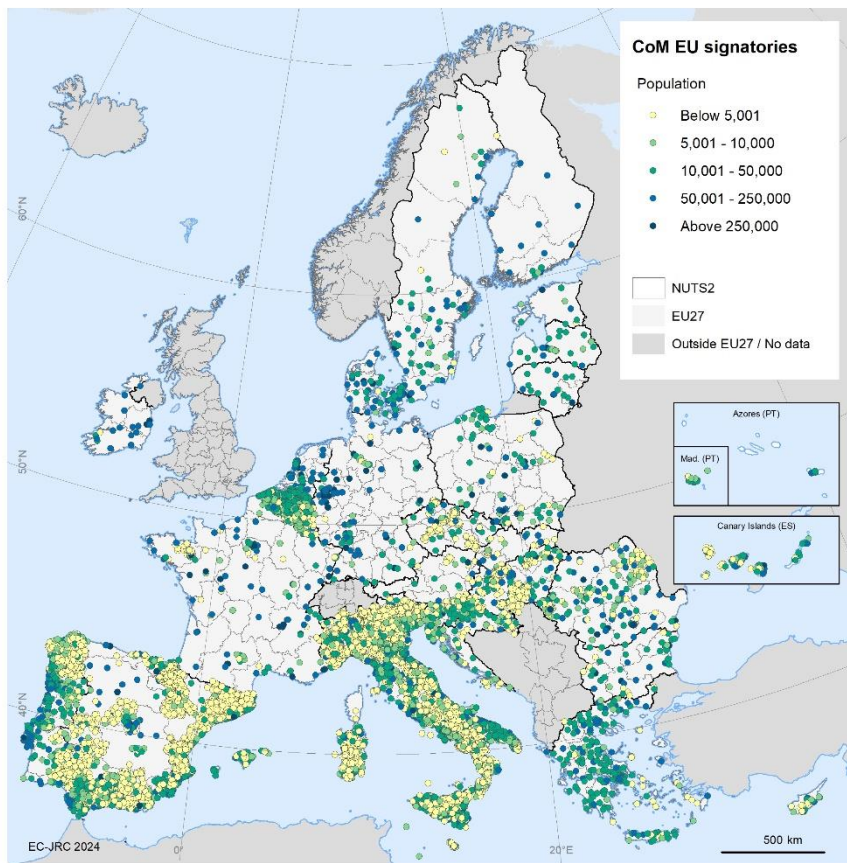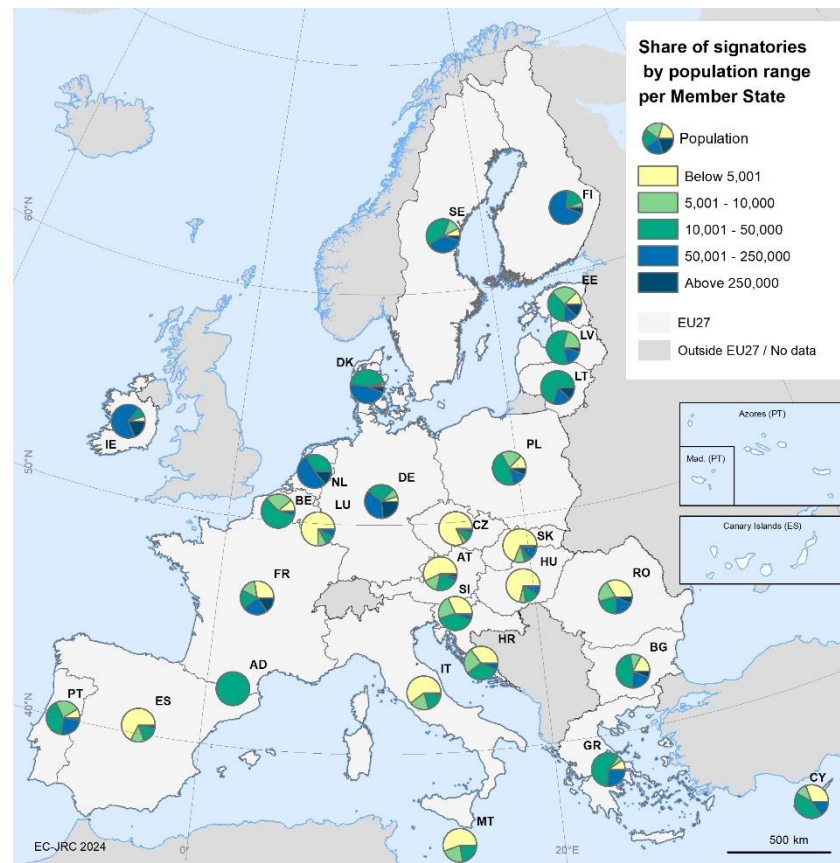
Source: JRC elaboration based on GCoM data

Figure 3. Share of country population covered by the CoM, for EU-27
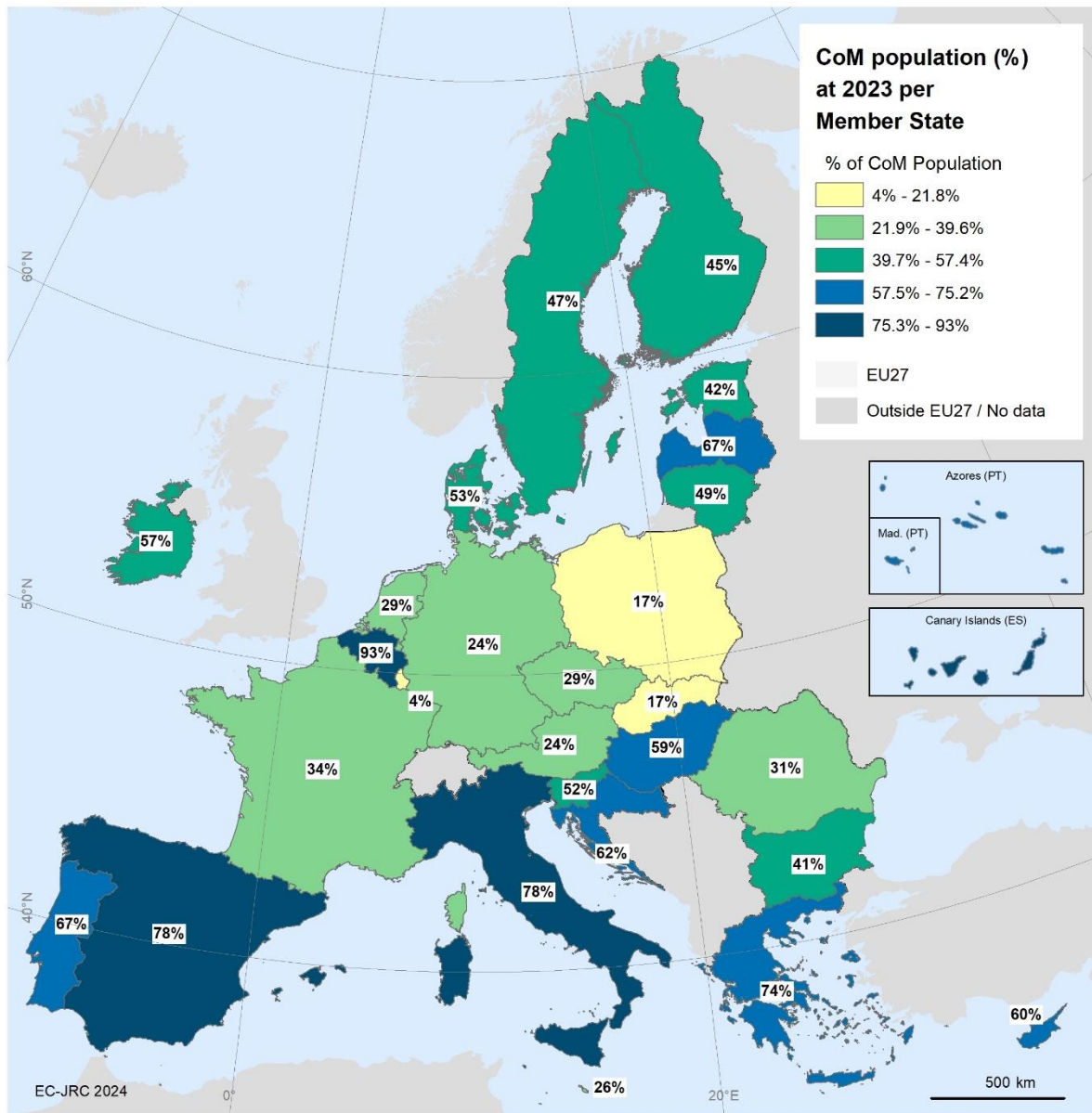
Source: JRC elaboration based on GCoM data

As described in Section 1.1, the Covenant initiative has evolved over time in line with the EU energy and climate policy. Signatories have therefore undertaken different commitments according to the moment of adhesion. Table 2 and Table 3 show the number of signatories and the population covered by region, based on the commitment they signed up to:

— CoM 2020 refers to signatories of the Covenant of Mayors up to October 2015, commiting only to mitigation with a minimum 20% emission reduction target by 2020;

— Mayors Adapt refers to Mayors Adapt signatories up to October 2015, committing only to climate change adaptation;

— CoM 2030 refers to signatories of the Covenant of Mayors for Climate and Energy, with a commitment to adaptation combined with a 40% mitigation target by 2030[30];

— CoM 2050 refers to signatories of the new Covenant of Mayors for Climate and Energy, with a commitment to adaptation combined with climate neutrality by 2050 and a recommended interim target of 55% emission reduction by 2030.

Table 2. CoM signatories by region and by commitment.

Region	CoM 2020	Mayors Adapt	CoM 2030	CoM 2050
Europe – EU-27	7 870	178	3 718	787
Europe - EFTA	20	0	14	3
Europe - Non EU	45	6	12	6
Eastern Europe – CoM East	195	1	424	29
Southern Mediterranean – CoM South	45	105	105	0
Western Balkans and Türkiye	58	4	76	40
Central Asia	15	0	0	0
Total	8248	294	4349	865

Source: JRC elaboration based on GCoM data

Table 3. Population covered by region and by commitment.

Region	CoM 2020	Mayors Adapt	CoM 2030	CoM 2050
Europe – EU-27	182 626 572	23 947 974	114 586 416	39 595 854
Europe - EFTA	2 539 308	0	930 833	430 994
Europe - Non EU	21 112 244	4 503 799	4 600 711	1 227 025
Eastern Europe – CoM East	20 108 032	98 953	20 727 860	1 692 886
Southern Mediterranean – CoM South	6 094 911	9 172 982	9 172 982	-
Western Balkans and Türkiye	15 719 043	1 544 146	24 141 172	23 504 080
Central Asia	2 945 955	-	-	-
Total	251 146 065	39 267 854	174 159 974	66 450 839

Source: JRC elaboration based on GCoM data

A more detailed analysis on the number of signatories and population covered by country is presented in Annex 1.

As shown in Figure 4, despite the high number of signatories, about 55% of them has not yet renewed their commitment by joining CoM 2030 or 2050. In terms of population, however, the signatories committed to 2030 or 2050 targets represent about 61% of the CoM population. At the cut-off date there were no signatories that only subscribed to the CoM 2050 commitment, suggesting that the most ambitious cities were already engaged in the Covenant under previous commitments.

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[30] For CoM-East signatories, the 2030 target was originally set to 30% by 2030.

18

Figure 4. Number of signatories and population covered by commitment.
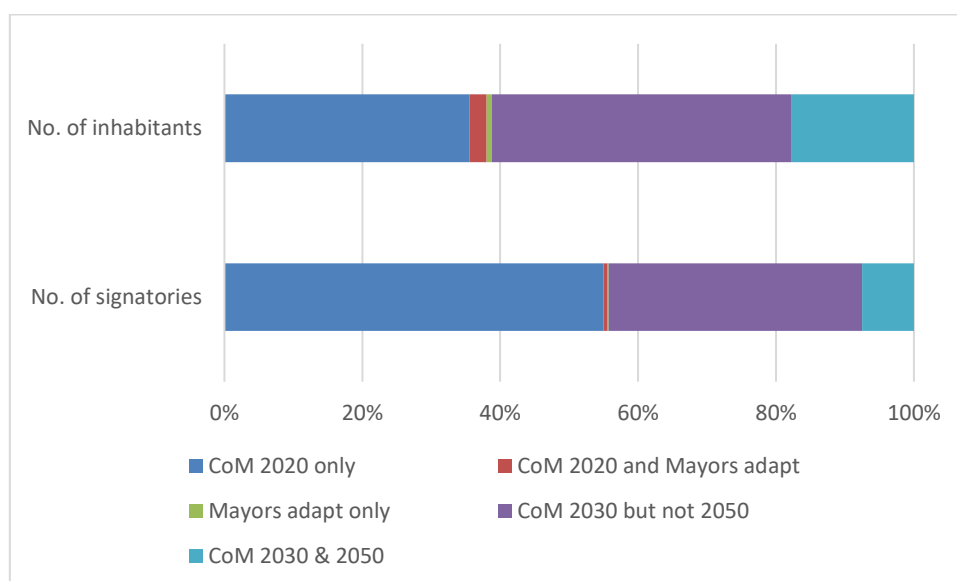
2.3   Submitted action plans

Following the data cleaning process described in section 3.2.1 and 3.2.2, the total number of signatories with a submitted action plan retained in the dataset is 7 268, covering about 271 million inhabitants.

Table 4 shows the number of signatories with a submitted action plan by region, in total and for each commitment, while Table 5 shows the population covered.

Table 4. No. of submitted action plans for each commitment.

| Region	Total	Mitigation	*Mitigation 2020*	*Mitigation 2030*	*Mitigation 2050*	Adaptation
Europe - EU	6 893	6 869	*5 770*	*1 660*	*33*	1 703
Europe - Efta	21	20	*15*	*13*		14
Europe - Non EU	43	43	*33*	*26*		26
Eastern Europe	221	221	*109*	*124*	*1*	121
Southern Mediterranean	26	26	*21*	*5*		5
Western Balkans and Turkey	62	62	*35*	*40*		40
Central Asia	2	2	*2*			
Total	7 268	7 243	*5 985*	*1 868*	*34*	1 909

Table 5. No. of inhabitants in cities with submitted action plans.

Region	Total	Mitigation	*Mitigation 2020*	*Mitigation 2030*	*Mitigation 2050*	Adaptation
Europe - EU	184 315 327	184 029 682	*155 057 990*	*84 998 786*	*2 573 260*	89 105 716
Europe - Efta	2 649 968	2 588 548	*2 333 136*	*2 415 306*		2 476 726
Europe - Non EU	22 834 467	22 834 467	*18 065 563*	*19 125 793*		19 125 793
Eastern Europe	18 493 202	18 493 202	*13 082 670*	*5 929 781*	*39 400*	5 820 658
Southern Mediterranean	4 306 970	4 306 970	*3 876 225*	*430 745*		430 745
Western Balkans and Turkey	38 485 595	38 485 595	*13 360 916*	*32 495 283*		32 495 283
Central Asia	377 486	377 486	*377 486*			
Total	271 463 015	271 115 950	*206 153 986*	*145 395 694*	*2 612 660*	149 454 921

Source: JRC elaboration based on GCoM data

An overview of the signatories with a submitted action plan is provided in Figure 5. Similarly to what we observed regarding the number of signatories, also the majority of action plans have a time horizon limited to 2020. However, it must be noted that between March 2022 and March 2023 the number of action plans with a mitigation target by 2030 increased by 45% (from 1 292 to 1 868) and the population covered has doubled. Similarly, the number of adaptation plans has grown by 47%. It must be noted however that the figures are not directly comparable, since the previous report did not include the SECAPs submitted via the CDP-ICLEI Track reporting platform.

Figure 5. Overview of signatories with a submitted action plan covering only mitigation until 2020 (a) or both mitigation until 2030 or 2050 and adaptation (b).

(a)

(b)
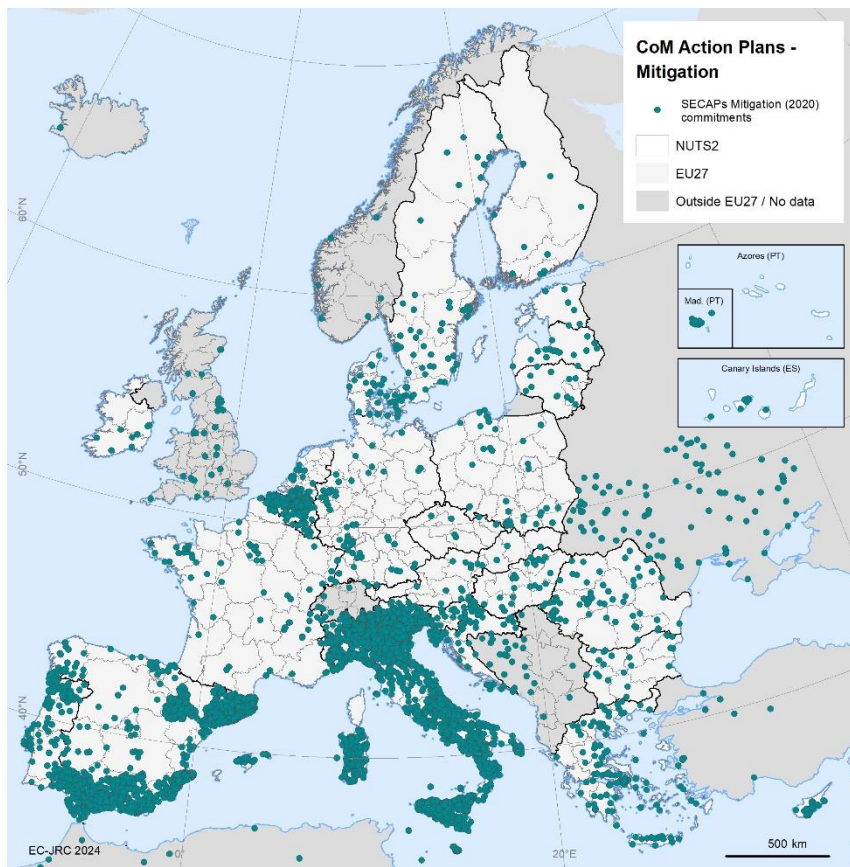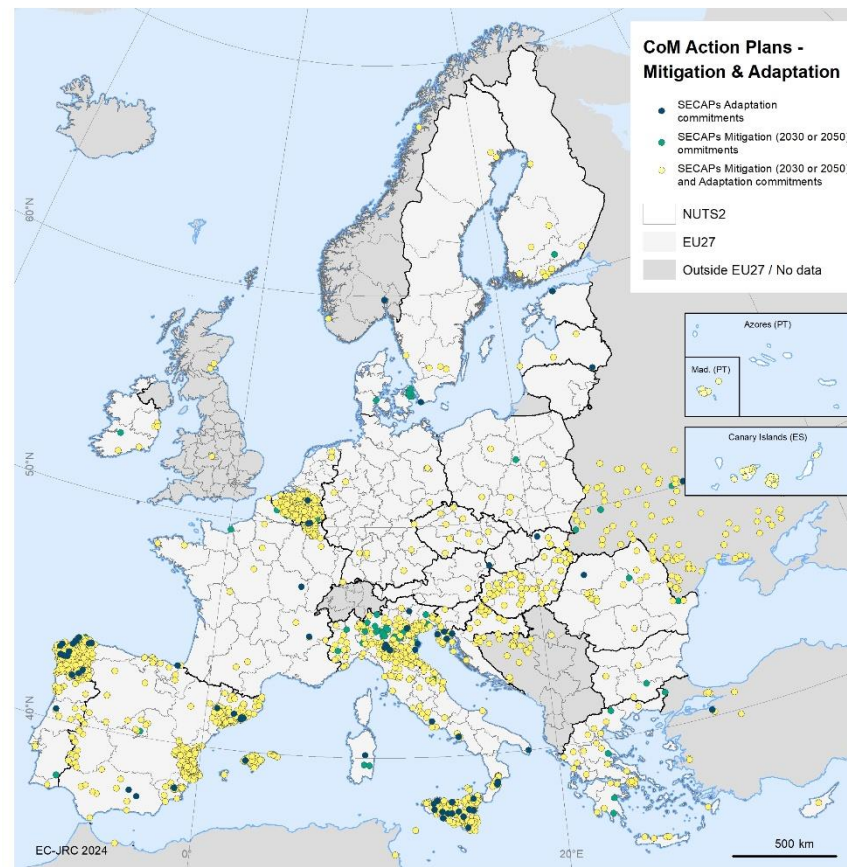
Source: JRC elaboration based on GCoM data

Looking at the action plans by pillar (Figure 6.), it is noted that 73.7 % of the action plans only address the mitigation pillar and that just 25.9 % of the actions plans address simultaneously mitigation and adaptation. Less than 0.5 % of the action plans address the adaptation pillar alone. In terms of population, however, the situation is more positive, with the action plans addressing both mitigation and adaptation covering more than half of the action plans population.

Figure 6. No. of action plans and population covered as a function of the pillar addressed.
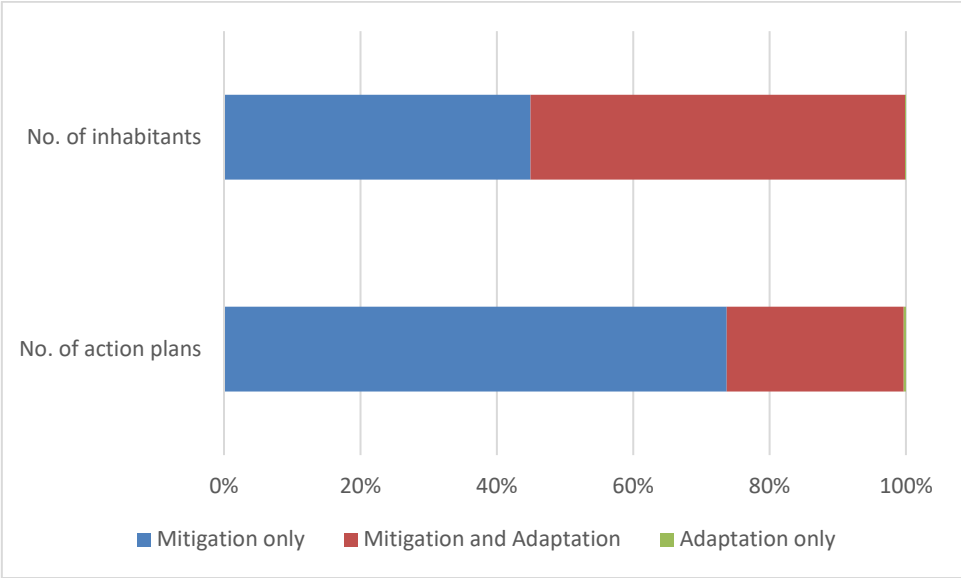
Source: JRC elaboration based on GCoM data

Figure 7. shows the mitigation plans and the population covered as a function of the target year. It can be observed that 73.7% of the mitigation plans (covering 45.4% of the population) has only a 2020 target; 25.8% of the mitigation plans (covering 53.6% of the population) have a 2030 target, either combined with a 2020 target or not; 0.5% of the mitigation plans (covering 1% of the population) have a plan consistent with the CoM 2050 commitment, i.e. with a climate neutrality target to 2050.

Figure 7. No. of mitigation plans and population covered as a function of the target year.

Source: JRC elaboration based on GCoM data

2.4 Monitoring reports

Based on MyCovenant data[31], Table 6 and Table 7 show that the number of signatories having submitted at least one monitoring report by the cut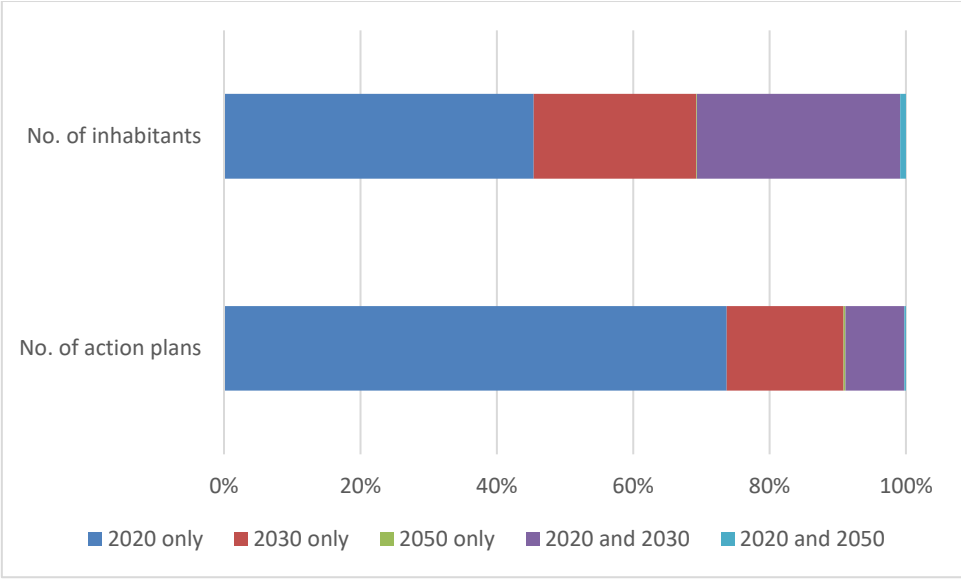-off date is 2 927, covering 117.3 million inhabitants. That represents 40 % of the signatories with an action plan and 47 % of the population covered by action plans. The shares appear rather low and might reflect difficulties in complying with the reporting requirements or a lack of implementation of the action plans on the ground. However, it must be stressed that these percentages do not take into account how many signatories have actually reached the deadline to submit their first monitoring report.

As shown in Figure 8, out of 2 927 signatories with a monitoring report, 1 510 (covering nearly 79 million inhabitants) submitted a monitoring report flagged as "complete", i.e., including at least one monitoring emission inventory. That corresponds to 21% of the signatories with an action plan and 32% of the action plans population. The other 1 417 signatories submitted a "light" monitoring report, mainly including qualitative information on the actions' implementation status.

An estimation of the number of monitoring reports that were actually due by the cut-off date of the analysis has been made based on the number of years that had passed since the approval of the plan by the city council, (more than 2 years for "light" reporting or more than 4 years for "complete" reporting). It is observed that approximately 42 % of "light" monitoring reports and 22 % of "complete" monitoring reports were submitted by the cut-off date of the analysis (end-March 2023).

Looking at different regions, a higher share of monitoring reports over action plans from signatories from the EU-27 can be observed. The CoM initiative has been established initially in the EU and has been extended later on to other regions, hence in the EU, a higher share of signatories may already be in the monitoring phase compared to other world regions.

Table 6. No. of signatories with at least one submitted monitoring report

Region	Signatories with at least one monitoring report, with or without MEI	Share of monitoring reports over action plans	Signatories with at least one monitoring report with MEI	Share of monitoring reports with MEI over action plans
Europe - EU	2849	41%	1472	21%
Europe - Efta	5	29%	5	29%
Europe - Non EU	10	29%	6	17%
Eastern Europe	55	25%	22	10%
Southern Mediterranean	1	4%		0%
Western Balkans and Turkey	7	12%	5	8%
Central Asia		0%		0%
Total	2 927	40%	1 510	21%

Source: JRC elaboration based on GCoM-MyCovenant data

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[31] This part of the analysis is only based on data submitted through MyCovenant, since this platform allows continuos reporting. By contrast, CDP-ICLEI Track requires annual reporting during pre-defined reporting windows.

Table 7. No. of inhabitants in cities with submitted monitoring reports

Region	Signatories with at least one monitoring report with or without MEI	Share of monitoring reports over action plans	Signatories with at least one monitoring report with MEI	Share of monitoring reports with MEI over action plans
Europe - EU	102 174 874	56%	70 328 449	38%
Europe - Efta	825 509	34%	825 509	34%
Europe - Non EU	4 177 019	22%	2 709 019	15%
Eastern Europe	7 755 798	42%	3 384 113	18%
Southern Mediterranean	63 000	1%		0%
Western Balkans and Turkey	2 305 125	10%	1 739 654	8%
Central Asia		0%		0%
Grand Total	117 301 325	47%	78 986 744	32%

Source: JRC elaboration based on GCoM-MyCovenant data

Figure 8. Overview of signatories with at least one submitted monitoring report, either qualitative (a) or quantitative, with MEI (b)

(a)

(b)
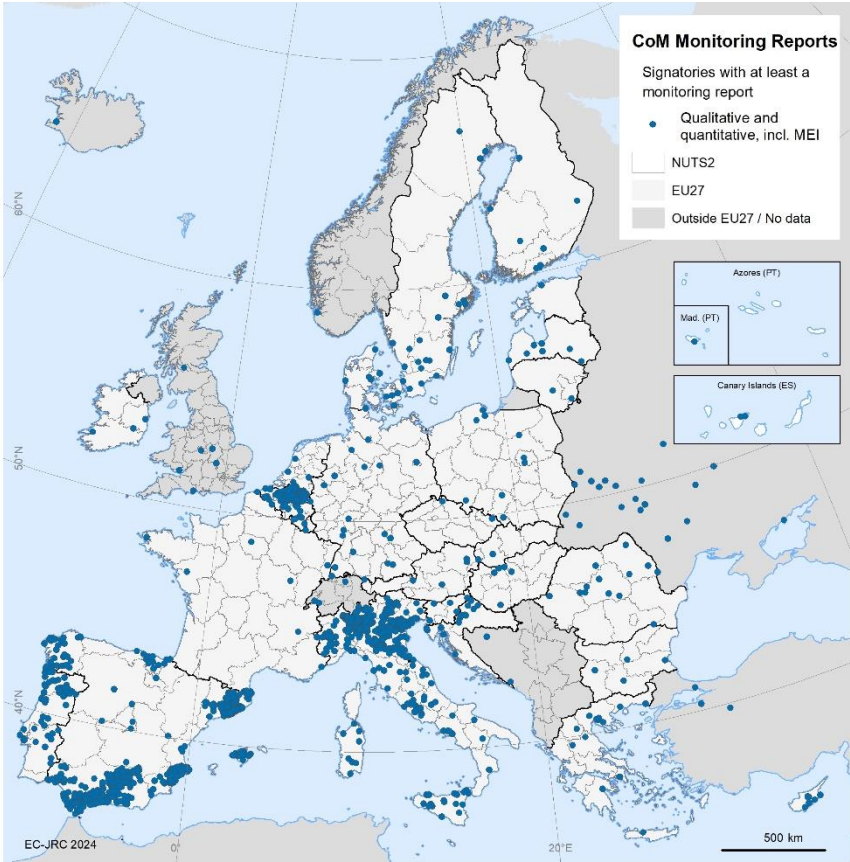
Source: JRC elaboration based on GCoM-MyCovenant data

3 Approach and methodology on mitigation

3.1 The Covenant of Mayors' approach to mitigation

A local authority willing to develop a climate mitigation plan should start by developing a Baseline Emission Inventory (BEI). The BEI quantifies the level of GHG emissions in a base year according to a common methodological approach (Bertoldi, P., 2018); it allows identifying the main emitting sectors and consequently prioritising areas for action.

Similar to the UNFCCC, the Covenant of Mayors recommends 1990 as the baseline year or the closest subsequent year for which the most comprehensive and reliable data can be provided.

Signatories are given various options to calculate their emission inventories. They can choose the standard IPCC approach[32], the Life-Cycle Assessment (LCA) approach[33] or National/sub-national emission factors which have been validated by a public body. In the IPCC approach (also referred to as the activity-based approach), emission factors are based on the carbon content of fuels. In the LCA approach, emission factors consider the whole supply chain and not only the final combustion of fuels. Finally, signatories choosing to report according to National/sub-national emission factors will need to specify the emission factors used and provide the source/validating body.

According to the approach chosen and emitting sectors included in the inventory, signatories define the GHGs to account for: they may report only carbon dioxide emissions (CO_2) or also emissions of methane (CH_4) and nitrous oxide (N_2O), converted into CO_2-equivalents (CO_2-eq) according to their global warming potential.

The CoM inventories account for direct emissions (also referred to as Scope 1 emissions) generated within the territory of the local authority (e.g., from the combustion of fossil fuels) and for indirect emissions (also referred to as Scope 2 emissions) associated with the consumption of grid-supplied energy (electricity or district heating and cooling) irrespective of where the energy generation actually occurs.

The CoM inventories include the main sectors and sub-sectors not covered by the EU Emissions Trading System (EU ETS), as described in Table 8 [34]. Activity data and GHG emissions associated with energy supply are also calculated and reported in the context of the CoM inventories. However, they are not included in the total emissions since they are already captured through indirect emissions from grid-supplied energy. Indirect emissions associated with grid-supplied energy that is consumed in the territory of the local authority may cover electricity and heat/cold production plants involved in the ETS.

Notation keys may be used to accommodate limitations in data availability and differences in emission sources between local governments:

— **"NO" (not occurring)**: this notation key applies to an activity or process that does not occur or exist within the city. It may also be used for insignificant sources.

— **"IE" (included elsewhere)**: this notation key may be used for activity sectors whose GHG emissions are estimated and presented in another category in the same inventory, stating where it is added. It may be used where it is difficult to disaggregate data into multiple sub-sectors.

— **"NE" (not estimated)**: this notation key applies to activity sectors whose GHG emissions occur but have not been estimated or reported, with a justification why.

— **"C" (confidential)**: this notation key applies to activity sectors whose GHG emissions could lead to the disclosure of confidential information, and as such, are not reported publicly.

With the BEI results at hand, the local authority can identify the most emitting sectors in its territory and quantify the effort needed to reach the minimum target set by the initiative or possibly a more ambitious target. In addition to the BEI, CoM signatories may also calculate more recent emission inventories that would allow understanding emission trends in different sectors. Consequently, they may choose the priority areas for action, taking due consideration of the local/regional/national policy priorities and of existing opportunities available for achieving the target. The target can be set on an absolute or on a per capita basis; a third option, only given to CoM signatories from outside the EU, is to set the GHG emission reduction target based on a business as usual scenario.

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[32] Emissions Factors Database (IPCC): https://www.ipcc-nggip.iges.or.jp/EFDB/main.php
[33] For the LCA approach many datasets are available on the market.
[34] Adapted from the "The Covenant of Mayors for Climate and Energy Reporting Guidelines".

Table 8. Description of the sectors and sub-sectors for GHG emission inventories in the CoM context.

Sector	IPCC (ref no.)	Subsector	Description
Stationary Energy / Buildings	1A4a	Municipal buildings, equipment/ facilities	Energy consumption and GHG emissions in buildings and facilities owned by the local authority. Facilities refer to energy-consuming entities that are not buildings, such as wastewater treatment plants.
		Public lighting	Public lighting owned or operated by the local authority (e.g., street lighting and traffic lights). Non-municipal public lighting is included in the 'Tertiary buildings, equipment/facilities' sector.
		Tertiary buildings, equipment/ facilities	Energy consumption and GHG emissions in buildings and facilities of the tertiary sector (services); e.g., offices of private companies, banks, commercial and retail activities, hospitals, etc.
	1A4b	Residential buildings	Energy consumption and GHG emissions in buildings that are primarily used as residential buildings. Social housing is included in this sector.
	1A1 1A2	Industries	Non-ETS: Energy consumption and GHG emissions in manufacturing and construction industries not covered in the EU ETS.
			ETS: Energy consumption and GHG emissions in manufacturing and construction industries covered in the EU-ETS. Integrating them into emission inventories is not recommended unless such plants were included in previous energy plans and in the local authority's CO_2 emission inventories.
	1A4c	Agriculture/ Forestry/ Fisheries	Energy consumption and GHG emissions in buildings, facilities and machinery in the primary sector (agriculture, forestry and fisheries); e.g., greenhouses, livestock facilities, irrigation systems, farm machinery and fishing boats.
Transportation	1A3a 1A3b 1A3c 1A3d 1A3e	Municipal fleet	All GHG emissions from fuel combustion and use of grid-supplied energy for transportation within the city boundary shall be reported and disaggregated by mode: on-road, rail, waterborne navigation, aviation and off-road:
			- 1A3b: on-road transportation: urban street network under the competence of the local authority;
		Public transport	- 1A3b: on-road transportation serving a larger area and/or not under the competence of local authority (e.g. highways) may be included if mitigations actions are planned in that area
			- 1A3e: off-road transport: off-road traffic of vehicles/mobile machinery in any activity sector
		Private and commercial transport	- 1A3c: rail transportation: local transport (metro, tram and local trains); long-distance trains, intercity trains, regional and cargo rail transportation may be included if mitigations actions are planned in that area

Sector	IPCC (ref no.)	Subsector	Description
			- 1A3d: waterborne navigation: local ferries in public and private transport acting on the local territory
			- 1A3a: aviation: local governments may choose to report GHG emissions from the in boundary component of domestic and/or international aviation (such as the landing and take-off cycle for aviation), or assume these are all out of boundary emissions and use the notation key "Included Elsewhere"
Waste	4A	Solid waste disposal	All emissions from solid waste that are disposed of at managed sites (e.g., sanitary landfill and managed dumps), and unmanaged sites (e.g., open dumps, including above-ground piles, holes in the ground, and dumping into natural features such as ravines).
	4B	Biological treatment	All emissions from biological treatment of waste, including composting and anaerobic digestion of organic waste.
	4C	Incineration and open burning	All emissions from waste that are burned either in a controlled, industrial, process or in an uncontrolled, often illicit, process. The former is often referred to as incineration, and the latter as open burning. Note that this excludes emissions from waste incineration for the purposes of energy generation, also known as energy recovery.
	4D	Wastewater treatment	All emissions from the treatment process of wastewater, either aerobically or anaerobically
Energy supply	1A1	Electricity-only generation	All activity data and GHG emissions from energy (both renewable and non-renewable) consumption for the purpose of generating grid-supplied electricity in power plants that solely generate electricity.
		Combined heat and power (CHP) generation	In the case of CHP plants, which generate heat and electricity simultaneously, or any other plants not listed, the amount of electricity produced, both from renewable and non-renewable energy sources shall be reported.
		District heating/cooling generation	All activity data and GHG emissions from energy (both renewable and non-renewable) consumption for the purpose of generating thermal energy in district heating/cooling plants
		Distributed local renewable energy generation	All activity data and GHG emissions from local energy generation (electricity, heat, etc.) facilities not grid-connected.

Source: Bertoldi P. (2018)

3.2   Statistical analysis

3.2.1   Harnessing the information in the GCoM datasets (MyCovenant)

The JRC-harnessing procedure of the GCoM datasets followed some specific steps for enhancing the quality of the signatories' reported data. Emphasis was placed on energy consumption and supply together with their associated GHG emissions inventories, and on the declared actions set out to fulfil the signatories' commitments[35]. The harnessing of the supply data and mitigation actions was developed following some internal-consistency general rules that will be explained below, while for the cities' GHG emissions inventories, a more detailed analysis was performed.

For energy consumption and its associated emissions, the first task was to develop a general methodology for screening outlier energy-activity observations with respect to national (per capita) references. In this way, the reported city energy activity was compared with national energy consumption per capita reference values (Eurostat, 2021, IEA, 2021). To simplify the analysis, the complete methodology for screening outlier energy activity starts by grouping electricity separately from thermal carriers. For both groups, the industry sector is excluded, and national consumption references are taken for commercial and public services, road and residential sectors. After analysing the result of taking different thresholds, outliers (to the right) are tagged if the declared electricity consumption per capita is greater than five times the maximum threshold, if the declared thermal activity per capita is greater than two times the maximum threshold, or (to the left) if the declared consumption per capita is less than a threshold of 0.01 (MWh/year per capita).

To compute the maximum threshold for each group (by electricity and thermal carriers), countries are clustered together according to their median per capita national energy consumption (following the *k-medoids* technique). Partitions of 2 to 5 clusters are considered, and a unique partition is identified according to relevant statistical indices measuring the density and separation between clusters (namely the Calinski-Harabasz, C-index, Davies-Bouldin and Dunn indices), also analysing if there are important differences between the respective thresholds and the observations being tagged as outliers. Following this approach, the chosen partition consists of three clusters with maximum thresholds of 2.9, 4.8 and 13.1 (MWh/year per capita), for electricity, and with maximum thresholds of 16.8, 21.8 and 100.4 (MWh/year per capita), for thermal carriers.

After completing the outlier screening process, a more exhaustive analysis is performed on the subset of inventories initially tagged as being outliers. Some outliers might be rare but plausible, and if an evident error is detected, it can be corrected. For example, if the city reports in kWh instead of MWh, or in activity per capita instead of absolute activity. Only if the reported values appear to be incomplete or to make no proper sense, then the inventory is removed. Finally, internal coherence is checked regarding past inventories, verifying that there are no outlier values which cannot be empirically justified. As a result of this validation process for the reported energy consumption, 0.2% of all signatories had to be discarded.

Once the energy activity data is cleaned from evident outliers, the emissions are estimated by multiplying the activity (MWh) times the corresponding emission factor. Cities report their own estimation of the emissions, making it necessary to validate the emission factors they used for computing their reported emissions. When available, those factors are validated against carrier-specific references, taken from the JRC repository ((Bastos, Monforti-Ferrrario, & Melica, 2024) (Lo Vullo, Monforti-Ferrario, Palermo, & Bertoldi, 2022)(Koffi, et al., 2017)Lo Vullo et al., 2020; Koffi et al., 2017). The values are revised only in case the emission factors reported by the cities are too different from the carrier-specific references (50% or 100% off from the national or local electricity factor references, respectively, and 20% off from their corresponding references for all other energy carriers). On the other hand, signatories might not report on their emission factors, and in that case the corresponding reference values must be inserted. As a result of this emission factor validation process, 12% of all signatories reported some emission factors that had to be revised, and missing emission factors had to be inserted for 36% of all signatories.

Regarding the internal consistency rules applied for cleaning the reported energy supply values, the following was implemented. Firstly, for local heat/cold energy and local-distributed electricity production, an implicit emission factor was computed between the reported supply and emissions, aggregating them by renewable and fossil sources. Setting lower and upper bounds for acceptable emission factors (see again Lo Vullo et al., 2020; Koffi et al., 2017), emissions were validated only if that implicit emission factor was less than 2 and greater or equal than 0.1 (t CO_2-eq/MWh) for fossil sources (0 for renewables). Secondly, considering renewable energy only for locally distributed electricity production, the reported energy supply was compared

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[35] For the procedure and data cleaning on adaptation information, see section 5.2.

with energy consumption, and only if the energy produced was much greater than the consumption (over 150 times the reported consumption), it was taken out from the validated data set.

For certified green electricity purchases, the reported purchases were compared with electricity consumption, and they were validated only if the energy purchased was not greater than 1.05 times the electricity consumption.

On the commitments and mitigation actions included in the signatories' energy and climate action plans (SEAPs/SECAPs), the validation process consisted of an initial screening aiming at detecting evident inconsistencies in the reported data. After an initial assessment of acceptable commitments, they should consist of reasonable CO_2 targets, both under BEI and business as usual (BAU) scenarios, not greater than a 100 % reduction of the baseline emissions. Then, following an empirical analysis, the proposed CO_2 reduction estimates were validated only if they were not greater than 2.2 times the targeted baseline emission reduction and less than the total baseline emissions. Likewise, estimated energy savings reported by the cities were checked for excluding values that were greater than 1.2 times the energy consumption. Further analysis was developed by action sectors, e.g., checking that the CO_2 reduction estimates by sector did not exceed the total reported emissions, or by computing an implicit factor between the estimates of CO_2 reduction and the sum of energy savings and production. Here, if such a factor was greater than 2 or less than 0.01 (t CO_2-eq/MWh), then the action-sector was excluded from the validated data set (again, the limits for acceptable emission factors were based on Lo Vullo et al., 2020; Koffi et al., 2017).

Finally, regarding the actions' details, the estimated impact of CO_2 reduction was validated against the targeted CO_2 reduction estimates. It was considered, after empirical analysis, that the mitigation estimated impact could not be greater than 2 times the targeted CO_2 reduction estimates. Similarly to the validation of the mitigation sector, which was performed according to the implicit emission factor computed between the (reported) estimated CO_2 reduction and the sum of the estimated energy savings and renewable energy production, an analogous approach was followed for individual actions/measures: the action was validated only if the implicit emission factor was lower than 2 or greater than 0.01 (t CO_2-eq/MWh).

3.2.2   Harnessing the information in the GCoM datasets (CDP-ICLEI Track)

Concerning the data reported through CDP-ICLEI Track, the commitments information and emissions values were collected from detailed inventories (by sectors and scope) and total emissions figures (focusing on retrieving, whenever possible, baseline and follow-up emissions inventories), as reported by the cities in the yearly questionnaires, dating from 2018 to 2022. For each signatory, baseline emissions were directly extracted or computed from the available information, e.g., if a "fixed-level target" was selected by the signatory, the percentage target reduction was computed from the fixed target emissions and the first available emissions inventory, or in case of a per-capita target, the baseline emissions and the target were translated into absolute terms. Besides, the most ambitious percentage reduction targets were selected for the target year of 2030 or onwards. When the target year was later than 2030, the corresponding reduction target for 2030 was interpolated on the basis of the baseline and reported target years. As for the emissions, their values were modified if an evident error was detected and could be directly corrected, for example, if the units of the emissions seemed to be given in per-capita terms, or in GWh or kWh instead of MWh. Additionally, internal coherence was checked among the available inventories (and population values), verifying that there were no outlier values which could not be empirically justified. Only the emissions inventories values that passed these checks were included in the analysis. As a result of this curation process, 5% of the signatories reporting through CDP were modified, and 1% had to be discarded. A total number of 127 action plans reported via CDP-ICLEI Track, covering almost 84 million inhabitants, were included in the analysis.

To consider both MyCovenant and CDP-ICLEI Track data, the emissions were aggregated by scope and sector, grouping the activity sectors into Residential buildings, Municipal buildings, Tertiary (non-municipal) buildings, Industry, Transport, Waste and Other. Considering the information on local mitigation actions, their action sectors were aggregated into Buildings, Transport, Industry, Electricity, Heat, Waste and Other. Lastly, when a signatory reported in both MyCovenant and CDP reporting platforms, the one holding the most recent submission date was considered.

3.2.3   Statistical methods for estimating the signatories' achievements

GCoM signatories present their action plans (SEAPs/SECAPs), which include an emission inventory for the base year, i.e., the year against which the achievements of the emission reductions in the target year are measured. Following the plan submission, signatories should present, ideally every two years, a monitoring report with its

corresponding MEI, enabling to follow the performance of their proposed actions according to their declared ambitions.

In order to develop the analysis of the signatories' achievements, emissions must be converted into the same units (IPCC, tCO_2-eq). Given the 'GCoM – MyCovenant, 2023' dataset (Baldi et al., 2023), the reported emissions can be aggregated after i) assuming that all emissions are reported in t CO_2-eq. and ii) multiplying LCA inventories by a factor of 0.885, according to the fraction of direct emissions embedded in LCA inventories (Cerutti, et al., 2013).

Concerning the analysis of the signatories' accomplishments for their SECAPs, Section 4.3.2 presents the analysis and results for the expected accomplishments of European signatories. Such an analysis focuses only on signatories having submitted at least one monitoring report besides their action plan. Following the statistical methodology presented in (Franco, et al., 2022b), (Melica, et al., 2022) (Melica, et al., 2022b) the emissions inventories are estimated for a common baseline year of 2005, and then predicted for the target year of 2030. Therefore, emissions are forecasted by adjusting a statistical model on their reported data, after minimising the prediction error for the last known value. The complete methodology is summarized in Annex 2.

4 Results on mitigation

4.1 Emission reduction targets

Covenant signatories are free to set a more ambitious GHG emissions reduction target than the minimum target proposed by the initiative. As a result, different levels of ambition among Action Plans can be seen.

Looking at the SECAPs with a 2030 time horizon (Figure 9), it can be observed that in 59% of the cases the minimum 40% target set for EU signatories is chosen, while in about one fourth of the cases a more ambitious target is selected, yet not as ambitious as the 55% headline target set by the EU for 2030[36]. About 4% of the signatories set a target lower than 40%, which is only allowed to CoM signatories outside the EU. Finally, just 11% of the action plans set a target of at least 55% emission reduction. High-population signatories showed a distinct proclivity to setting high targets (above 54%).

Figure 9. Number of action plans with a 2030 horizon and population coverage as a function of the level of ambition of the target.
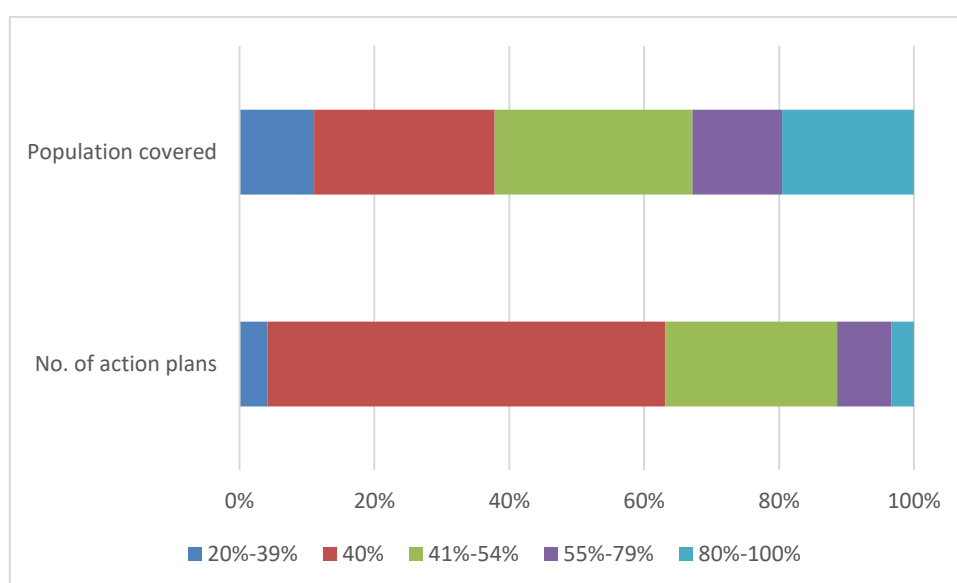
Source: JRC elaboration based on GCoM data

Based on the targets and on the results of baseline emissions inventories reported by 1 698 cities and local authorities with data considered valid according to the procedure described in Section 3.2.1, the overall commitment by 2030 (Table 9) has been calculated. Overall, EU-27 signatories have made a commitment aligned with the EU level reduction target by 2030. Annex 1 presents the same analysis at country level.

Table 9. Overall commitment by 2030, based on submitted action plans.

Region	Total emissions in BEI [t CO₂.eq/year]	Targeted emissions in 2030 [t CO₂.eq/year]	Overall committed reduction by 2030
Europe – EU-27	469 096 214	210 160 751	55.2%
Europe - EFTA	9 213 163	2 386 502	74.1%
Europe - Non EU	122 470 482	8 810 884	92.8%
Western Balkans and Türkiye	83 488 514	75 354 415	9.7%
Total	684 268 373	296 712 552	56.6%

Source: JRC elaboration based on GCoM data

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[36] Regulation (EU) 2021/1119 'European Climate Law'

4.2 Baseline emission inventories

4.2.1 Baseline year

As mentioned previously in Section 3.2.3, signatories are free to choose the base year against which their performance can be measured. Thus, different BEI years are used, as shown in Figure 10 and Figure 11 for EU and the rest of EU 2030 commitments, respectively. In total, for all the EU-27 GCoM signatories with a 2030 commitment, there are 1 612 signatories holding a BEI (from which 676 have reported at least one MEI). Most of them have chosen 2010 as their base year, representing 23 % of all the BEIs (see Figure 10). This 23 % represents a population of 6.9 million inhabitants, generating 4.3 t CO_2-eq per capita. Other frequently used base years are 2005 and 2011, including 14 % and 16 % of all the BEIs, respectively. On the other hand, 1990 is the base year with the highest population, holding 15 million inhabitants and accounting for 8 t CO_2-eq per capita.

Figure 10. Frequency of BEIs for the different base years regarding 2030 commitments in EU-27, along with the population (in millions) and emissions per capita (t CO_2-eq) for every year.
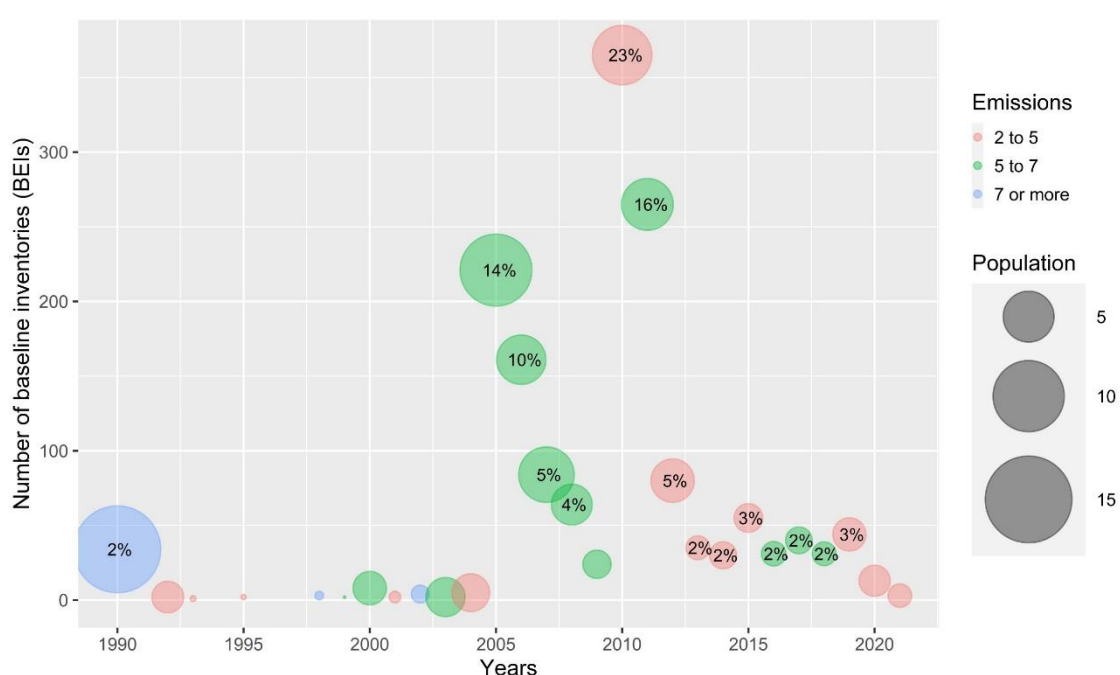
Source: JRC elaboration based on GCoM data

Concerning 2030 commitments in the rest of Europe, in total there are 75 GCoM signatories with a BEI (from which 48 have also reported at least one MEI). For these signatories, 15 % of them have 2019 and another 11 % have 2010 as their base year (see Figure 11). The 2019 BEIs hold a population of 19 million inhabitants with 3.5 t CO_2-eq per capita, against the 2010 BEIs representing a population of 0.4 million inhabitants with 2.4 t CO_2-eq per capita. It can also be highlighted the year 1990, with the second-highest population of 13.7 million inhabitants and 5.8 t CO_2-eq per capita.

Figure 11. Frequency of BEIs for the different base years regarding 2030 commitments in Europe non-EU-27, along with the population (in millions) and emissions per capita (t CO_2-eq) for every year.
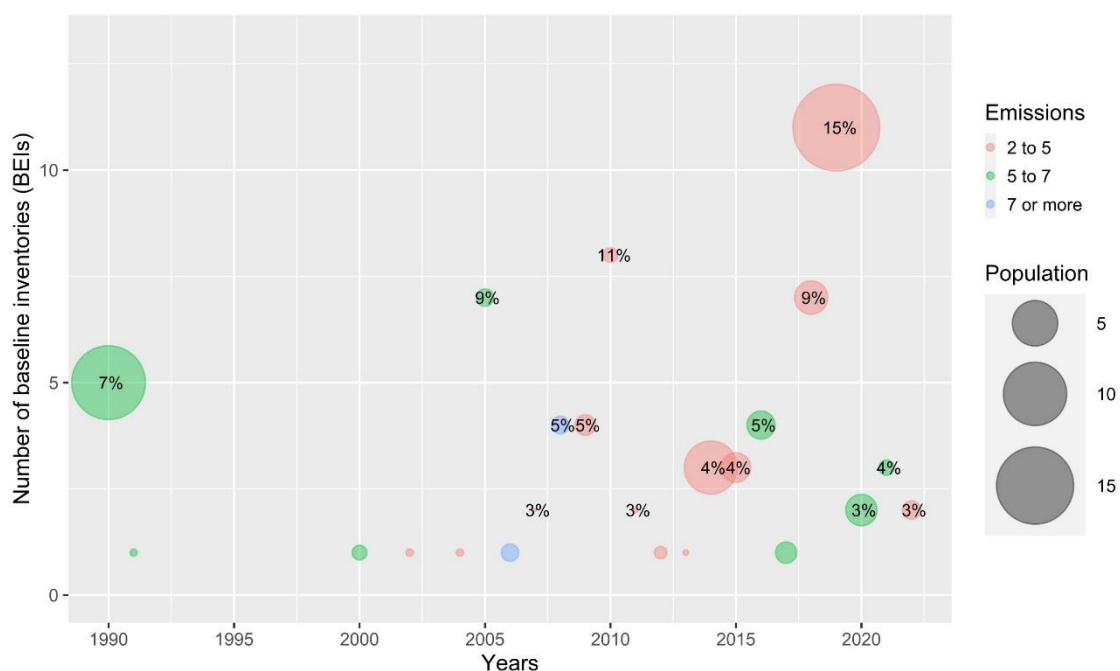
4.2.2 GHG emissions in **cities'** latest available GHG emission inventories

This section provides a more detailed view of the GHG emissions declared by the signatories through their latest EIs from SECAPs with a 2030 horizon. The following tables show a finer disaggregation by sector and scope for both EU-27 (Table 10) and non-EU signatories (Table 11).

For comparison, the overall amount of emissions declared by EU-27 (Table 10) corresponds to almost 10% of the overall EU-27 CO_2 emissions as estimated for 2022 by EDGAR (Crippa, 2023), showing how the CoM actually involves an important share of the GHG emission sources.

As shown in Figure 12, buildings account for almost two-thirds of the total emissions in EIs from EU-27 signatories. Residential buildings account for more than half of sectoral emissions, with tertiary buildings being the second most important, with roughly one-third of emissions. Municipal buildings, under the direct control of the local administration, account for just about 4% of sectoral emissions. Transportation represents 31% of total GHG emissions, while waste and other altogether account for 4% of total emissions. The picture is very similar in EIs from non-EU signatories, although we note a slightly higher share of emissions associated with municipal buildings and waste.

Almost the totality (>98%) of the reported emissions are related to energy use, with waste treatment playing a minor role in the inventories, due to the fact that waste is an optional sector in the EU CoM and therefore just a limited number of cities report on it. Direct (Scope 1) emissions represent 64% of the total GHG emissions, followed by 34% indirect (Scope 2) emissions, associated with the consumption of grid-supplied energy. Scope 3 emissions represent only 2% of the total GHG emissions.

A more detailed analysis by energy carrier could be performed based on the data reported through MyCovenant and is shown in Figure 14.

Based on the EIs of signatories from EU-27, fossil fuels cause 61% of reported emissions, while electricity is the second carrier with 33% of reported emissions. District heating follows with 4% of reported emissions while both renewable fuels and non-energy related emissions account for about 2%. Looking at EIs of signatories from non-EU countries, fossil fuels play a somewhat smaller role (49% of emissions), while electricity represents a higher share compared to EU-27 signatories (39%), probably due to a less decarbonised electricity mix, and non-energy related emissions become more significant (10% of emissions).

Table 10. GHG emissions in the cities' latest EIs related to 2030 commitments, by sector and scope - EU27 (in t CO_2-eq/year)

Sector	Scope 1	Scope 2	Scope 3	Total
Municipal buildings equipment/facilities	2 909 008	5 454 586	14 442	8 378 036
Residential buildings	58 218 012	49 729 012	512 898	108 459 922
Tertiary (non municipal) buildings equipment/facilities	26 973 063	43 661 741	626 007	71 260 812
Industry	25 842 347	18 797 443	38 871	44 678 661
Transportation	108 119 225	3 520 861	2 571 451	114 211 537
Waste/wastewater	2 576 394	24 055	2 515 248	5 115 697
Other	2 215 756	1 132 100	395	3 348 251
Total	226 853 804	122 319 799	6 279 312	355 452 916

Source: JRC elaboration based on GCoM data from MyCovenant and CDP-ICLEI Track

Table 11. GHG emissions in the cities' latest EIs related to 2030 commitments, by sector and scope – Non-EU (in t CO_2-eq/year)

| Sector	Scope 1	Scope 2	Scope 3	Total
Municipal buildings equipment/facilities	2 596 765	3 167 893	298 388	6 063 047
Residential buildings	39 343 363	24 600 499	2 315 155	66 259 017
Tertiary (non municipal) buildings equipment/facilities	9 501 697	19 397 620	888 342	29 787 659
Industry	12 279 929	14 063 426	1 140 328	27 483 683
Transportation	59 449 335	776 825	10 194 954	70 421 113
Waste/wastewater	7 091 106	11 792	4 213 420	11 316 318
Other	760 105	51 157	21 662	832 924
Total	131 022 300	62 069 213	19 072 248	212 163 761

Source: JRC elaboration based on GCoM data from MyCovenant and CDP-ICLEI Track

Figure 12. GHG emissions by sector in the cities' latest EIs related to 2030 commitments for EU-27 SECAPs (a) and non-EU SECAPs (b)


(a)   (b)
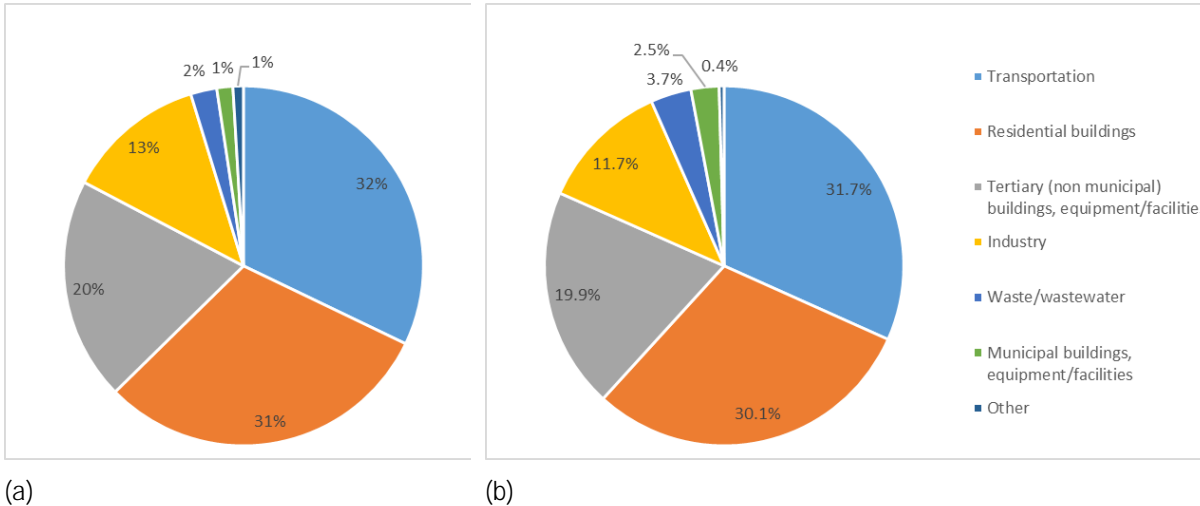
Source: JRC elaboration based on GCoM data from MyCovenant and CDP-ICLEI Track

Figure 13. GHG emissions by scope in the cities' latest EIs related to 2030 commitments for EU-27 SECAPs (a) and non-EU SECAPs (b)

(a)

(b)
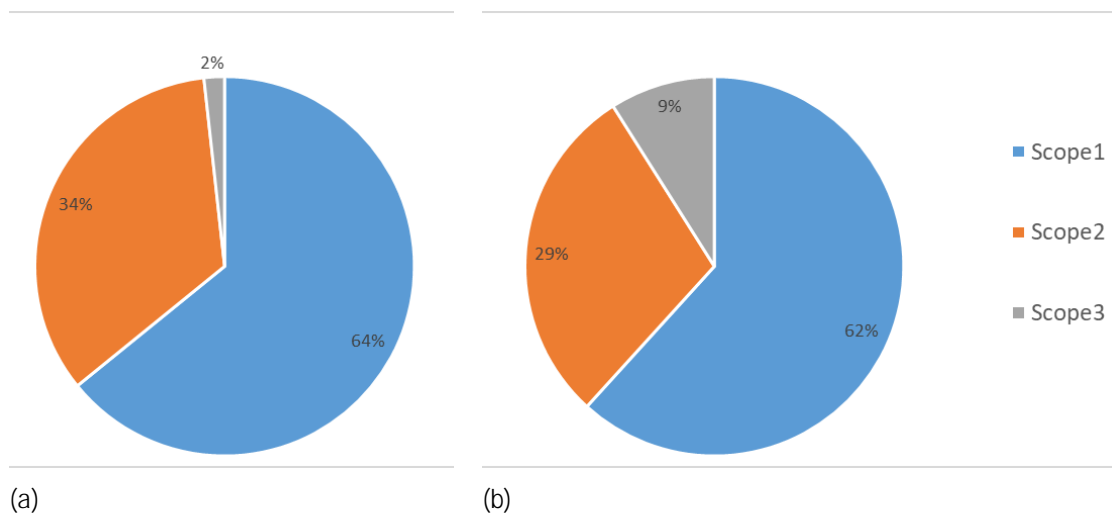
Source: JRC elaboration based on GCoM data from MyCovenant and CDP-ICLEI Track

Figure 14. GHG emissions by energy carrier in the cities' latest EIs related to 2030 commitments for EU-27 SECAPs (a) and non-EU SECAPs (b)


(a)

(b)
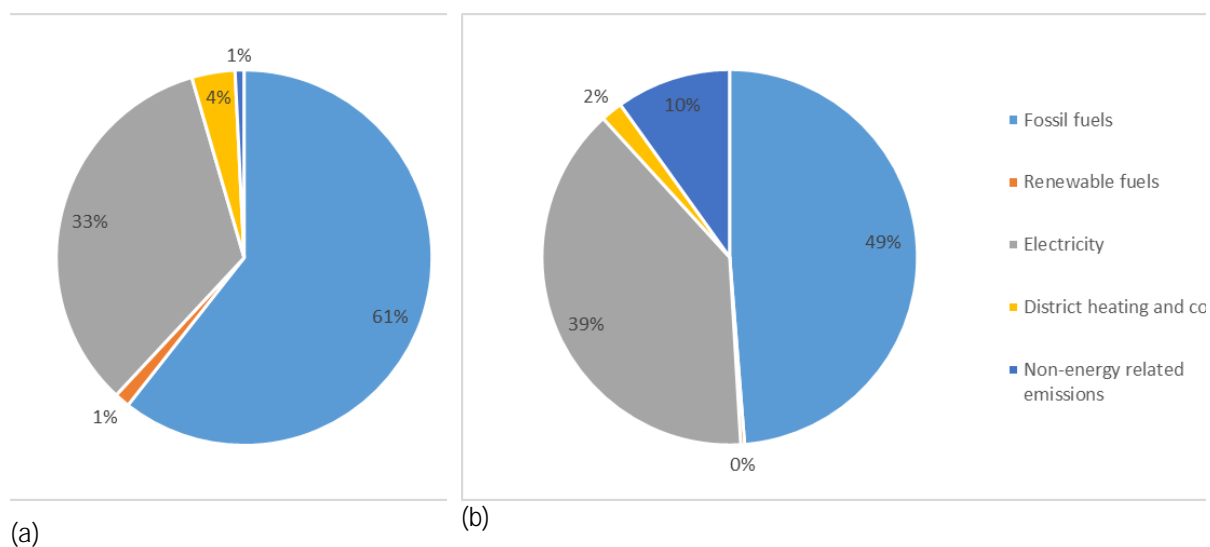
Source: JRC elaboration based on GCoM data from MyCovenant

4.3 Monitoring emission inventories

4.3.1 Monitoring years

Signatories are free to choose the monitoring years for their emissions inventories. Although it is recommended to have the first MEI in the following four years after the submission of the BEI (see the frequency of reporting in the GCoM Reporting Guidelines), most of them require more time. Figure 15(a) shows the frequency of MEIs, observing that 75% (80%) of EU-27 (non-EU-27) signatories are able to report one MEI, while 20% have two MEIs (19% for non-EU-27) and only 5% have more than three MEIs (no European signatory outside EU-27 has more than 2 MEIs). Meanwhile, as shown in Figure 15(b), the majority of EU-27 signatories (34%) requires from 5 to 6 years to submit their first MEI, and another 31% requires from 7 to 10 years, against a share of 12% of signatories whose SECAP includes a MEI before completing the four years since their BEI submission. As for European signatories outside EU-27, the majority (35%) are able to have a MEI in place before the four years counting from their BEI submission, against a 25% share requiring from 11 to 15 years.

Figure 15. For all European signatories, (a) the frequency of monitoring reports and (b) the number of years elapsed between the BEI and the signatories' first MEI.

(a)   (b)
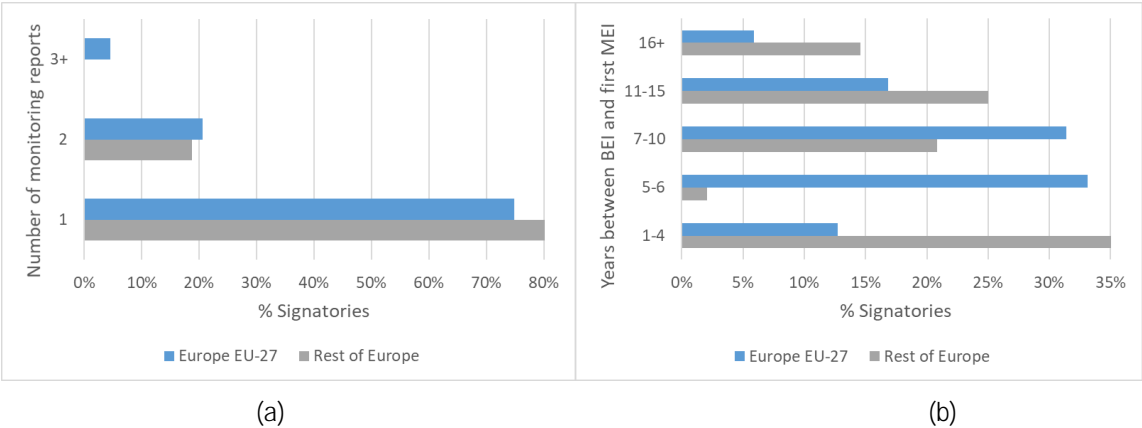
Source: JRC elaboration based on GCoM data

Concerning SECAPs for EU-27 signatories (see Figure 16), most of them choose 2015, 2016 and 2018 as monitoring years, representing 17%, 16% and 14%, respectively of all MEIs. For 2015, there are 5.3 million inhabitants and 3.5 t CO_2-eq per capita. Meanwhile, for 2016, there are 5.1 million inhabitants and 4.2 t CO_2-eq per capita, and for 2018, there are 13.4 million inhabitants and 3.9 t CO_2-eq per capita.

Figure 16. Frequency of MEIs for the different monitoring years regarding 2030 commitments in EU-27, along with the population (in millions) and emissions per capita (t CO_2-eq) for every year.
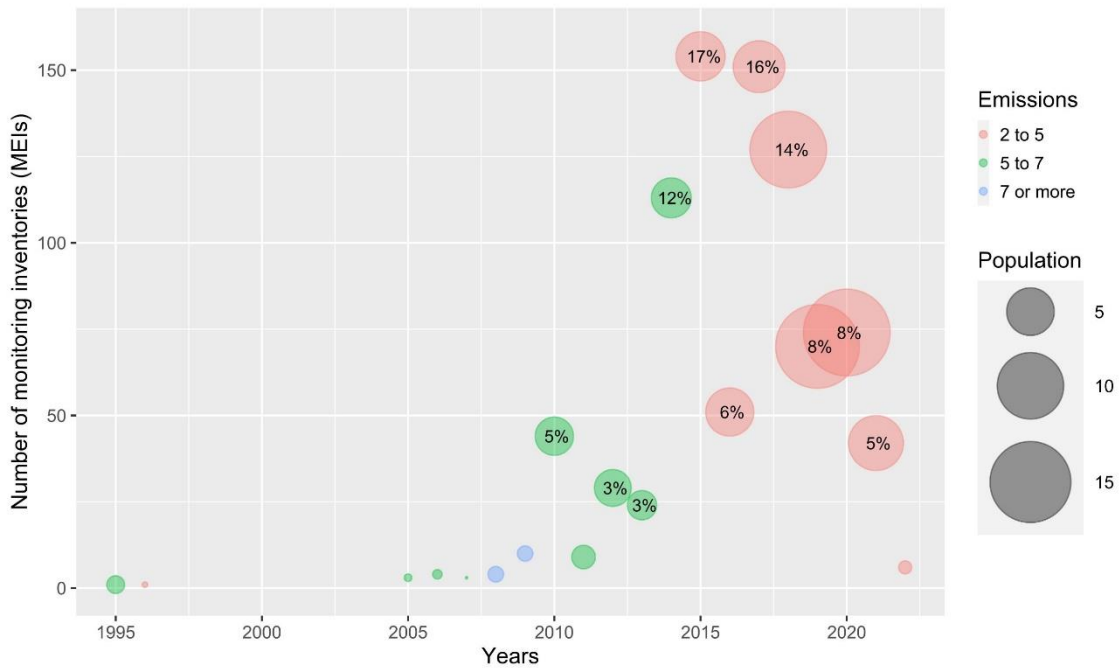
As for 2030 commitments in the rest of Europe (see Figure 17), most signatories have a MEI on 2020 and 2019, with a share of 51% and 23%, respectively. The MEIs from 2020 represent 6.6 million inhabitants with 4.2 t CO_2-eq per capita. Meanwhile, in 2019, there were 18.5 million inhabitants with 3.7 t CO_2-eq per capita.

Figure 17. Frequency of MEIs for the different monitoring years regarding 2030 commitments in Europe non-EU-27, along with the population (in millions) and emissions per capita (t CO_2-eq) for every year.
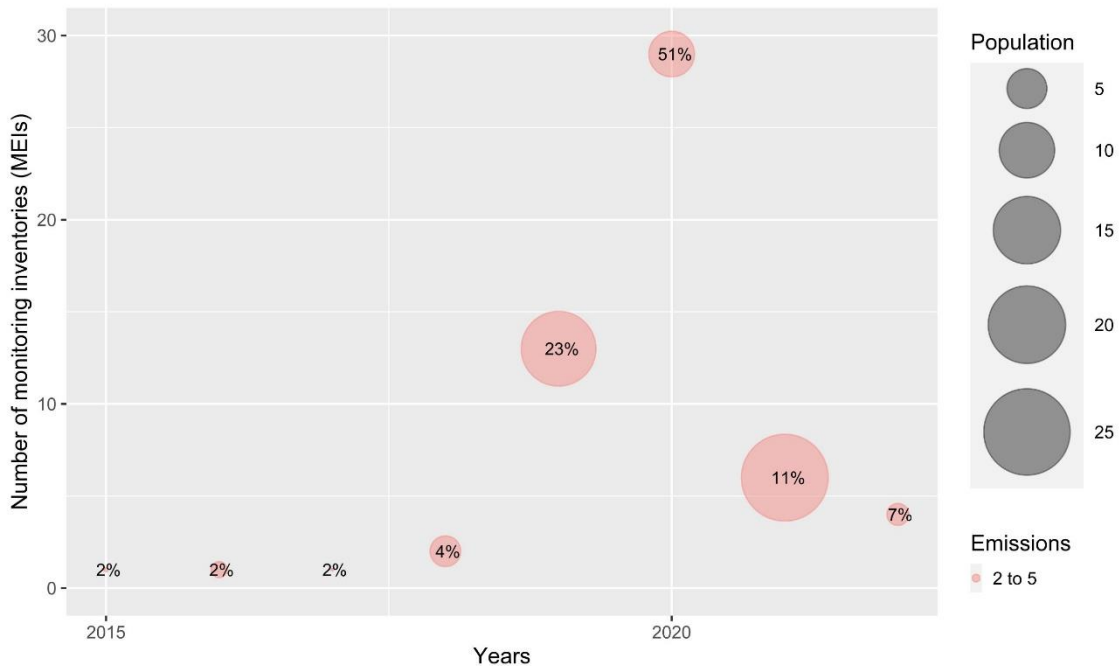
4.3.2 Reported progress in the European Union from BEIs to MEI

Following the statistical methodology described in the previous section 3.2.3, there are 676 signatories in EU-27 with a commitment for 2030, with a BEI and at least one MEI. For this subset of signatories and focusing only on the emissions consistently reported for the same sectors throughout the different inventory years, it is observed that an estimated 48 % mean absolute reduction is expected to be achieved, counting from a common base year of 2005 to the target year 2030[37]. Such an expected reduction amounts to 162.029 t-CO$_2$ (see Figure 18). As a result, from 2005 to 2030, the signatories would be falling short from their targeted mean reduction of 56 %.

Figure 18. Trajectories of forecasted emissions and 2030 targets for EU-27 signatories.
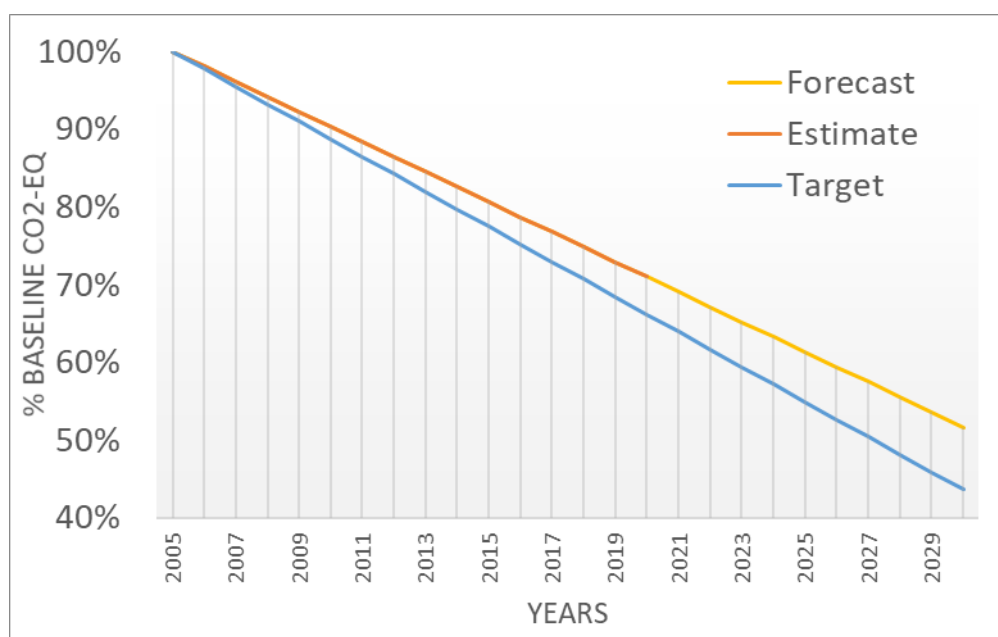
Source: JRC elaboration based on GCoM data

Extending the previous analysis to a *per capita* frame, EU-27 signatories with a 2030 commitment are expected to achieve an estimated 51 % reduction in the volume of their per capita emissions. The total GHG emissions reduction sums up to 3.11 t-CO$_2$ per capita (as shown Figure 19), falling short by 8 % from the targeted mean reduction of 59 % (for the period between 2005 and 2030).

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[37] It is important to note that signatories choose any base year, and that this analysis sets the base year to 2005, which in fact can be farther away, or closer, to the target year. In case the actual base year occurs before 2005, the signatory's ambition (measured by the annual rate of reduction) will be higher (with respect to their chosen base year) when measured from 2005. Conversely, if the actual base year occurs after 2005, the signatory's ambition will be lower (with respect to their chosen base year) when measured from 2005.
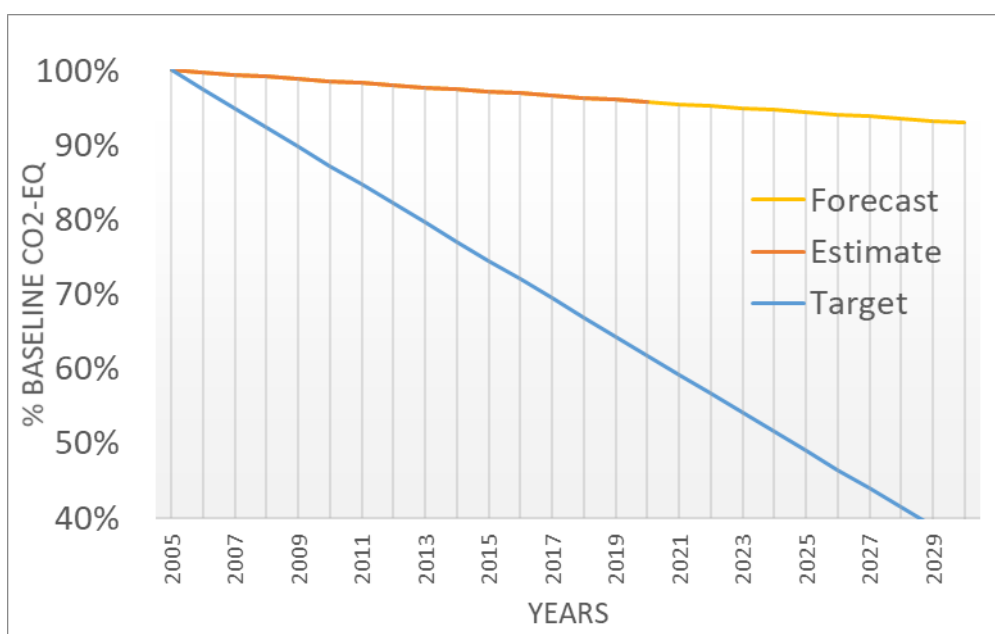
Figure 19. Trajectories of forecasted emissions per capita and 2030 targets in EU-27 action plans.
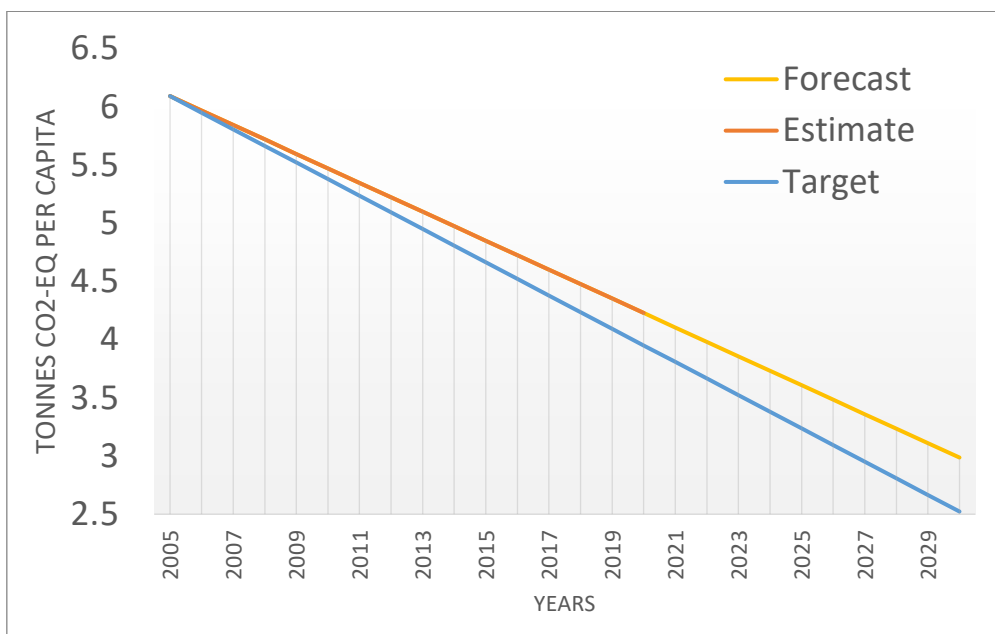
Source: JRC elaboration based on GCoM data

On the other hand, for all other European signatories with 2030 commitments, there are 48 having a BEI and at least one MEI. After setting the base year to 2005, and considering only the coherent sectors, this subset of signatories has the ambition of reducing their absolute emissions, on average, by 64 %, but their predicted achievements fall 57 % short from such an ambition. In this way, the forecasted emissions in 2030 are in line with achieving a 7 % reduction (see Figure 20), entailing an absolute GHG emissions reduction of 10.6 Mt-CO_2. This insight suggests that more time and effort is necessary for signatories to advance in the implementation of their complete action plans and obtain more encouraging results.

Figure 20. Trajectories of forecasted emissions and 2030 targets in European non-EU-27 action plans.

Source: JRC elaboration based on GCoM data

As for per capita figures, European non-EU-27 signatories with 2030 commitments are predicted to accomplish a 15 % reduction in t-CO_2 per capita, hence achieving a total reduction of 0.546 t-CO_2 per capita. The results fall short when compared to their declared ambitions, aiming at a 67 % reduction between 2005 and 2030. The trajectory of the signatories' emissions against their proposed target is shown in Figure 21.

Figure 21. Trajectories of forecasted emissions per capita and 2030 targets in European non-EU-27 action plans.
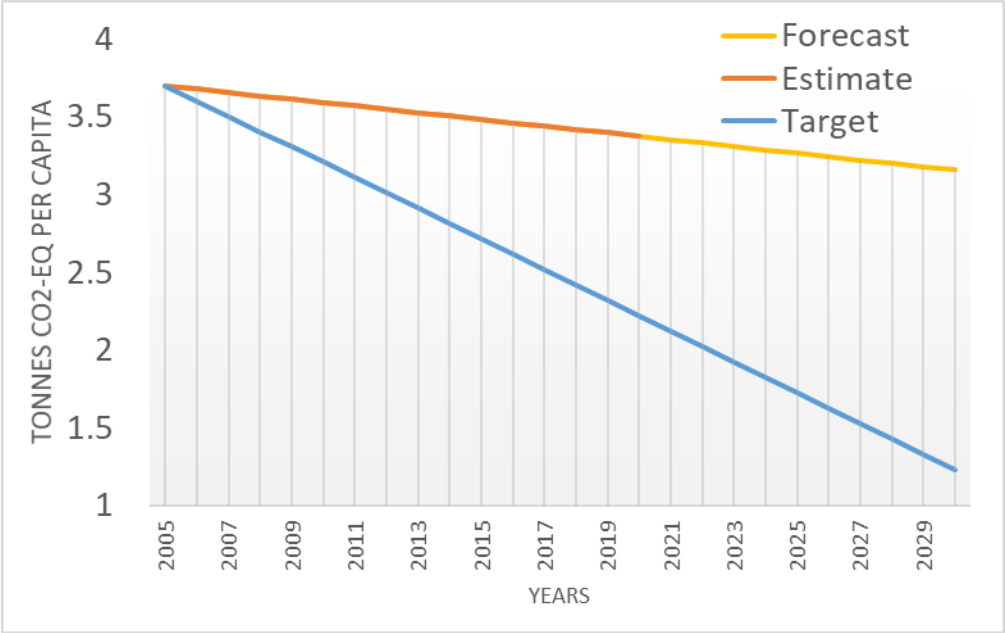
Source: JRC elaboration based on GCoM data

4.4   Climate change mitigation actions and measures

As part of the reporting to the initiative, Covenant of Mayors' signatories provide information on the estimated emission reduction per sector, associated with specific actions.

Based on the data reported through MyCovenant or CDP-ICLEI Track by EU-27 signatories (Figure 22), it is observed that most of the actions target the building sector (54%), followed by the transport sector (22%) and the waste & other sectors (11%). In terms of estimated emission reduction, however, electricity production largely dominates the scene with 40%, followed by transport (21%) and buildings and waste & other (each contributing 17%).

For Europe non-EU-27 signatories (Figure 23) the picture is quite different. About one third of the actions target the buildings sector and are expected to deliver 21% of the expected emission reduction by the target year. One third of the actions target the waste & other sector, contributing 30% to emission reduction, while transport accounts for 26% of the actions and 28% of emissions reduction. Local electricity production actions, although less numerous (7% of the actions) are expected to deliver 18% of the expected emission reduction.

Figure 22. No. of actions and sector contribution to emission reduction in SECAPs from EU-27
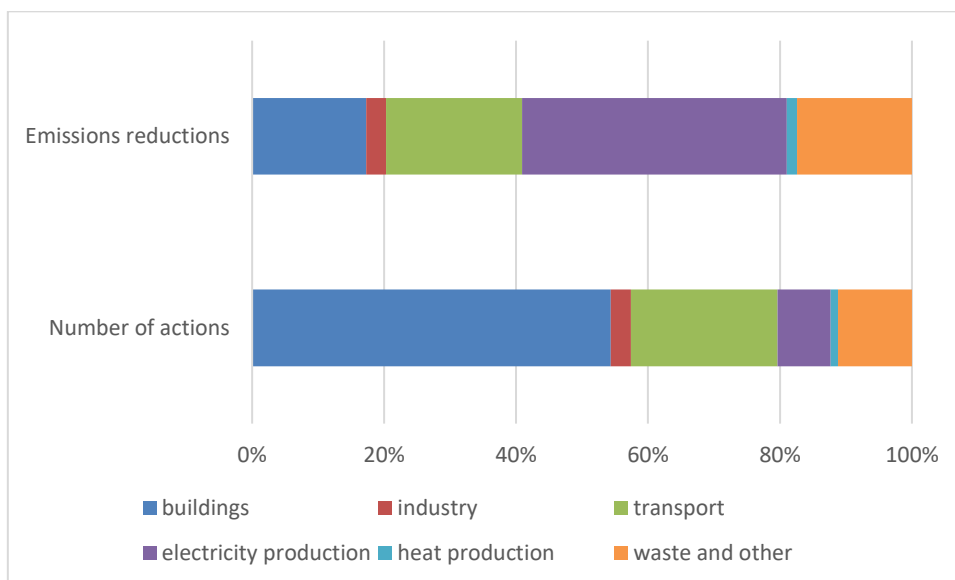
Source: JRC elaboration based on GCoM data

Figure 23. No. of actions and sector contribution to emission reduction in SECAPs from non-EU-27
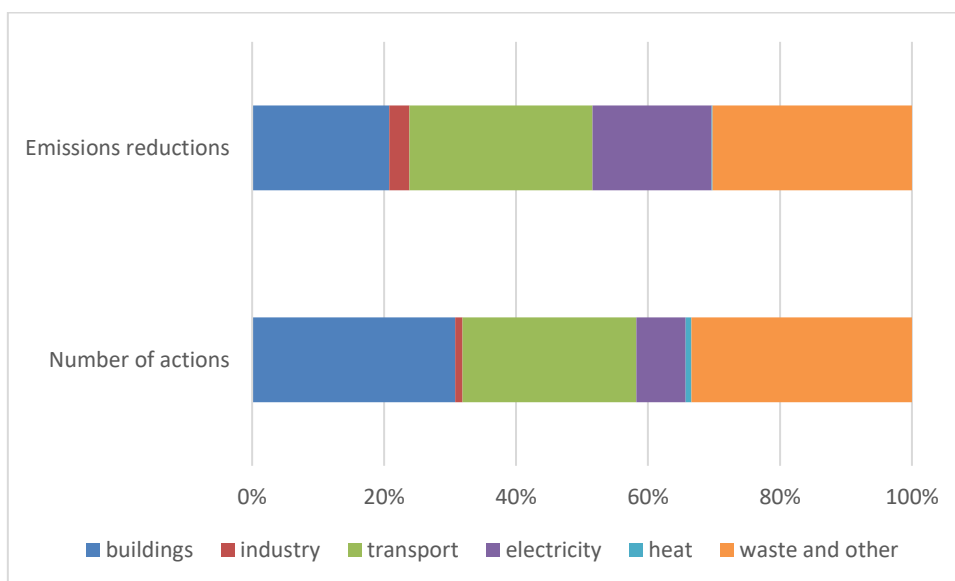
Source: JRC elaboration based on GCoM data

A more detailed analysis has been conducted on the actions reported through the MyCovenant reporting platform, which allows cities to categorise the actions by the sector they address, the specific area of intervention and the type of policy instrument they rely upon. It also allows indicating the initiator of the actions, considering that a local action plan may also, to a certain extent, rely on measures decided by other levels of governance, such as the national or the regional one. This section describes the mitigation actions/measures based on the categories assigned by signatories.

The analysed MyCovenant dataset contains 50 941 mitigation actions/measures from signatories located in Europe, committed to 2030 and/or 2050 targets. That corresponds to an average of about 28 mitigation actions/measures per action plan.

Out of those 50 941 mitigation actions/measures, 2 861 are also targeting adaptation to climate change while 1 090 are also targeting energy poverty.

### 4.4.1 Actions/measures by area of intervention

MyCovenant allows signatories to classify their actions targeting each sector according to the specific area of intervention they tackle. This section analyses separately the four macro-sectors, as the areas of intervention are very different among them:

— Stationary energy

— Transport

— Energy production

— Waste and others

Actions planned by signatories from EU-27 and Europe non-EU-27 are analysed jointly.

The stationary energy sector is addressed by 28 454 actions/measures. Most of the actions for which an area of intervention is indicated are classified as "integrated action", meaning that they target in a holistic way the building system (Figure 24). Many measures aim at improving the energy efficiency of lighting systems and building envelopes. Several measures target space heating and hot water systems, by promoting either energy efficient boilers or the use of renewables (notably through solar thermal collectors and biomass boilers). Triggering behavioural changes is also a prominent area of intervention. A significant share of actions concern information and communication technologies (ICT), for example, remote management systems and energy management software for municipal buildings and street lighting. A lower share of actions/measures targets the industrial sector (being this an optional sector in the European Covenant of Mayors), mainly aiming at improving energy efficiency in industrial processes. About 16% of the actions/measures were reported under the category "Other" or not specified.
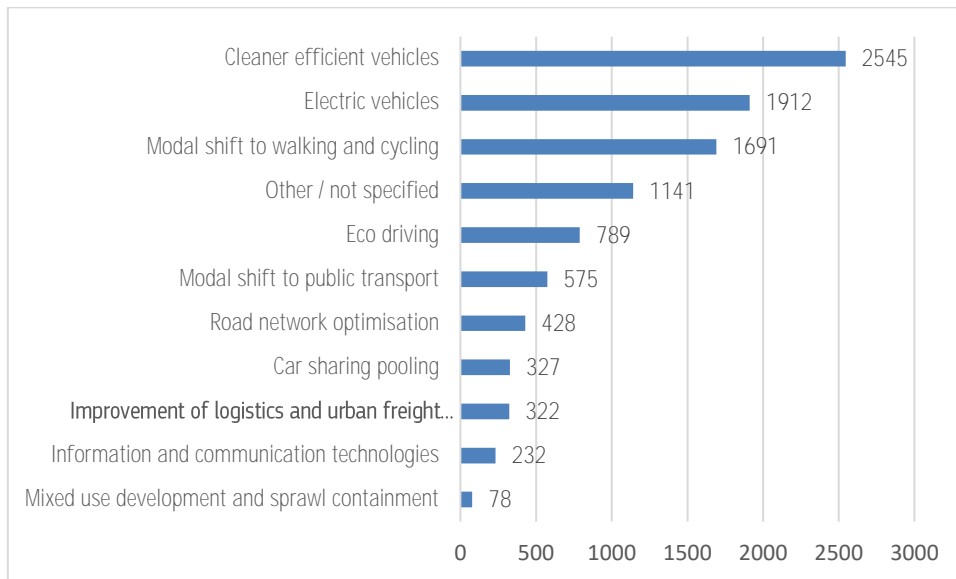
Figure 24. Stationary energy sector – Actions/measures by area of intervention.
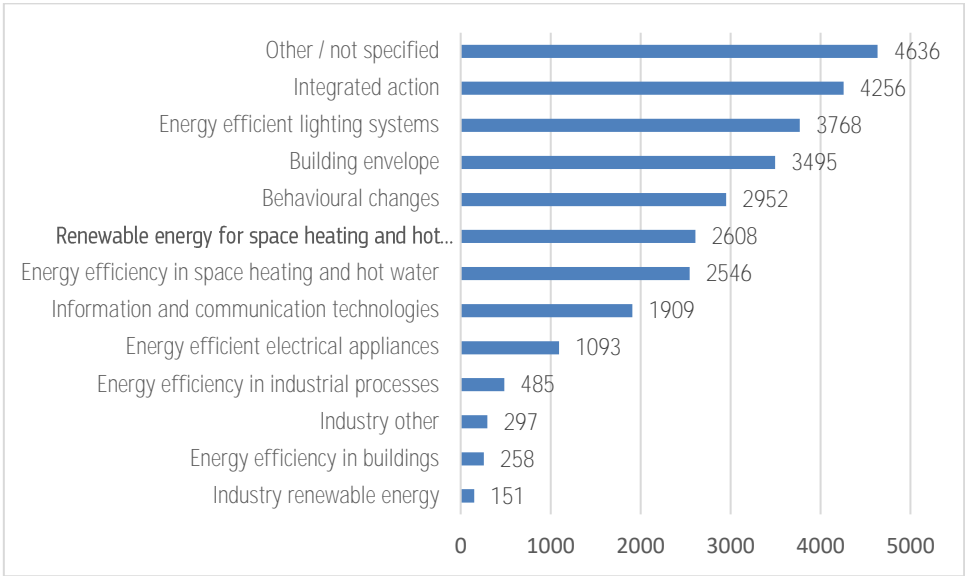
Source: JRC elaboration based on GCoM data

In the transport sector (Figure 25), the large majority of the 10 040 total planned actions concerns cleaner/efficient vehicles and electric vehicles (more than 2 545 measures), showing that local authorities rely to a great extent on the gradual improvement of the fleet of vehicles, which are bound by European standards, and might also depend on national incentives and economic performance. Local authorities then try to promote electric vehicles and to encourage a shift towards active mobility (with almost 1 700 measures classified as a modal shift to walking and cycling) or towards public transport (more than 575 measures) and to promote eco-driving (789 measures).
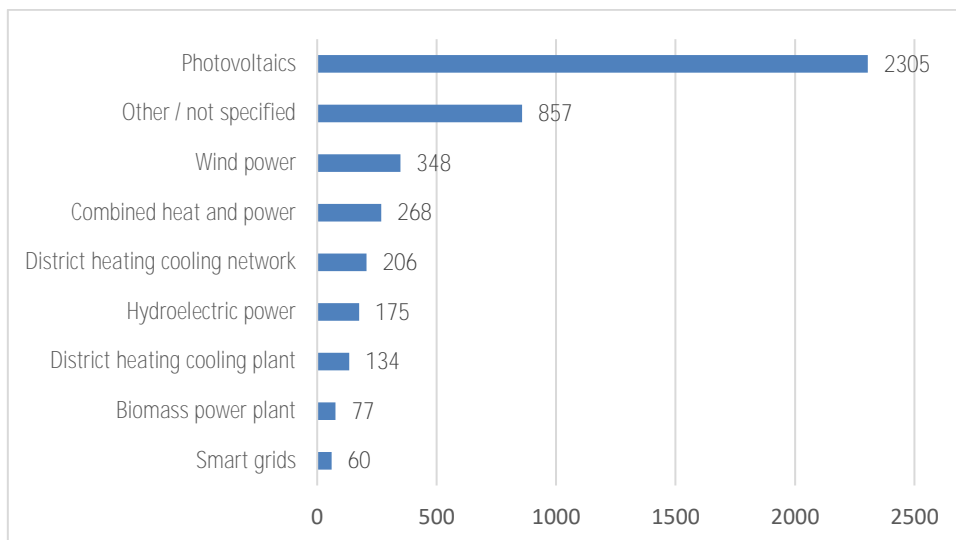
Figure 25. Transport sector - Actions/measures by area of intervention.

Cleaner efficient vehicles	2545
Electric vehicles	1912
Modal shift to walking and cycling	1691
Other / not specified	1141
Eco driving	789
Modal shift to public transport	575
Road network optimisation	428
Car sharing pooling	327
Improvement of logistics and urban freight...	322
Information and communication technologies	232
Mixed use development and sprawl containment	78

Source: JRC elaboration based on GCoM data

Looking at the 4 430 measures addressing the energy production sector (Figure 26), a strong push towards photovoltaic (2 305 measures) can be seen – probably thanks to its decreasing costs and growing accessibility. In contrast, other technologies for renewable energy production, such as hydroelectric and biomass, seem to receive less attention from local authorities.

Figure 26. Energy production sector – Actions/measures by area of intervention.

Photovoltaics	2305
Other / not specified	857
Wind power	348
Combined heat and power	268
District heating cooling network	206
Hydroelectric power	175
District heating cooling plant	134
Biomass power plant	77
Smart grids	60

Source: JRC elaboration based on GCoM data

The last sector, including waste and others (Figure 27), is more heterogeneous and comprises many actions that were not classified under the proposed categories. Its importance is likely to grow in the future, with cities currently expanding the scope of their action plans to include more emitting sectors (e.g., agriculture, forestry and other land use, or industrial processes and products use) in an effort to reach climate neutrality goals.

Figure 27. Waste and other sectors - Actions/measures by area of intervention.
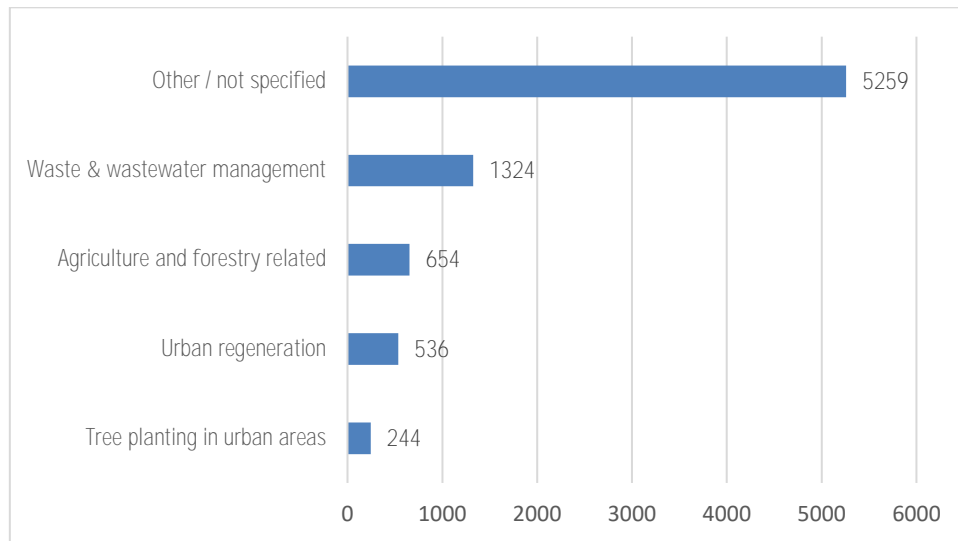
4.4.2 Actions/measures by policy instrument

Similarly to what is observed for the "area of intervention" categories, also the "policy instrument" categories vary depending on the sector. Therefore, in this section, the actions falling under the same macro-sector were grouped for analysis purposes.

Figure 28 shows the policy instrument assigned to actions/measures targeting the stationary energy sector. The energy management policy instrument is associated with 8 566 reported actions (30 %), mainly addressing municipal buildings. The second preferred instrument is awareness-raising and training (6 486 actions), targeting, in particular, the residential buildings sector, but also municipal and tertiary buildings. Grants and subsidies are also a quite common instrument (2 673), followed by public procurement (2 103 actions), energy certification/labelling (1 481) and building standards (1 302). Other instruments, such as energy suppliers obligations or third party financing, seem less common in local mitigation plans.

Figure 28. Stationary energy sector - Actions/measures by policy instrument.
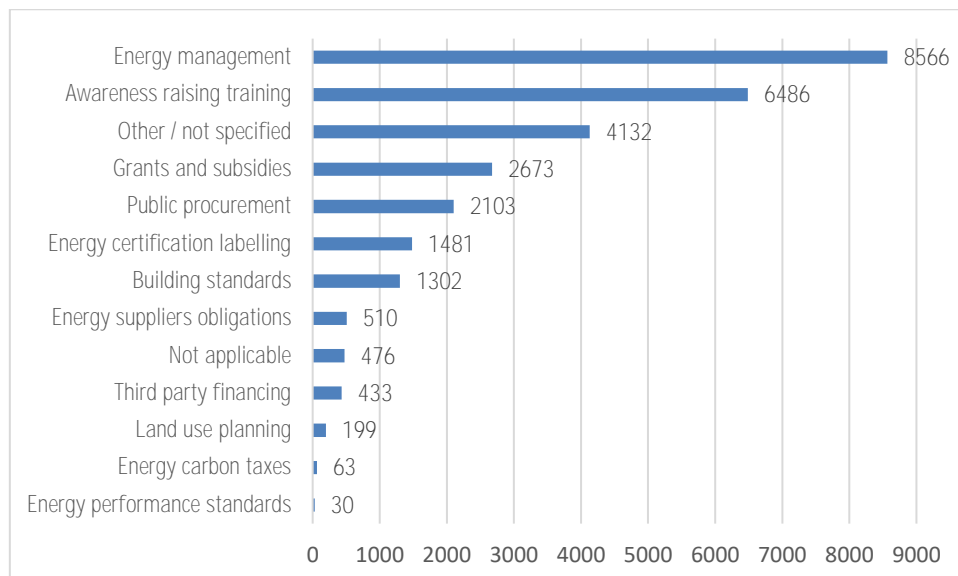
In the transport sector (Figure 29), the preferred instrument is awareness-raising and training (1 917 actions out of 10 040), followed by mobility planning regulation (1 726 actions), public procurement to renew municipal fleet and vehicles used in public transport (1 092 actions), and grants and subsidies (914 actions, which may include tax reduction or subsidies for more efficient vehicles or incentives for the purchase of electric bikes). Instruments classified as road pricing and integrated ticketing and charging are less numerous, probably because they mainly apply to larger urban centres that represent a small number of Covenant signatories, compared to the high number of small towns. Almost one third of the reported actions/measures are not classified under any of the proposed policy instruments.

Figure 29. Transport sector - Actions/measures by policy instrument.
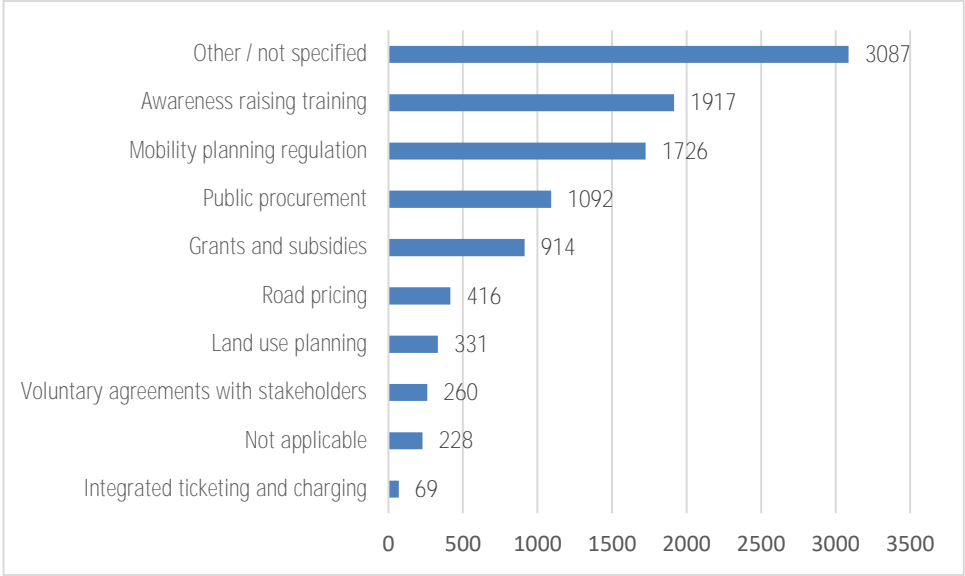
Source: JRC elaboration based on GCoM data

In the energy production sector (Figure 30), the most common policy instrument (when indicated) are grants and subsidies (1 390 actions out of 4 430), followed by awareness-raising and training (523 actions), third party financing (408), public procurement (375), land use planning regulation (171), building standards (170), energy suppliers obligations (94).

Figure 30. Energy production sector – Actions/measures by policy instrument.
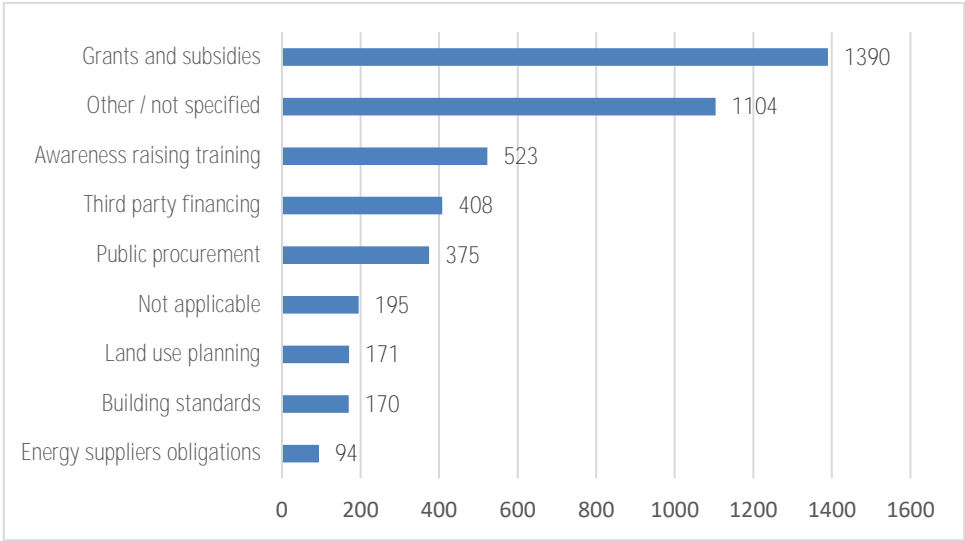
Source: JRC elaboration based on GCoM data

Finally, the sector **"waste and others"** (Figure 31) includes two main policy instruments (when reported): awareness-raising and training (2 205 actions) and land use planning (784 actions).

Figure 31. Waste and other sectors - Actions/measures by policy instrument.
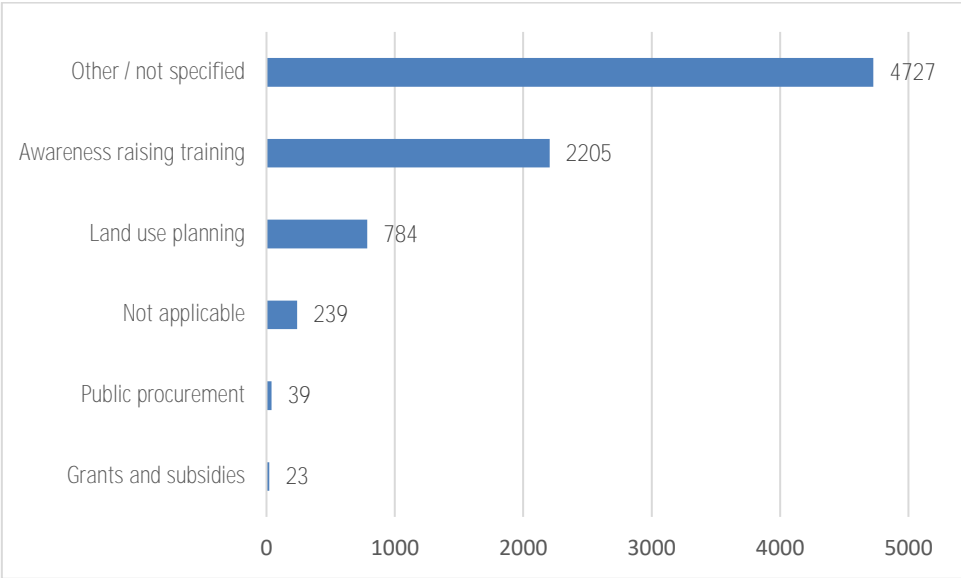
Source: JRC elaboration based on GCoM data

4.4.3   Actions/measures by origin of the action

Covenant signatories are also invited to indicate the level of governance initiating each action/measure. This allows appreciating if the local authority is actually taking the lead in the effort to reduce emissions in its territory or rather counting on the effect of actions decided by other authorities. About three fourths of the actions/measures are declared as being initiated by the local authority. Covenant coordinators or supporters are indicated as the initiators of about 9 % of the actions/measures. For about 11% of the actions, the initiator is either "other" or not specified (Figure 32).

Figure 32. Share of actions/measures by action initiator.
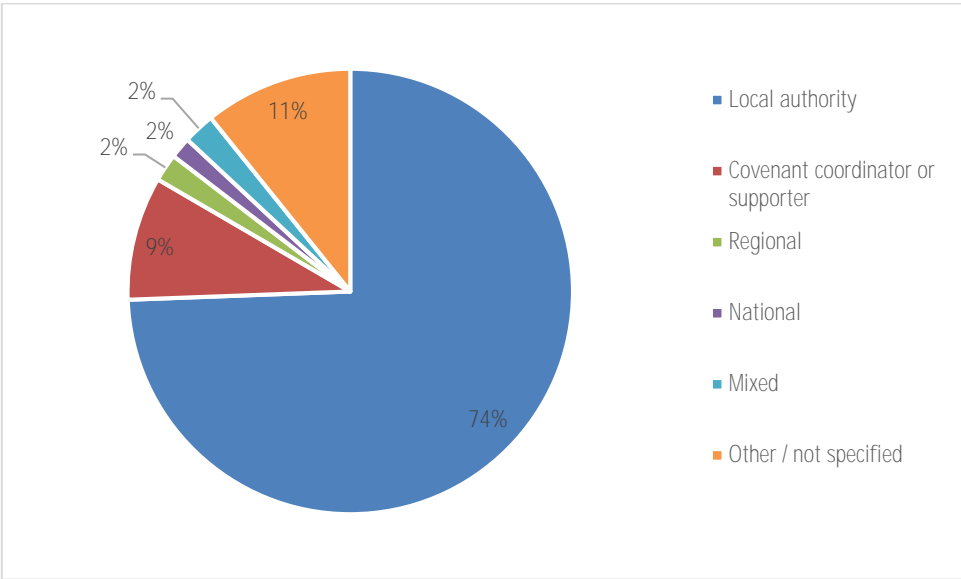
Source: JRC elaboration based on GCoM data

5 Approach and methodology on adaptation

5.1 The Covenant **of Mayors' approach to adaptation**

The adaptation pillar was first introduced through Mayors Adapt, launched in 2014 by the EC as a parallel initiative to the CoM. In 2015, the EC merged the two initiatives into the CoM for Climate and Energy in an effort to promote an integrated approach to climate and energy action. From 2015 onwards, adaptation and, therefore, the Mayors Adapt initiative are entirely integrated into the Covenant of Mayors for Climate and Energy, and local authorities are committed to both mitigation (2020 and/or 2030 target) and adaptation.

By joining the initiative, signatories commit to voluntarily developing a comprehensive local adaptation strategy or integrating adaptation into ongoing development plans, as well as reporting their progress every second year.

In January 2020, the reporting requirements changed, removing some mandatory information (i.e., Adaptation Scoreboard at the Registration stage) while introducing others (i.e., Adaptation goals). The reporting guidelines are in line with the Common Reporting Framework (CRF) by GCoM also for the adaptation pillar.

The current approach followed in the adaptation pillar of the Covenant of Mayors include:

— Committing to climate adaptation

— Conducting a Risk and Vulnerability Assessment (identifying the most relevant climate hazards and most vulnerable sectors)

— Identifying adaptation goals

— Defining adaptation actions

— Monitoring progress

The approach used for conducting a Risk and Vulnerability Assessment (RVA) follows the framework and core concepts of the IPCC AR5 (Figure 33). The risk of climate-related impacts results from the interaction of climate-related hazards (including hazardous events and trends) with the vulnerability and exposure of human and natural systems. Changes in both the climate system (left side in Figure 33) and socioeconomic processes, including adaptation and mitigation (right side), are drivers of hazards, exposure, and vulnerability.

Figure 33. Illustration of the core concept of risk (AR5), based on IPPC AR5[38].
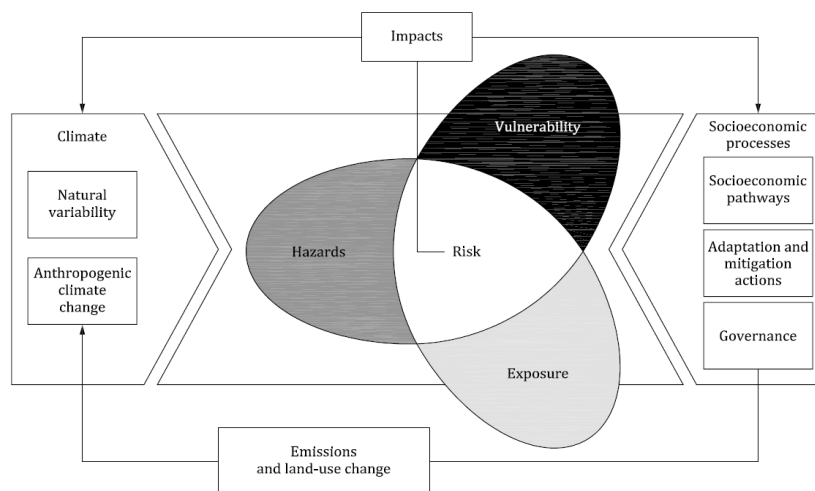
Source: IPPC AR5

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[38] IPCC, 2014: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Field, C.B., V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L.White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 1 132 pp.

5.2 Datasets and data analysis

A similar approach to the one described in section 3.2.1 was used for harnessing data on climate change adaptation from the datasets. For adaptation information, additional quality scrutiny steps were required on the information provided with a text, such as the adaptation goals[39].

GCoM dataset combines data coming both from MyCovenant and from CDP-ICLEI Track reporting platforms. When differences were found (because of dissimilar data collection and/or because of regional deviations), the definitions and methodology coming from the GCoM Common Reporting Framework (CRF) were used for this analysis.

Table 12 shows the number of GCoM signatories and the number of cities and local authorities with adaptation information: 1 941 reported information in risks and vulnerabilities while 1 764 reported adaptation actions. Because the CoM Europe reporting requirements allowed extra time to provide adaptation actions, about 9% of adaptation plans report a RVA but do not have corresponding reported adaptation actions.

Overall, 17% of signatories have reported information on the adaptation pillar. This is linked to the fact that the initiative started with a mitigation only commitment (i.e. in the European Union & Western Europe) and only later expanded to include the adaptation commitment as well as extending to other regions. It is interesting to note that most of the regions have committed to adaptation comparatively more than Europe.

Table 12. Adaptation signatories and action plans by region.

Region	No. of cities and local governments committed to the CoM	with reported RVA		with reported adaptation actions	
Europe – EU-27	10407	1727	17%	1568	15%
Europe - EFTA	31	17	55%	14	45%
Europe - Non-EU	62	31	50%	29	47%
Eastern Europe – CoM East	545	123	23%	112	21%
Southern Mediterranean – CoM South	147	3	2%	4	3%
Western Balkans and Türkiye	153	46	30%	43	28%
Central Asia	15		0%		0%
Grand Total	11360	1947	17%	1770	16%

Source: JRC elaboration based on GCoM data

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[39] The major steps in data cleaning and quality scrutiny included the following criteria:
- Action plans without a valid RVA (at least one hazard reported) were discarded;
- Adaptation goals with an invalid text or a text not connected to adaptation (i.e., emission reduction target) were discarded;
- Invalid info from RVA (i.e., open field for "other climate hazards") were discarded;
- Invalid info in other text fields (i.e., "progress toward target") were discarded.
A systematic cleaning on all action titles, in order to remove actions accidentally marked as adaptation by signatories (while being mitigation only) was not conducted at this stage.

6 Results on adaptation

6.1 Adaptation goals

In alignment with the targets delineated in Section 4.1, regarding the definition of mitigation targets, signatories set adaptation goals. In accordance with the Covenant guidelines, these adaptation goals are to be defined subsequent to the comprehensive analysis provided by the Risk and Vulnerability Assessment (RVA), incorporating a designated baseline year and specified timeframe for realisation. Whilst the guideline does not prescribe the specific nature of these goals, it is incumbent upon signatories to facilitate the monitoring of advancements towards these goals, optimally through the institution of defined Key Performance Indicators (KPIs), which are to be systematically tracked utilising the prescribed monitoring templates.

The requirement to set a minimum of one adaptation goal was introduced as of January 2020. The delineation of these objectives persists as a challenging element within the framework of action plans. An examination of the submitted templates reveals a prevalence of ambiguously defined objectives, with a scarce proportion demonstrably linked to the diminution of climatic hazard risks via the attenuation of exposure and/or vulnerabilities. Moreover, the quantitative aspects of these goals are frequently misreported, thereby obfuscating the evaluation of 'progress towards target'. However, the present iteration of the adaptation goals template (in MyCovenant) has been refined to accommodate the input of base year values alongside target year values, thus ameliorating the aggregation of quantitative data and bolstering the assessment of 'progress towards target'.

This prevalent difficulty may be attributed, in part, to an absence of internationally recognised standards pertaining to the definition of 'adaptation goals', coupled with a deficiency in explicit guidelines for signatories. However, in 2022 MyCovenant platform added a clarification on this matter, adding examples of well-defined adaptation goals[40].

6.2 Risk and Vulnerability Assessments (RVAs)

6.2.1 Climate hazards

Climate hazards are defined as "the potential occurrence of a natural or human-induced physical event or trend or physical impact that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems and environmental resources" (IPCC, 2014a, p. 1 766).

While only one hazard is the minimum reporting requirement, signatories averagely identify six hazards, and the dataset includes more than 11 600 reported hazards. Each hazard has the following data associated, which is mandatory for at least one level 1 climate hazard, and optional for sub-hazards:

— Level 1 (L1) hazard or level 2 (L2) sub-hazard[41]

— Current hazard probability

— Current hazard impact

— Expected change in hazard intensity

— Expected change in hazard frequency

— Timeframe: short-term, mid-term, long-term, not known (not possible to define).

For the purpose of this analysis, all reported hazards coming from the reporting platforms were re-classified using the CRF categories, with ten L1 categories (plus "Other"), each of them allowing a possibility of L2 sub-hazards (see Table 13).

In some versions of the platforms, when a L2 hazard is reported, a L1 is automatically reported, leading to potential duplicates especially for the hazards with multiple L2 options, such as Floods& sea level rise. For this

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[40] "Examples of adaptation goals added in MyCovenant platmof: "Limit the loss resulting from river / coastal floods (Unit: €); Reduce the number of forest fires / hectares land burned (Unit: x fires/year or ha/year); Decrease of losses and damages on the building stock / infrastructure as a result of storms (Unit: %); Decrease in the number of citizens affected by drought (Unit: no. citizens)".

[41] MyCovenant and CDP-ICLEI Track use different labels for hazard and sub-hazard categories. CRF labels are used here, and a re-classification was conducted for harmonisation.

reason, in order to avoid double counting and give an idea of the most reported hazards, some data elaboration was conducted[42]. Duplicates values from CDP platform were also removed. In this cleaning process of duplicates, if multiple values were reported (i.e. "high" and "medium" probability or "increase" and "no change" for future frequency) the highest/worst scenario was kept (i.e. "high" probability, "increase" in future frequency). The cleaned hazard dataset kept 11 662 records from the original 14 547 records.

Of the total of 11 662 records reported for climate hazards: 3 904 specify a level 2 sub-hazard definition, available for some hazards (see Table 13).

Table 13. Climate hazards reported: level 1 hazards and level 2 sub-hazards.

Climate hazards	Count of hazards
Extreme heat	1763
Extreme hot days	11
Heat wave	25
(unspecified)	1727
Heavy precipitation	1706
Fog	33
Hail	58
Heavy snow	37
Rain storm	351
(unspecified)	1227
Droughts & water scarcity	1662
Drought	1658
(unspecified)	4
Floods & sea level rise	1649
Coastal flood	145
Flash / surface flood	176
Groundwater flood	12
Permanent inundation	1
River flood	171
(unspecified)	1144
Wild fire	1302
Forest fire	373
Land fire	41
(unspecified)	888
Storm & wind	1006
Cyclone (Hurricane / Typhoon)	4
Extra tropical storm	7
Lightning / thunderstorm	72
Severe wind	180
Storm surge	8
Tornado	2
Tropical storm	1
(unspecified)	732
Extreme cold	935
Cold wave	3
Extreme winter conditions	1

[42] For the purpose of Figure 34 pie chart, multiple climate hazards reported under the same level 1 were counted as one, to avoid double counting. Therefore, a signatory reporting both "forest fire" and "land fire" is counted as reporting one hazard "Wild fire".

Climate hazards	Count of hazards
(unspecified)	931
Mass movement	848
Avalanche	13
Landslide	237
Rock fall	21
Subsidence	17
(unspecified)	560
Other	382
(unspecified)	382
Biological hazards	262
Air-borne disease	58
Insect infestation	73
Vector-borne disease	20
Water-borne disease	13
(unspecified)	98
Chemical change	147
Atmospheric CO2 concentrations	60
Ocean acidification	2
Salt water intrusion	20
(unspecified)	65
Total	**11662**

Source: JRC elaboration based on GCoM data

The most reported L1 climate hazards in signatories' RVAs (see Figure 34) are "Extreme heat" (15 %), "Heavy precipitation" (15 %), Droughts & Water scarcity" (15%). "Floods & Sea level rise" (14 %).

Figure 34. Most reported climate hazards.
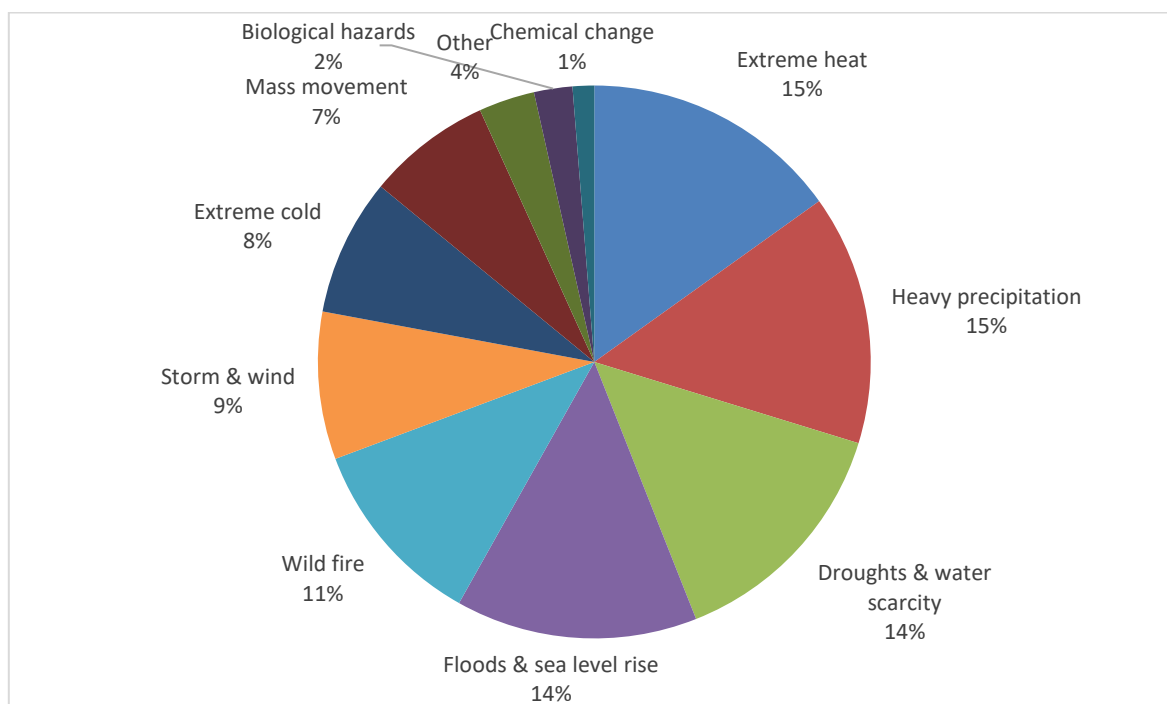
Source: JRC elaboration based on GCoM data

Signatories can also voluntarily report sub-hazards (see Figure 35).

The most reported sub-hazards are "Forest fire" (373 records), "Rain storm" (351records), "Landslide" (237).

Figure 35. Most reported climate hazards (inner circle) and sub-hazards (outer circle).

Source: JRC elaboration based on GCoM data

Another way of looking at the reported hazards (avoiding double counting issues) is to consider which ones are more recurrent in cities (see Table 14), by looking at each city's climate Risk and Vulnerability Assessment (RVA) and marking if the L1 hazard were or were not mentioned. This methodology confirms the top reported hazards of the cleaned dataset, avoiding the overrepresentation of L1 hazards with multiple sub-hazards (i.e. Floods & sea level rise).

— "Extreme heat" is present as a climate hazard in 91% of RVAs (1 781 out of 1 947)

— "Heavy precipitation" is present in 88% of RVAs (1 722)

— "Droughts & water scarcity" is present in 86% of RVAs (1 678)

— "Floods & seal level rise" is present in 86% of RVAs (1 671)

— "Wild fire" is present in 67% of RVAs (1 304)

— "Storm & wind" is present in 53% of RVAs (1 025)

— Other hazards are present in less than 50% of RVAs ("Extreme cold", 48%, Mass movement", 44%, "Other" 20%, "Biological hazard", 14%, and "Chemical change", 8%).

Table 14. Climate hazards reported: L 1 hazards and L 2 sub-hazards.

Climate Hazard	No. of cities mentioning the climate hazard	%
Extreme heat	1781	91%
Heavy precipitation	1722	88%
Droughts & water scarcity	1678	86%
Floods & sea level rise	1671	86%
Wild fire	1304	67%
Storm & wind	1025	53%
Extreme cold	939	48%
Mass movement	851	44%
Other	388	20%
Biological hazards	265	14%
Chemical change	147	8%
Total of cities with a RVA	1947	100%

Source: JRC elaboration based on GCoM data

The two following figures Figure 36 and Figure 37)[43] include the level of probability and impact reported by signatories in their RVAs. In order to avoid double counting and homogenise datasets some data elaboration was conducted.[44]

The climate hazard "Extreme cold" is proportionally reported with the current lowest probability and impact, "Chemical change" and "Other" are reported with the highest "Not known" probability.

All the other climate hazards are showing predominantly high/medium probability and impact.

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[43] The shares are based on percentage cover proportionally within the same category; absolute values are reported in the charts.
[44] For the purpose of these charts, some attributes were re-classified: "medium high" as "medium"; "medium low" as "medium", "does not currently impact the city" as "low", "Not expected to happen in the future" as "decrease", "not available" as "Not known", "immediately" as "short term". The field "future expected magnitude" was not taken in consideration for this analysis (not in CRF). L 2 hazards were reclassified to their corresponding L1 for these analyses.

Figure 36. Level of the probability of occurrence of the climate hazard in the present.
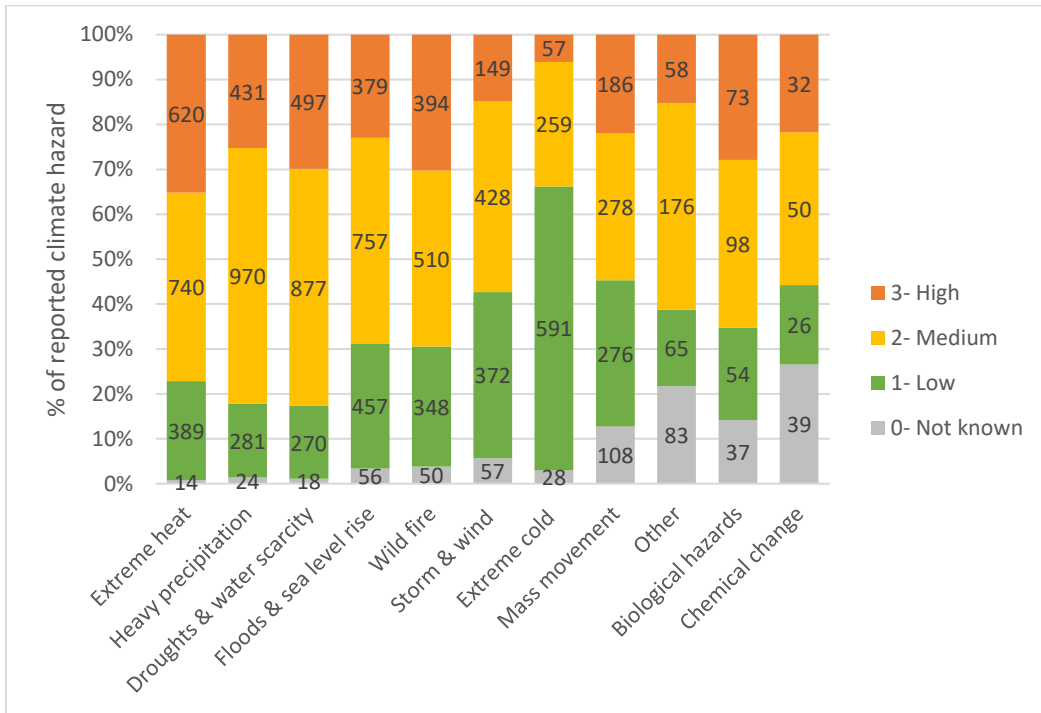
High = extremely likely that the hazard occurs (e.g., greater than 1 in 20 chance of occurrence).
Medium = likely that the hazard occurs (e.g., between 1 in 20 and 1 in 200 chance of occurrence).
Low = unlikely that the hazard occurs (e.g., between 1 in 200 and 1 in 2 000 chance of occurrence).
Not known = city has not experienced or observed climate hazards in the past or has no way of accurately reporting this information based on evidence or data.

Source: JRC elaboration based on GCoM data

Figure 37. Level of impact of the climate hazard in the present.
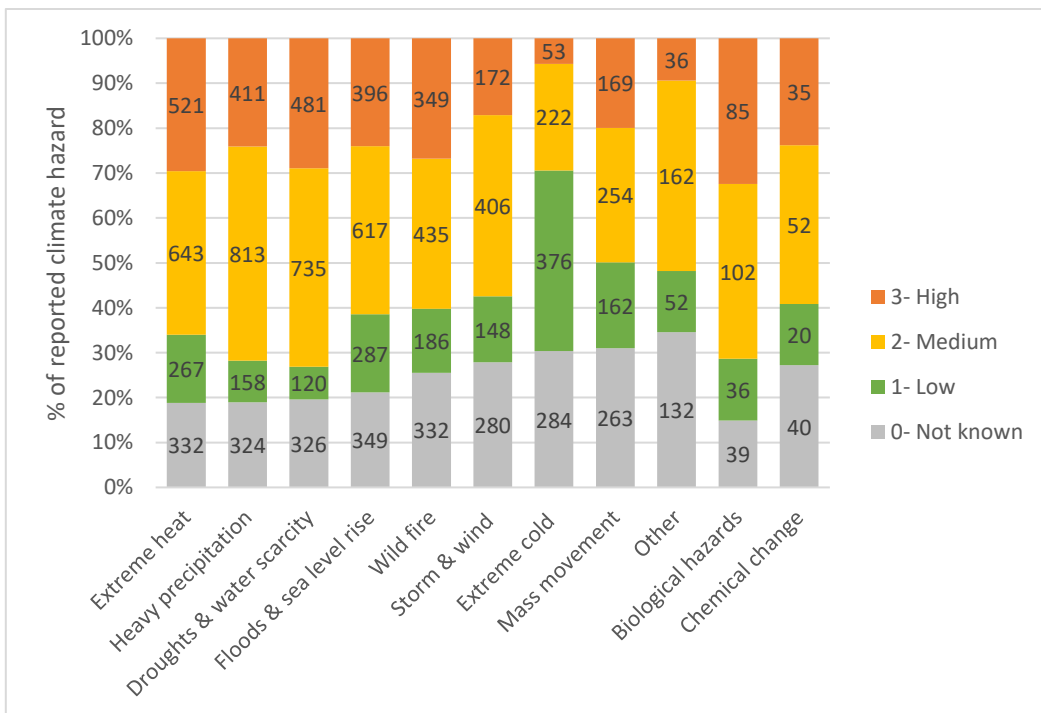
High = the hazard represents a high (or the highest) level of potential concern for your jurisdiction; when it occurs, the hazard results in (extremely) serious impacts to the jurisdiction and (catastrophic) interruptions to day-to-day life.

Medium = the hazard represents a moderate level of potential concern for your jurisdiction; when it occurs, the hazard results in impacts to your jurisdiction, but these are only moderately significant to day-to-day life.

Low = the hazard represents a lower (the lowest) level of potential concern for your jurisdiction; when it occurs, the hazard results in impacts to your jurisdiction, but these are deemed less significant (or insignificant) to day-to-day life.

Not known = city has not experienced or observed climate hazards in the past or has no way of accurately reporting this information based on evidence or data.

Source: JRC elaboration based on GCoM data

The two following figures (Figure 38 and Figure 39) include the future expected change in hazard intensity and frequency as reported by signatories in their RVAs.

The climate hazard "Extreme cold" is reported proportionally with the most expected "decrease" in intensity and frequency, while all the other climate hazards are expected to increase in both intensity and frequency. "Extreme heat" is reported as "increase" in both intensity and frequency in more than 92% of the records, followed by "Droughts & Water scarcity" reported with "increase" in both intensity and frequency in more than 88% of the records.

Figure 38. Future expected change in hazard intensity.
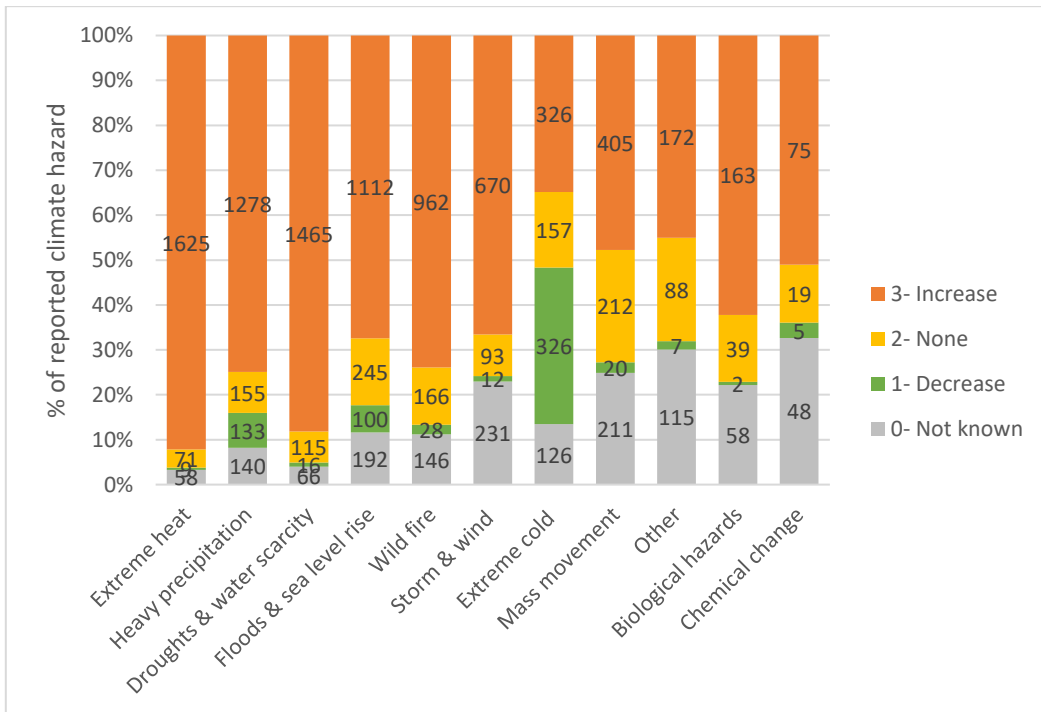
Source: JRC elaboration based on GCoM data

Figure 39. Future expected change in hazard frequency
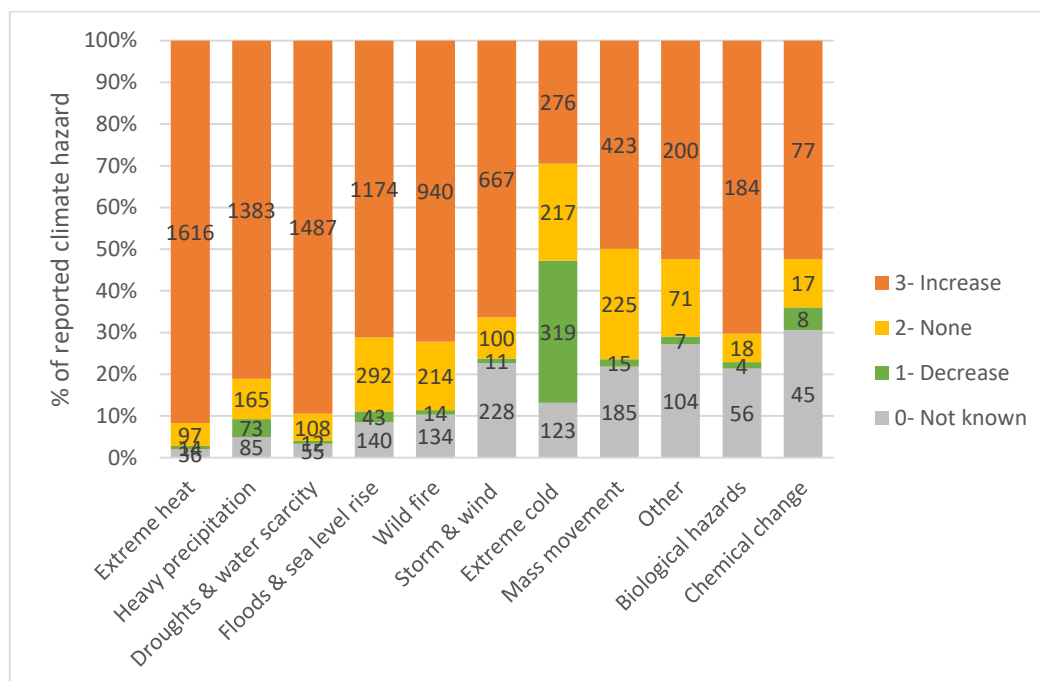
Source: JRC elaboration based on GCoM data

Figure 40 shows the timeframes of reported climate hazards[45]: "Wild fires" is reported with proportionally higher "short-term" attribute. "Mass movement", and "Chemical change" are reported with a higher share of unknown attributes.

Figure 40. Timeframe of reported climate hazards
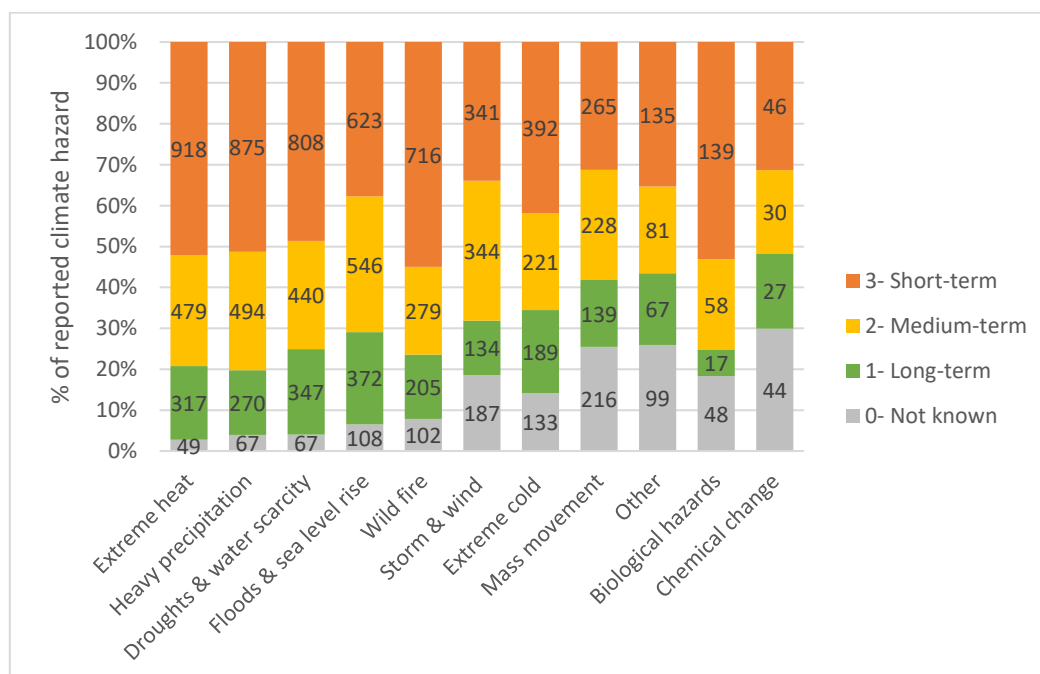
Source: JRC elaboration based on GCoM data

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[45]   Multiple options can be selected by signatories for each climate hazard reported in RVA in MyCovenant, while one option is available in CDP-ICLEI Track 2022.

Figure 41 shows all climate hazards and their characteristics for comparison:

— considering the green bars, "Extreme cold" is reported with the current lowest impact/probability, and is also expected to have the highest decrease in intensity/frequency; all the other climate hazards are showing predominantly high/medium impact and with expected increase in intensity/frequency;

— looking at the shift from current to future (first two bars vs last two bars), "Extreme heat" and "Droughts & water scarcity" show the most reported expected change (increase) in future intensity/frequency;

— considering the grey bars (not known), it can be noted that it is harder for some hazards to estimate the future conditions, in particular for "Chemical change", "Mass movement", and "Biological hazard".

Figure 41. Hazards and their attributes as reported by signatories
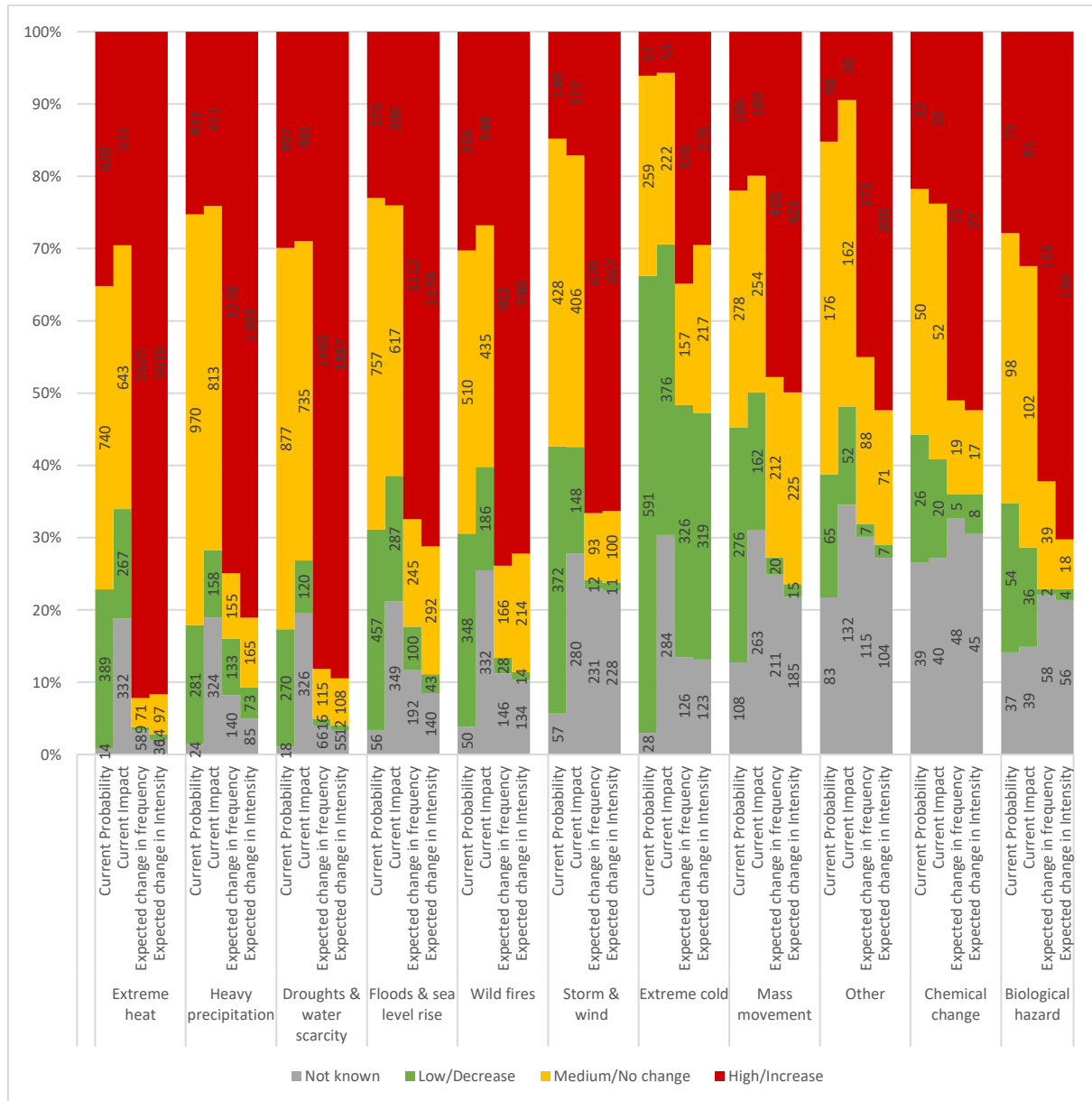
Source: JRC elaboration based on GCoM data

6.2.1.1   High-Risk Climate Hazards

Only 16% (1 920 out of 11 662) of the reported climate hazards can be classified as "high-risk climate hazards", defining them as hazards with both high probability level and high impact level.

However, 43% of RVAs (834 out of 1 947) include at least one high-risk hazard.

Considering only the high-risk climate hazards, the most reported climate hazards are (Figure 42): "Extreme heat" (21%), "Droughts & water scarcity" (18%), "Heavy Precipitation" (16%), "Wild fire" (14%). The top reported climate hazards are therefore slightly different compared to the overall most reported ones (as shown in in Figure 35). In particular, "Floods & sea level rise" was a top reported hazard but it is ranked as fifth when considering only high-risk hazards.

Figure 42. Most reported high risk climate hazards.
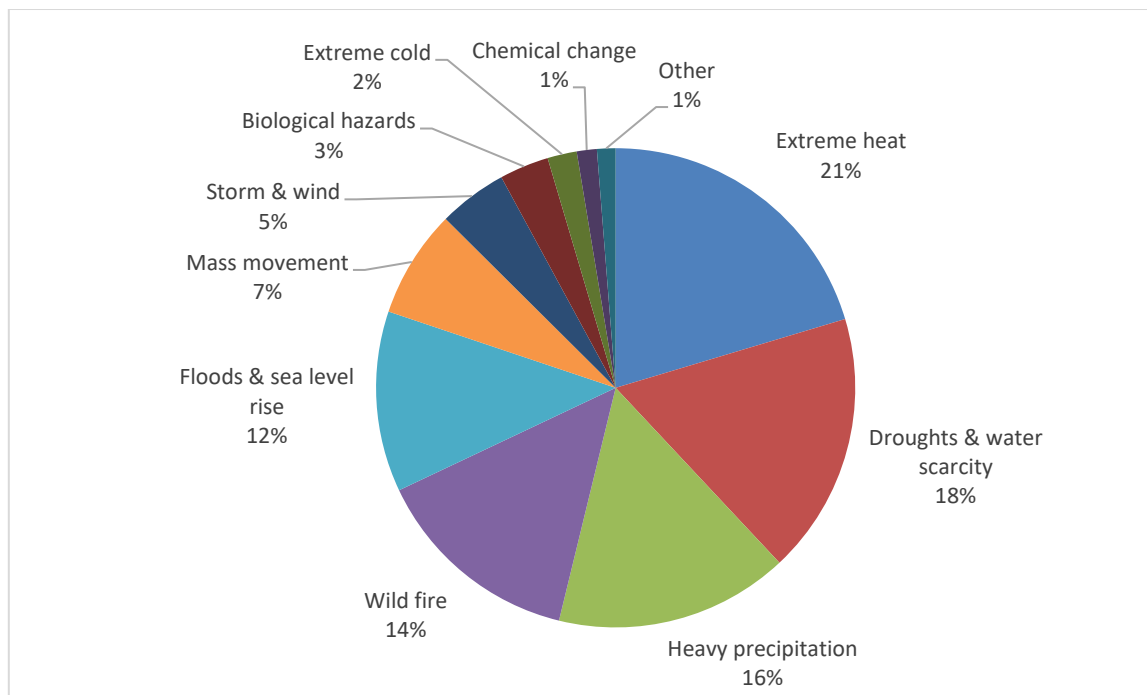
Source: JRC elaboration based on GCoM data

In terms of future expectations of the reported high-risk climate hazards, signatories reported:

- 90 % of the high-risk hazards with a future expected increase in hazard intensity
- 88 % of the high-risk hazards with a future expected increase in hazard frequency.

The expected change for high-risk climate hazards is reported as:

- 65 %: short-term
- 24 %: medium-term
- %: long-term
- 4 %: not known.

6.2.2 Vulnerable sectors

More than 34 500 local vulnerabilities are reported by signatories for specific vulnerable sectors[46].

As shown in Figure 43, the most reported vulnerable sectors are: are: "Food & Agriculture" (14%), "Environment & Biodiversity" (12%), "Public Health" (11%), "Civil protection & Emergency" (11%), "Buildings, Commercial, Residential" (10%).

Figure 43. Most reported vulnerable sectors
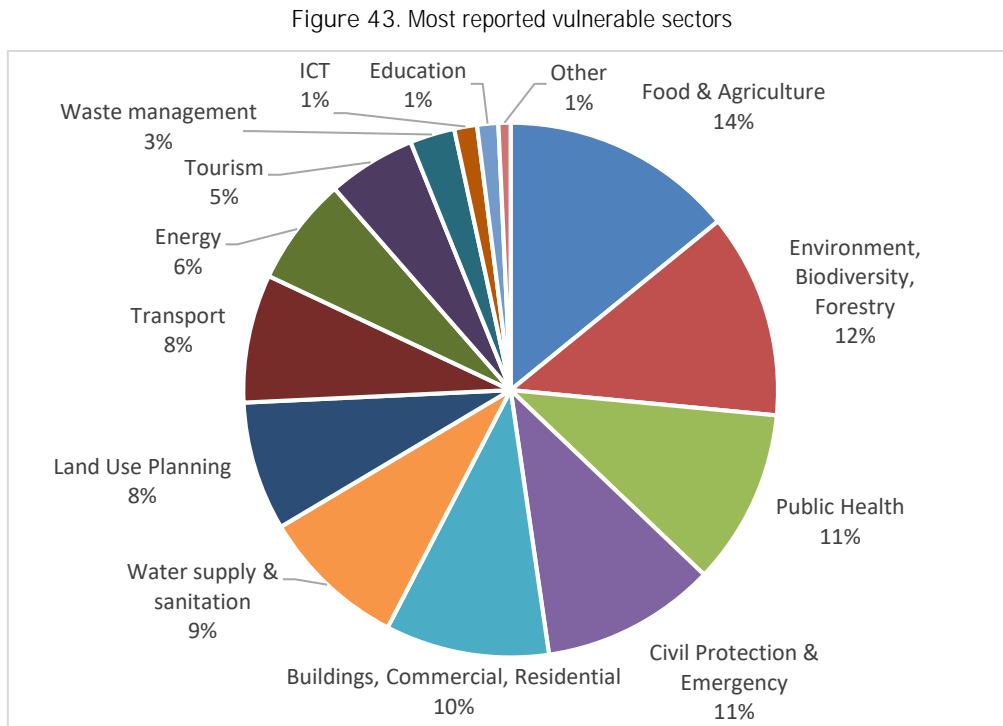
Source: JRC elaboration based on GCoM data

Because each sector is reported as vulnerable to a specific climate hazard, it is possible to analyse the most reported hazards per sector. Figure 44 shows that:

- "Food & Agriculture" is reported as most vulnerable to "Droughts & Water scarcity""
- "Environment & Biodiversity" is reported as most vulnerable to "Droughts & Water scarcity"
- "Public Health" is reported as most vulnerable to "Extreme heat"
- "Civil protection & Emergency" is reported as most vulnerable to "Floods & Sea level rise" and "Heavy precipitation"
- "Building" sector is reported as most vulnerable to "Floods & Sea level rise" and "Heavy precipitation"
- "Water supply & sanitation" is reported as most vulnerable to "Droughts & Water scarcity"
- "Land use planning" is reported as most vulnerable to "Floods & Sea level rise"
- "Transport" is reported as most vulnerable to "Heavy precipitation" and "Floods & Sea level rise"
- "Energy" is reported as most vulnerable to "Extreme heat"
- "Tourism" is reported as most vulnerable to "Extreme heat"

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[46] MyCovenant and CDP-ICLEI Track use different labels for sectors. The ones from the CRF are used here, and a re-classification was conducted (i.e. "Commercial" re-classified as "Buildings").

Figure 44. Vulnerable sectors and climate hazards.
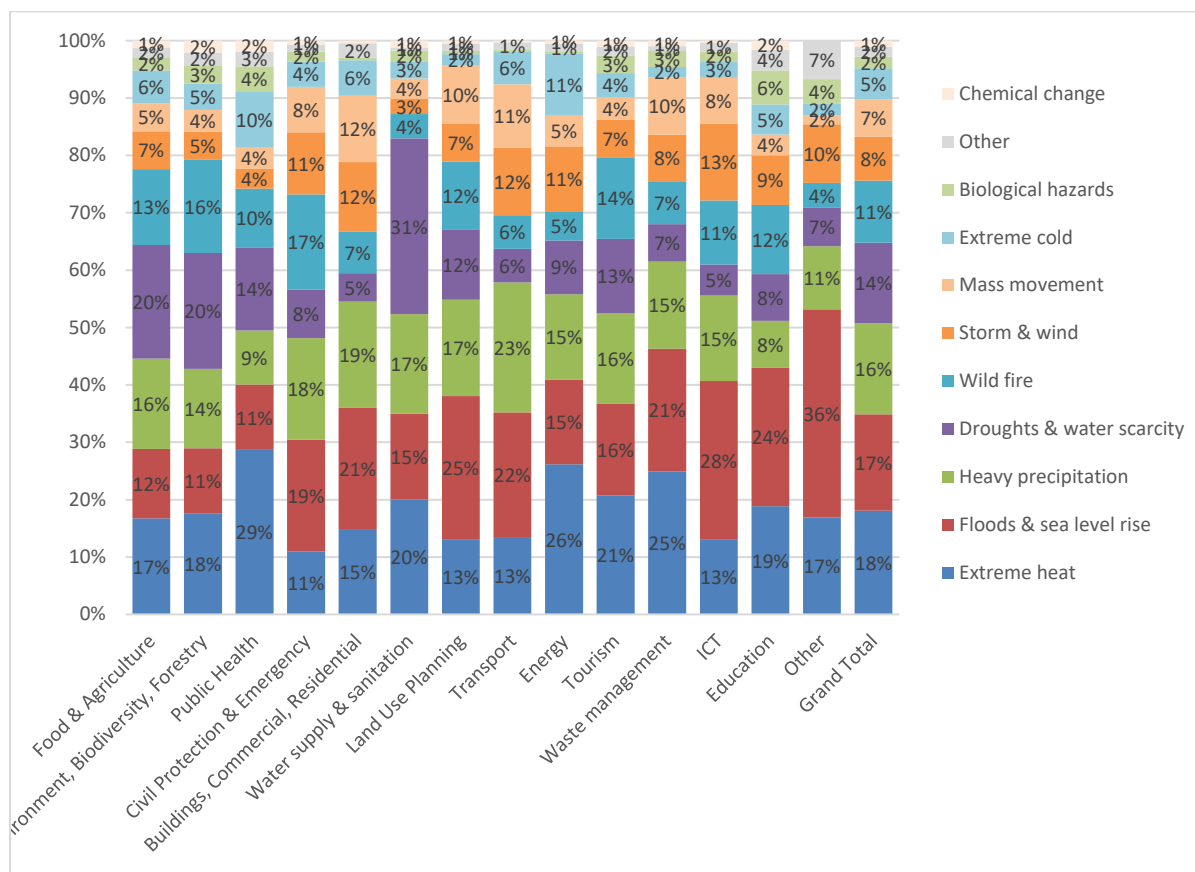
Another way of looking at the reported sectors is to consider which ones are more recurrent in cities (see Table 15), by looking at each city's RVA and marking if the sectors were or were not mentioned. This methodology helps removing bias and confirms the top sectors, with a slight difference in their order (i.e. Civil protection & Emergency" here is not in the top five reported sectors).

- "Food & Agriculture" is present in 60% of RVAs (1 237 out of 2 066)

- "Public Health" is present in 58% of RVAs (1 190)

- "Environment, Biodiversity, Forestry" is present in 57% of RVAs (1 179)

- "Water supply & sanitation" is present in 54% of RVAs (1 115)

- "Buildings, Commercial, Residential" is present in 50% of RVAs (1 042)

- Other sectors are present in less than 50% of RVAs.

Table 15. Sectors reported as vulnerable/impacted in **cities' RVAs**, number of cities mentioning each sector and respective share, out of 2066 cities.

Vulnerable/Impacted Sector	Number of cities mentioning the sector	Share of cities
Food & Agriculture	1237	60%
Public Health	1190	58%
Environment, Biodiversity, Forestry	1179	57%
Water supply & sanitation	1115	54%
Buildings, Commercial, Residential	1042	50%
Civil Protection & Emergency	969	47%
Land Use Planning	924	45%
Transport	903	44%
Energy	842	41%
Tourism	584	28%
Waste management	398	19%
Education	245	12%
ICT	227	11%
Other	95	5%
Industrial	5	0%
Society, Community & Culture	2	0%
Law & order	1	0%

Source: JRC elaboration based on GCoM data

6.2.3 Vulnerable population groups

46 % of the action plans (888) report information on Vulnerable population groups in their RVA, despite the fact that this information is not mandatory[47].

As shown in Figure 45[48],, the most reported vulnerable population groups are[49]:

- "Elderly" (18 %),

- "Low-income households" (14 %),

- "Persons living in sub-standard housing" (13 %),

- "Children & youth" (12%), and

- "Persons with chronic diseases" (9 %)

Figure 45. Most reported vulnerable population groups.
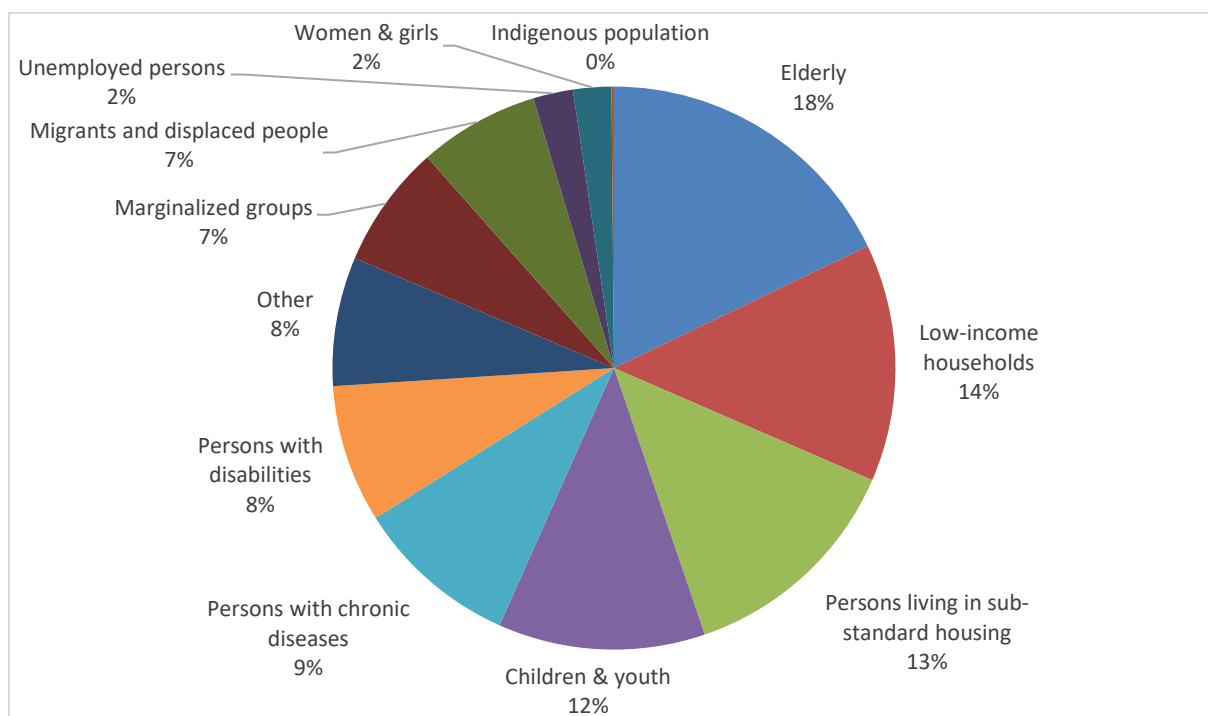
Source: JRC elaboration based on GCoM data

Excluding the category "All" and "Other "(2 174 and 686 records, respectively), more than 9 256 vulnerable population groups are reported as exposed to climate hazards. Because each group is reported as vulnerable to a specific climate hazard, it is possible to analyse the most reported hazards per group.

Figure 46 shows that:

- "Elderly", "Children & "Youth", "Persons living with chronic diseases", "Women and girls", "Persons with disabilities" are reported as most vulnerable to "Extreme heat"

- "Low-income households" are reported as most vulnerable to "Extreme heat" , "Floods & sea level rise" and "Heavy precipitation"

- "Persons living in sub-standard housing" are reported as most vulnerable to "Heavy precipitation"

- "Marginalized groups" are reported as most vulnerable to "Floods & sea level rise"

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[47] In MyCovenant reporting platform, as per CRF, this information is not mandatory.
[48] To avoid double counting, each category was counted as one even when reported multiple times (as vulnerable to multiple hazards).
[49] The template in MyCovenant allows selecting "All" and other categories at the same time (multi-choice option). 1 334 records are reported as "All" in the vulnerable population groups section of the RVA template, but they have been discarded for purpose of this analysis.

- "Migrants and displaced people" are reported as most vulnerable to "Heavy precipitation"
- "Unemployed persons" are reported as most vulnerable to "Drought & water scarcity"

Figure 46. Vulnerable population groups and climate hazards.
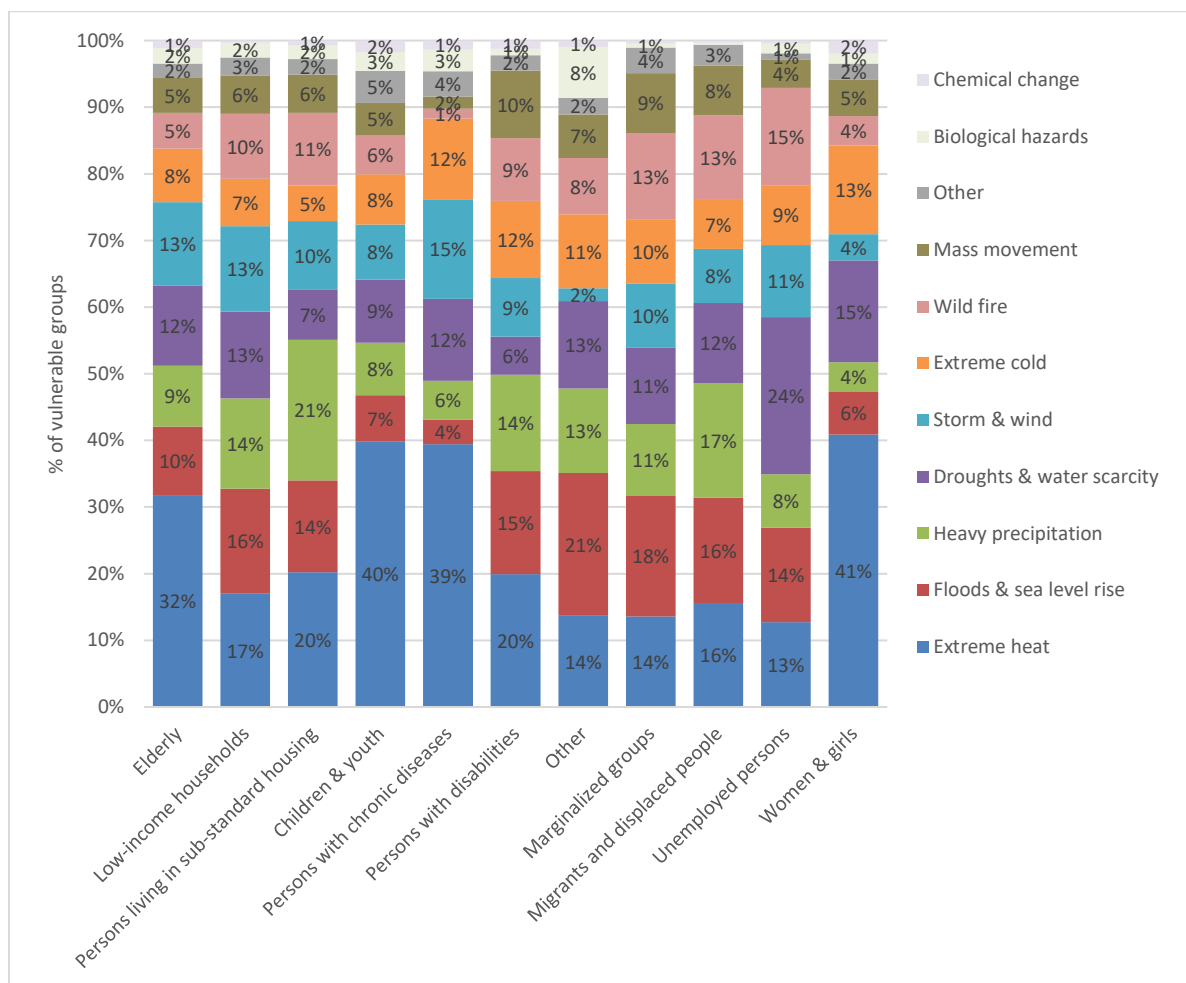
Considering only the signatories reporting high risk hazards (533), with both high level of probability and high level of impact (see 6.2.1.1), data shows an estimated amount of population exposed of more than 65.3 million of inhabitants.

6.3   Climate adaptation actions and measures

More than 20 170 adaptation actions are reported by signatories, with an average of 9.9 adaptation action per plan. As shown in Figure 47, since the beginning of the Mayors Adapt/Covenant of Mayors 2030 initiative in 2015 up to 2020 the number of actions planned has been growing every year with a peak in 2020, while it has experienced a decrease in the following years.

Figure 47. Adaptation actions with their reported implementation start year.
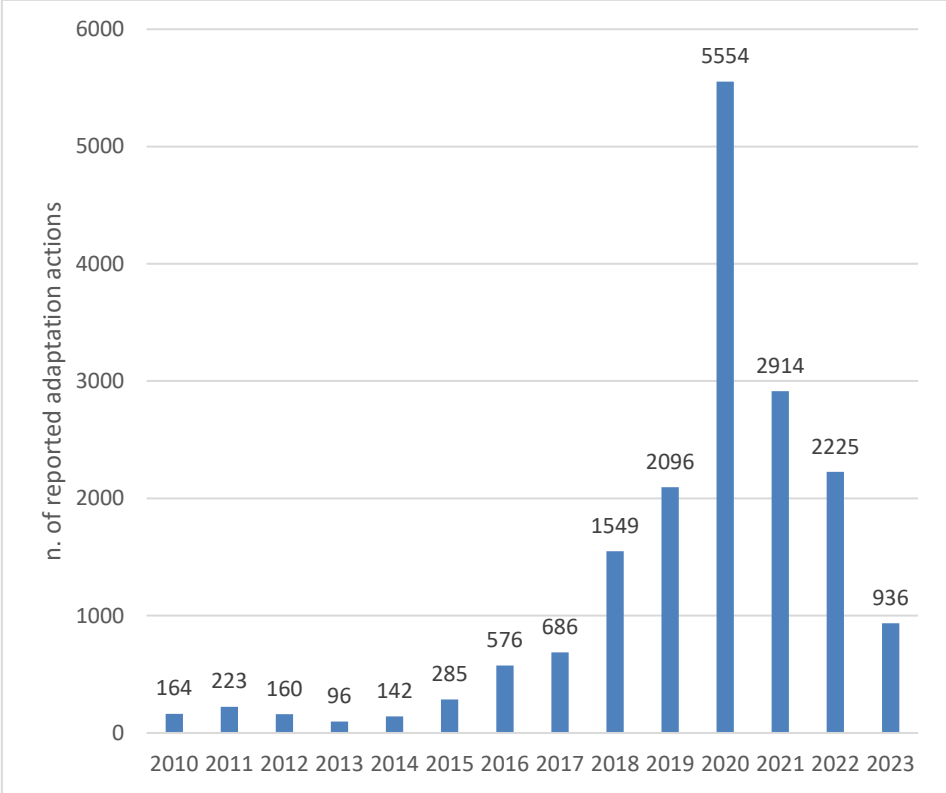
Source: JRC elaboration based on GCoM data

6.3.1 Actions and most addressed climate hazards

A total of 9 972 out of 20 170 adaptation actions (49%) report which climate hazard(s) they are addressing. Multiple hazards can be selected for each action.

According to the data shown in Figure 48, **the most addressed hazards are: "Extreme heat", "Droughts & Water scarcity", and "Heavy precipitation".**

That slightly differs from the most reported hazards in the RVA (see also 6.4).

Figure 48. Adaptation actions and most addressed climate hazards.
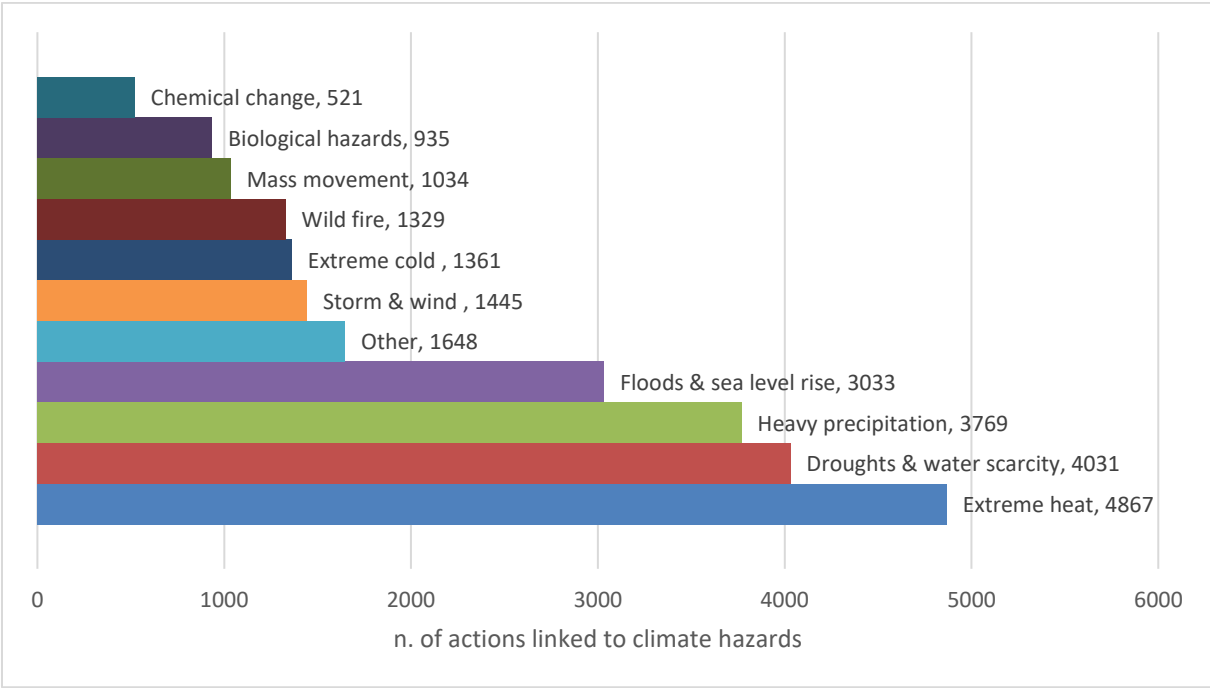
Source: JRC elaboration based on GCoM data

6.3.2 Actions and most targeted vulnerable sectors

89% of adaptation actions (18 020) report which sector they are targeting. This information has become mandatory for all actions in the recent version of the reporting guidelines. Multiple sectors can be selected.

According to the data shown in Figure 49, the most targeted sectors are "Environment, Biodiversity, Forestry", "Buildings, Commercial, Residential", and "Water supply & sanitation".
That slightly differs from the most reported sectors in the RVA (see also 6.4).

Figure 49. Adaptation actions and most targeted vulnerable sectors
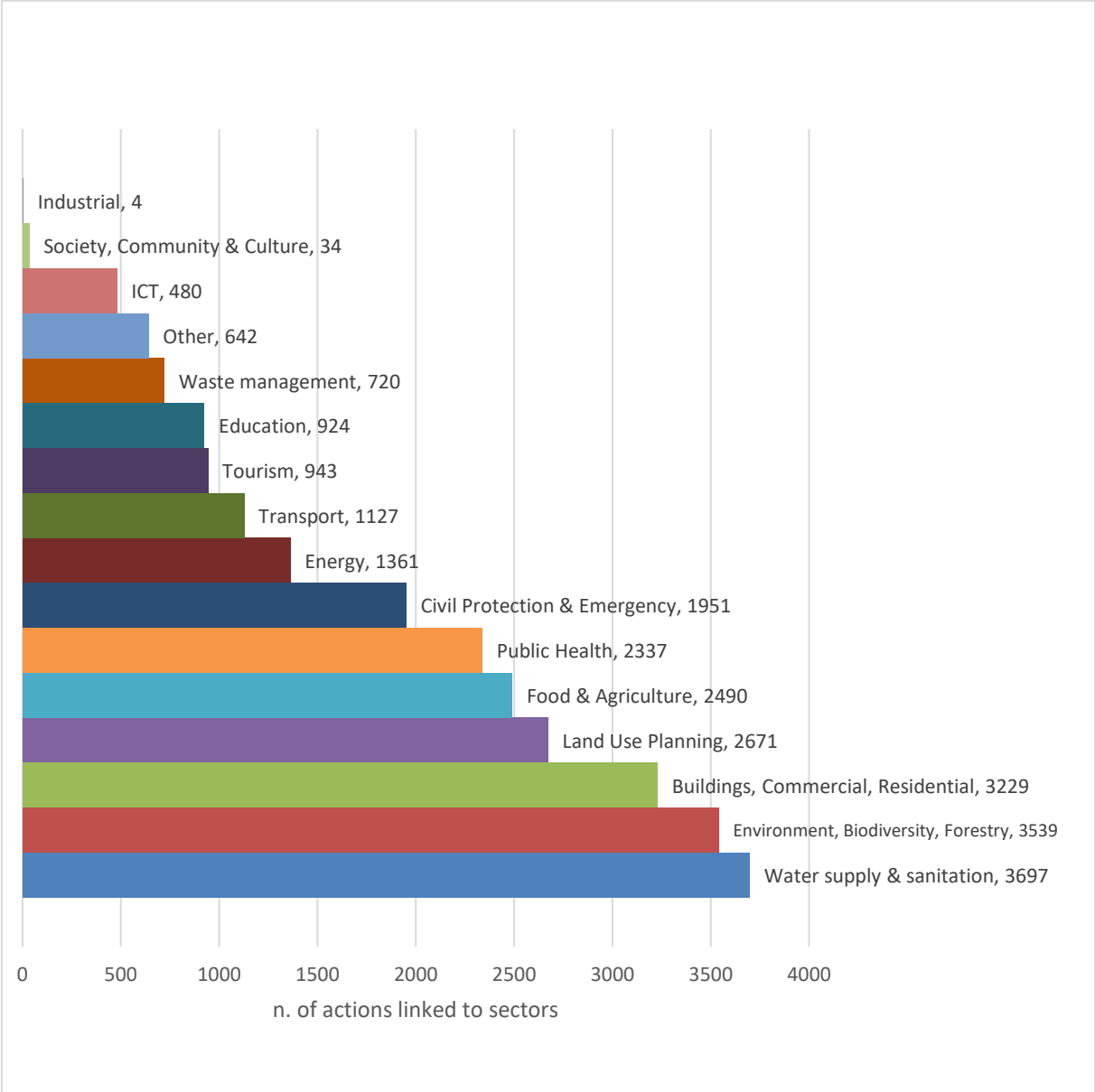
Source: JRC elaboration based on GCoM data

6.3.3 Actions and most targeted vulnerable population groups

20 % of the adaptation actions (3 973) report which vulnerable population group they are targeting. This information is optional in older and also in most recent version of the reporting guidelines.

According to the data shown in Figure 50, the most targeted population groups are[50]: "Children" and "Elderly".

That slightly differs from the most reported vulnerable groups in the RVA (see also 6.4).

Figure 50. Adaptation actions and most targeted vulnerable population groups
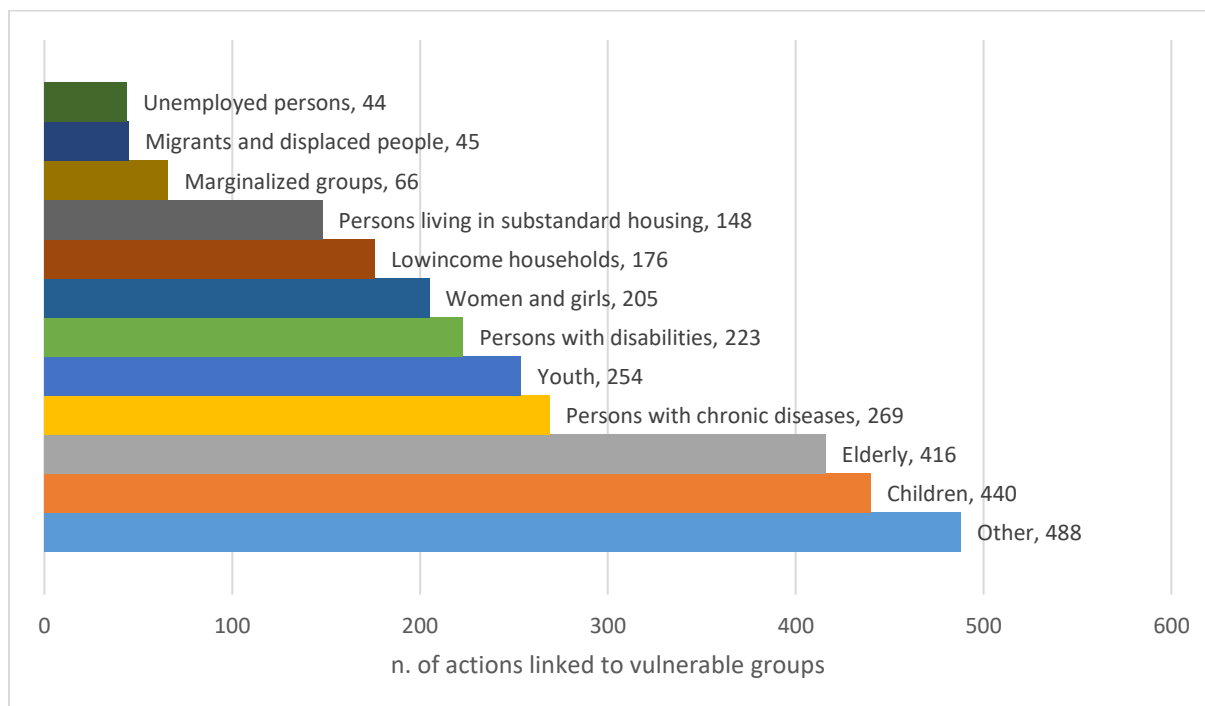
Source: JRC elaboration based on GCoM data

6.4 A**daptation "gap"** and potential incoherence among RVA and actions

As noted in the previous sections, there is a slight incoherence among hazards and sectors reported in SECAPs (goals, RVA, and actions). The major differences are among the hazards and sectors reported in RVA and in the actions:

- While "Wildfires" is among the most reported high-risk hazards in RVA, it is not among the most addressed hazards in the action plans.

- The top three climate hazards reported in RVA are also the top three addressed hazards in adaptation actions, while only the order differs. However, when considering the high-risk hazards, then the order is the same, confirming the priority and urgency in addressing high-risk hazards.

- While "Agriculture & Forestry" is the most reported vulnerable sectors in RVA, is it the fifth most addressed sector in the action plans. "Public Health" is among the most three reported vulnerable sectors, but it is not among the top five targeted sectors.

- On the contrary, "Water supply and sanitation" is not among the most vulnerable sectors in RVA, but it is the most targeted sector by adaptation actions.

This can be linked to difficulties in developing actions in sectors in which signatories have limited jurisdictional competence. For example, in some EU signatories, Agriculture and Forestry are managed and regulated at the regional or national level, leaving little room for actions to local authorities. The same applies to Public Health.

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[50] The template in MyCovenant allows selecting "All" and other categories at the same time (multi-choice option). 2 646 records are reported as "All" in the vulnerable population groups section of the action template, but they have been discarded for purpose of this analysis.

On the contrary, building codes, land use planning and education with public awareness campaigns are often the sectors where local authorities can exercise more influence and plan actions.

6.4.1   Climate hazards in RVA and actions

Considering only the "high-risk hazards" (as defined in 6.2.1.1), it is possible to analyse how many of them are targeted by planned actions. Figure 51 shows the proportion of signatories reporting a "high-risk hazard" also reporting at least a matching action: the chart shows the number of reported high-risk hazards by signatories: the ones that are covered in the action plan are shown in blue, while the ones reported in RVA but not mentioned in the action plans are in red:

- Overall, among all the high risk hazard reported in RVA by signatories (1 920), 62 % of them (1 189) are already addressed by at least one adaptation action;

- Droughts & water scarcity (74%), "Extreme heat" (68%), and "Floods & sea level rise" (64%) show the highest share of high risk hazards covered by at least one adaptation action;

- "Extreme cold" (29%), "Wild fires" (46%), and "Storm & wind" (48%) show lower share of addressed high-risk hazards by at least one action.

- This result could be linked to the fact that while actions addressing extreme heat, droughts and floods are available and popular among signatories, adaptation strategies for storms and wind, and wild fires are more difficult to plan.

Figure 51. Proportion of signatories reporting a "high risk" hazard also reporting at least a matching action.
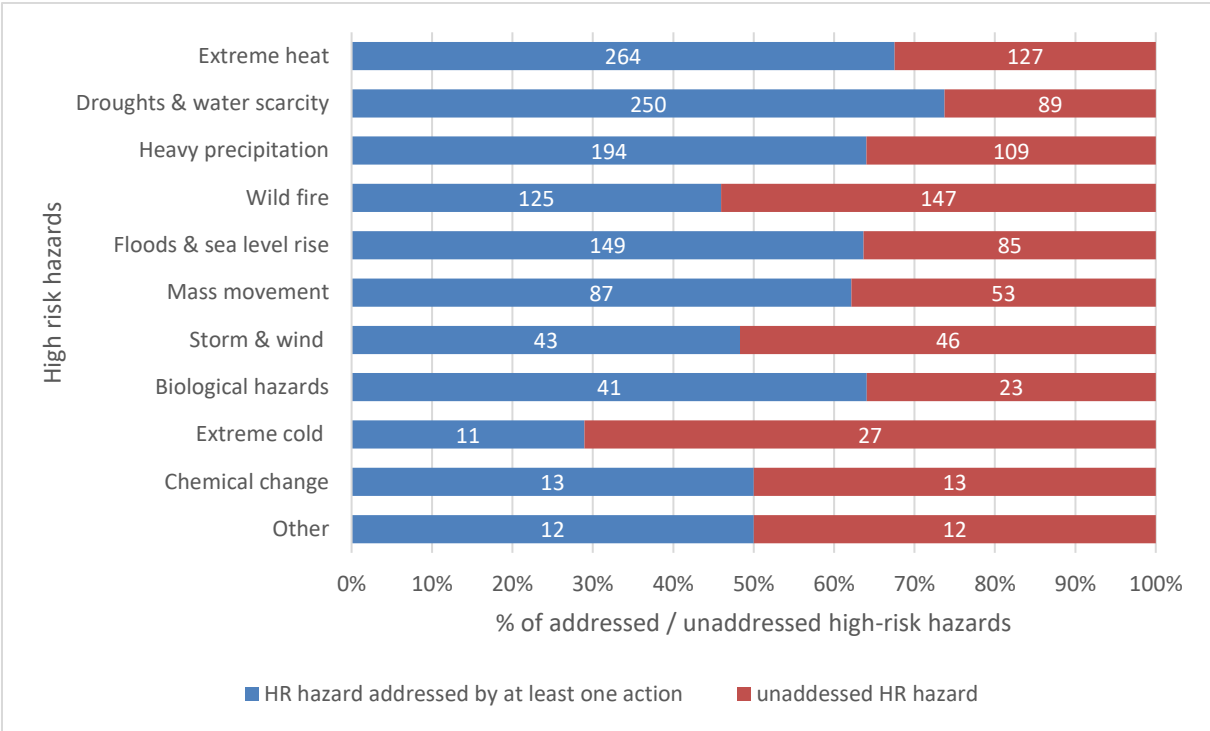
In blue: number of reported high-risk hazards covered in action plans.
In red: number of reported high-risk hazards not yet addressed in submitted action plans. Hazards are ordered by the number of signatories reporting them as high risk in their RVAs.

Source: JRC elaboration based on GCoM data

Considering the overall number of signatories reporting high-risk hazards:

- 68 % out of 834 signatories' action plans that report at least one high-risk hazard also report at least one matching action to address it.

- While there is a gap between the overall climate hazards identified and the actions taken, it can be noted that when it comes to high-risk hazards, the majority of action plans are probably well designed to address them.

6.4.2 Vulnerable sectors in RVA and actions

Looking at the sectors reported in RVA, it is possible to analyse how many of them are targeted by planned actions[51]. Figure 52 shows the proportion of signatories reporting a "high-vulnerable sector" also reporting at least a matching action: the chart shows the number of reported high-vulnerable sectorss by signatories: those that are covered in the action plan are shown in blue, while those reported in RVA but not mentioned in the action plans are in red:

- Overall, among all the vulnerable sectors reported in RVA by signatories (15 652), 45% of them (34 518) are already addressed by at least one adaptation action;

- "Water supply & sanitation" shows the highest share (56%) of high vulnerable sector covered by at least one adaptation action;

- More than 50% of the vulnerabilities in "Buildings, Commercial, Residential"" reported in RVA are addressed by at least one action., as well as "Land use planning".

Despite the fact "Buildings" is not among the top five vulnerable sectors, it is among mostly addressed by at least one action. This is probably linked to the fact that acting on "Buildings" is in the governmental domain of most local authorities signatories of the GCoM (i.e. promoting sustainable building codes, resilient retrofitting of public owned buildings, etc.).

Figure 52. Proportion of signatories reporting a vulnerable/impacted sector also reporting at least a matching action.
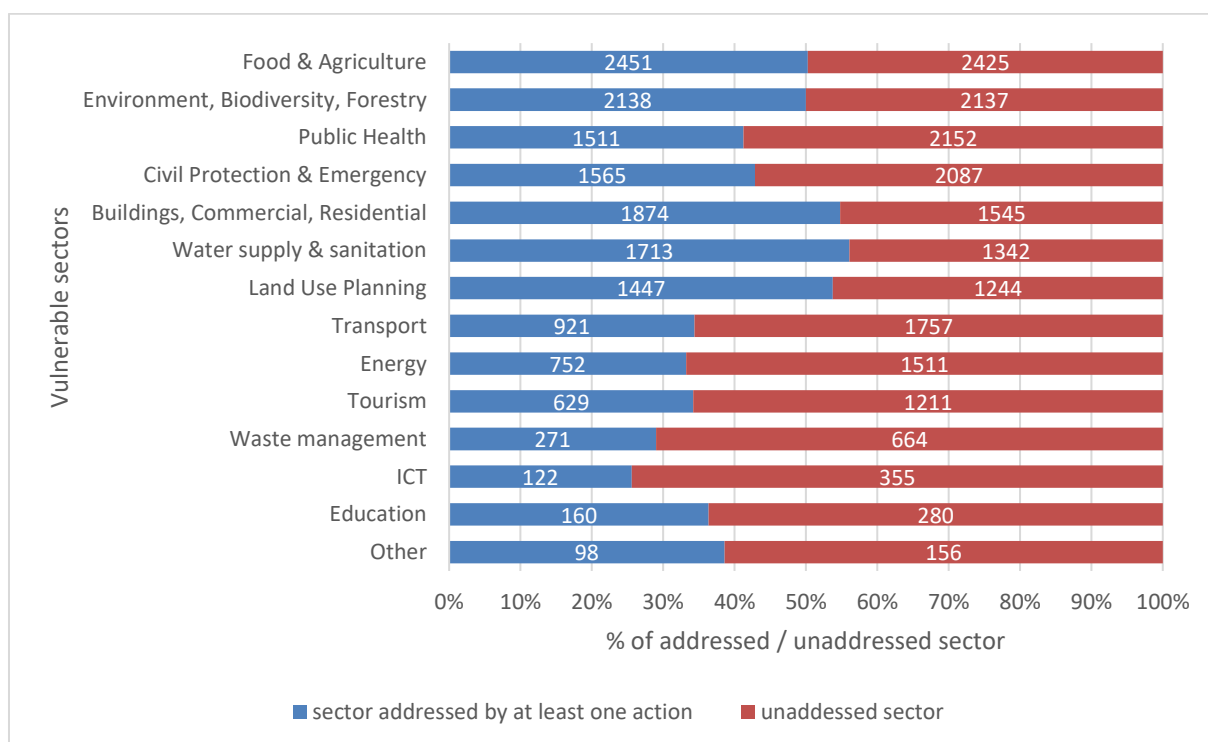
In blue: number of reported high-vulnerable sectors covered in action plans.
In red: number of reported high-vulnerable sectors not yet addressed in submitted action plans. Sectors are ordered by the number of signatories reporting them as high vulnerable in their RVAs.

Source: JRC elaboration based on GCoM data

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[51] While MyCovenant requires reporting a level of vulnerability for each sector, as per CRF, CDP-ICLEI-Track does not collect this data. For this reason, the information on the level of vulnerability has been discarded for this analysis, and all sectors (including the ones reported with "low" vulnerability in MyCovenant are kept.

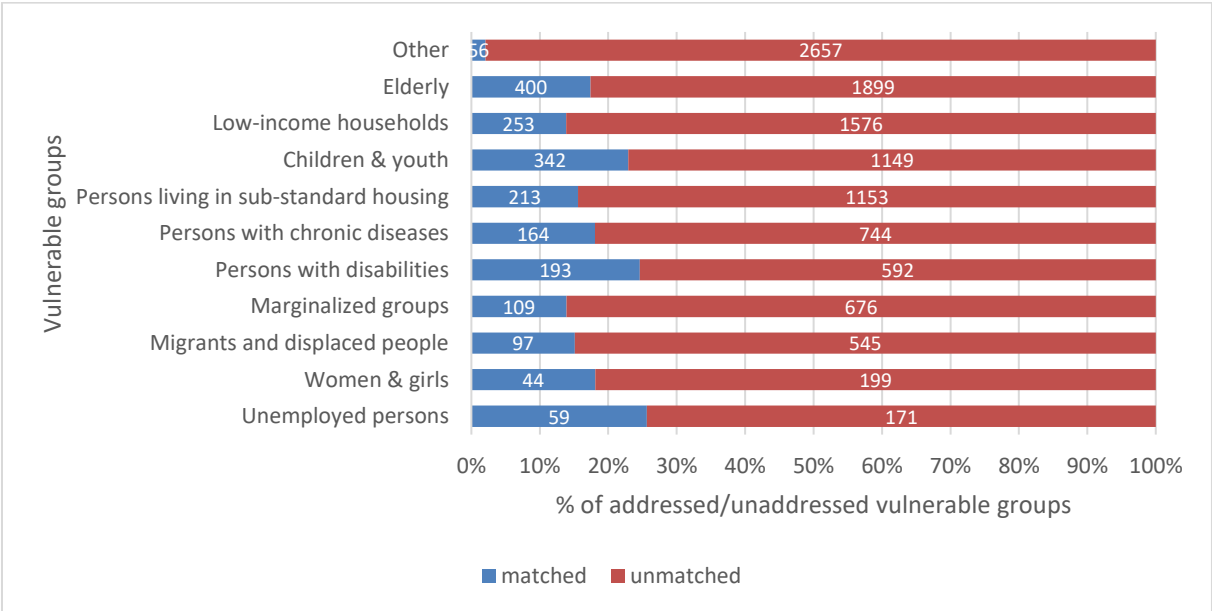Considering the overall number of signatories reporting vulnerable sectors (2 066):

- 922 (45 %) of signatories action plans that report at least one high-vulnerable sector are also reporting at least one matching action to address it.

6.4.3 Vulnerable population groups in RVA and actions

Looking at the vulnerable groups reported in RVA, it is possible to analyse how many of them are targeted by planned actions. Figure 53 shows the proportion of vulnerable groups in RVA also reported in at least one matching action: the chart shows the number of reported vulnerable groups by signatories: those that are covered in the action plan are shown in blue, while those reported in RVA but not mentioned in the action plans are in red:

- Overall, among all the vulnerable groups reported in RVA by signatories (13 291), only 15% of them (1 930) are addressed by at least one adaptation action[52];

- "Unemployed persons" and "Persons with disabilities" shows the highest share (26% and 25%) of vulnerable groups covered by at least one adaptation action;

- "Marginalized groups", and "Low-income households" are matched in less than 14% of cities.

Figure 53. Proportion of population groups reported as vulnerable in RVA also reported in at least a matching action.

In blue: number of reported vulnerable groups covered in action plans.
In red: number of reported vulnerable groups not yet addressed in submitted action plans. Groups are ordered by the number of signatories reporting them as vulnerable in their RVAs.

Source: JRC elaboration based on GCoM data

Considering the overall number of signatories reporting vulnerable groups (833):

- Only 145 (16%) of signatories action plans that report at least one vulnerable groups are also reporting at least one matching action to address it.

Addressing vulnerable population groups is still one of the main challenges in GCoM signatories.

[52] Category "All" is excluded from this analysis.

6.5 Monitoring and implementation

As mentioned in 6.1, the recent update on adaptation goals submissions in MyCovenant are defined in a way to allow quantitative monitoring of their progress. Next iteration of this report will be able to analyse adaptation goals and their progress toward target[53].

The only information retrievable in the dataset is the implementation status of adaptation actions[54].

The implementation status of the actions in the monitoring reports shows that 52 % of adaptation actions are reported as "completed" (15 %) or "ongoing" (37%), while 48 % are reported "not started" (Figure 54).

Figure 54. Implementation status of adaptation actions as reported in the platforms.
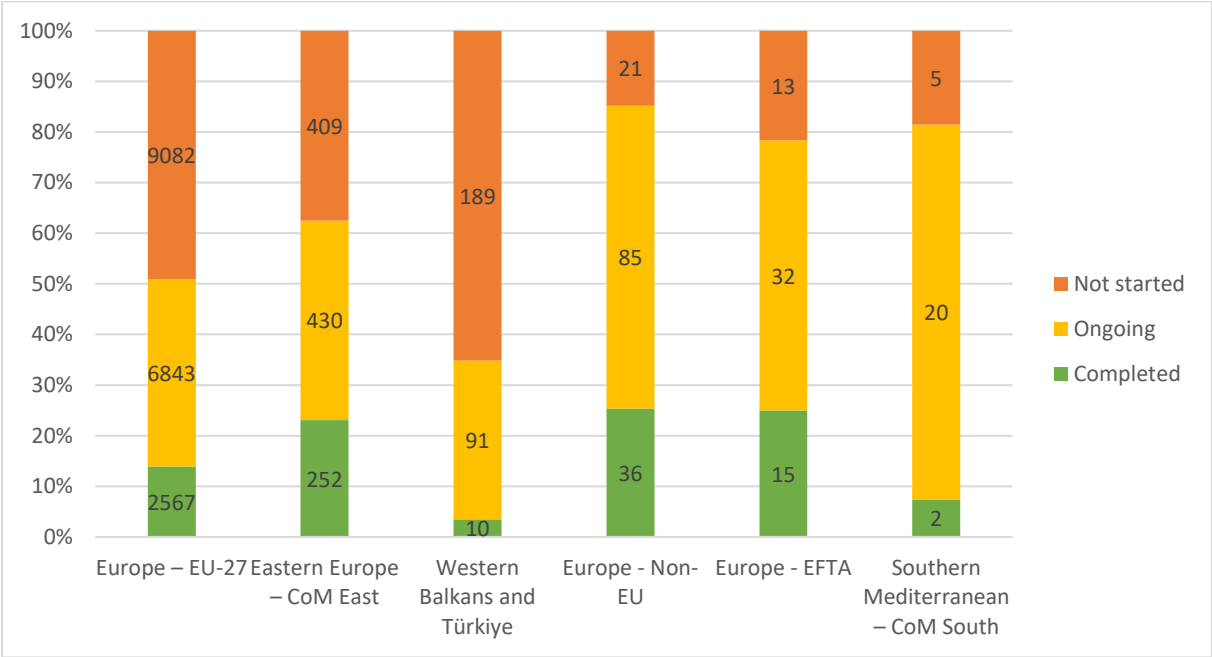
Source: JRC elaboration based on GCoM data

6.6 Cross-sectorial and co-benefit actions

Actions reported by signatories within the GCoM initiative can be marked as "mitigation", "adaptation", and "energy poverty/access". There are currently only 61 actions reported as "energy poverty/access" only.

92% of the actions are related to mitigation, while 9.7% are related to adaptation, and 0.7% to energy poverty.

Of the actions reported as adaptation (20 170), 82.3% are reported as adaptation only, while 14.3% are also addressing mitigation, 0.6% are also addressing energy poverty, and 2.8% are addressing also both mitigation and energy poverty (see Figure 55).

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[53] While MyCovenant allows reporting specific "monitoring reports", this information is not directly retrievable in CDP-ICLEI-Track. Is it therefore not possible to include valid information on adaptation: "progress toward target" (monitoring of the adaptation goal).

[54] While this information can be updated at each monitoring report in MyCOvenant (or each year for CDP-ICLEI-Track), an in depth analysis of the evolution of the implementation status over time was not conducted. Figures show the last available status in the datasets.

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Figure 55. Actions and their share among the three pillars of the GCoM initiative
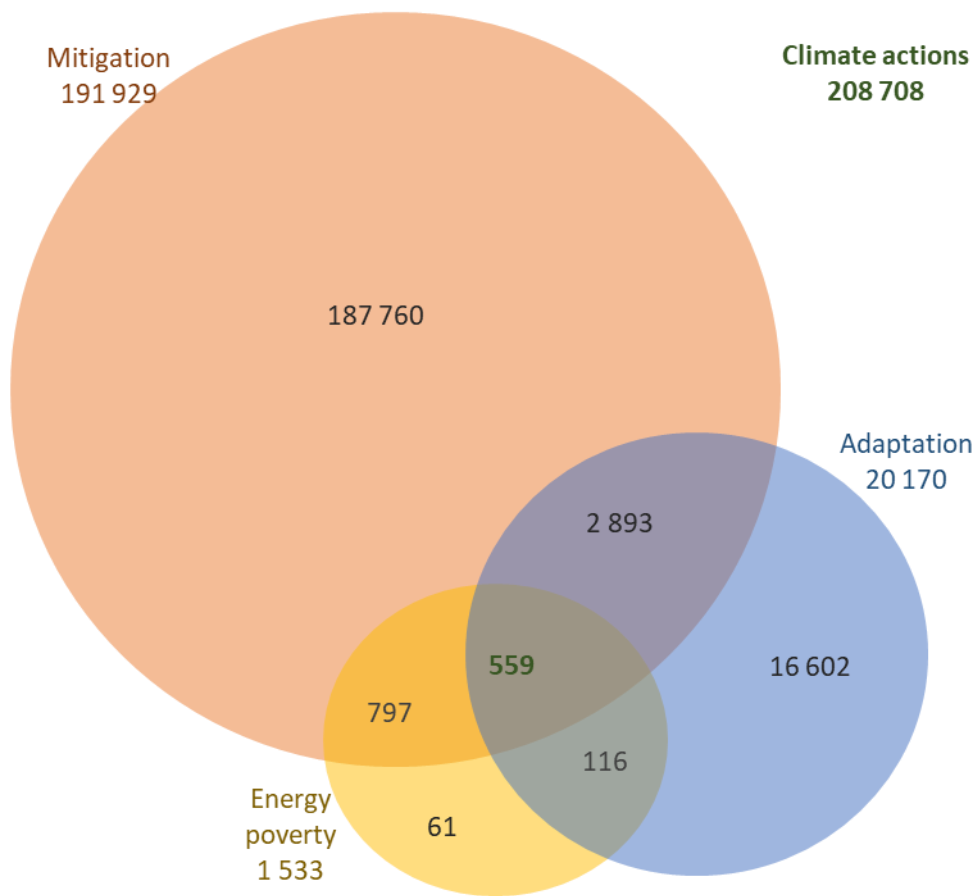
Source: JRC elaboration based on GCoM data

7 General conclusions on mitigation and adaptation

7.1 Overall considerations

Over the past 15 years, the Covenant of Mayors has contributed to the creation of a European and, later on, a global movement of cities and local authorities committed to taking action on climate change mitigation and adaptation. It has been instrumental in shaping approaches and methodologies for the development of climate plans at the local level, which can usefully complement national plans and programmes and thus contribute to the objectives of the Paris agreement and, at the EU level, to the 2050 climate neutrality target. A common but flexible approach to reporting allows assessing cities' efforts in a consistent manner and evaluating the collective level of ambition and achievements of cities of different sizes, geographies and backgrounds.

7.2 Main findings

This report is based on data collected through MyCovenant and CDP-ICLEI Track until end of March 2023, for Europe, the South Mediterranean Region, Turkiye and Central Asia. The initiative counts on 11 367 committed cities and local authorities, covering a total population of 370.8 million inhabitants.

Box 2. Signatories and commitments

Most of the signatories (10 414, covering 240.4 million inhabitants) come from the EU-27, followed by the Eastern Partnership countries (545 signatories, 33.8 million inhabitants) and by Western Balkans and Türkiye (153 signatories, 50.5 million inhabitants). MyCovenant is mostly used by signatories from Europe or from countries where the EU has been supporting the initiative since 2011.

The vast majority of the signatories (almost 55 %, covering 35.5 % of the inhabitants) remains committed only to the 2020 mitigation targets, while 44 % (representing about 61 % of the CoM population) are committed to a mitigation target by 2030 and/or by 2050 combined with adaptation. The remaining 1 % has a commitment to adaptation only or adaptation combined with a 2020 mitigation target.

The first part of the analysis underpinning the results presented in this report consisted of a harnessing procedure aimed at enhancing the quality of the signatories' reported data through a statistical analysis and internal-consistency general rules. On this basis, we defined a subset of 7 248 action plans, covering almost 265 million inhabitants.

Subsequently, in order to assess the collective achievements of EU-27 cities, we had to perform estimations to obtain the corresponding emissions on the same base year for all of the cities.

Box 3. Action plans and commitments

Looking at the action plans by pillar, we note that 73.7 % of the action plans only address the mitigation pillar and that just 25.9 % of the actions plans address simultaneously mitigation and adaptation. Less than 0.5 % of action plans and population address the adaptation pillar alone. That is due to the fact that the adaptation pillar was introduced more recently in the initiative compared to mitigation.

73.7% of the mitigation plans (covering 45.4 % of the population) have a 2020 target only; 25.8% of the mitigation plans (covering 53.6 % of the population) have a 2030 target, either combined with a 2020 target or not; 0.5% of the mitigation plans (covering 1% of the population) have a plan consistent with the CoM 2050 commitment, i.e. with a climate neutrality target to 2050.

In terms of reporting on the action plan's implementation, 2 927 signatories, covering 117.3 million inhabitants, have submitted at least one monitoring report. Out of these, 1 510 (covering nearly 79 million inhabitants) submitted a monitoring report flagged as "complete", i.e., including at least one monitoring emission inventory. The other 1 417 signatories submitted a "light" monitoring report, mainly including qualitative information on the actions' implementation status.

Regarding climate change mitigation, Covenant cities and local authorities with a submitted action plan show a collective ambition that exceeds the minimum commitments required by the Covenant Europe. The 2030 forecasts based on implementation reports however identify a delivery gap of 8 percentage points compared to targeted emissions in 2030 (Box 4).

> **Box 4. Climate mitigation: baseline emissions, overall ambition by 2030 and achievements**
>
> Based on data from 1 698 submitted action plans with a 2030 target, the overall committed GHG emission reduction is 56.6 % by 2030 (compared to a baseline level of 684 Mt CO_2-eq). Looking only at signatories from EU-27, the overall committed reduction is 55.2 % by 2030 (compared to a baseline level of 469 Mt CO_2-eq).
>
> Direct (Scope 1) emissions represent 64% of the total GHG emissions, followed by 34% indirect (Scope 2) emissions, associated with the consumption of grid-supplied energy. Scope 3 emissions represent only 2% of the total GHG emissions.
>
> Looking only at 676 action plans with at least one monitoring report, a 48 % reduction by 2030 is forecasted, while the targeted mean reduction is 56 %. This insight suggests that greater effort is necessary for signatories to advance in the implementation of their action plans and achieve the emission reduction targets they have set.

Almost 51 000 mitigation actions were reported by signatories reporting through MyCovenant, corresponding to an average of 28 mitigation actions/measures per action plan with a time horizon to 2030 or beyond.

> **Box 5. Climate mitigation actions and measures**
>
> As regards EU-27 signatories, we observe that most of the actions target the building sector (54%), followed by the transport sector (22%) and the waste & other sector (11%). In terms of estimated emission reduction however, electricity production largely dominates the scene with 40%, followed by transport (21%) and buildings and waste & other (each contributing 17%). For European non-EU-27 signatories, the picture is quite different: about one third of the actions target the buildings sector and are expected to deliver 21% of the expected emission reduction by the target year; one third of the actions target the waste & other sector, contributing 30% to emission reduction, while transport accounts for 26% of the actions and 28% of emissions reduction; local electricity production actions, although less numerous (7% of the actions) are expected to deliver 18% of the expected emission reduction.
>
> In the stationary energy sector, most of the actions are classified as "integrated action", meaning that they target in a holistic way the building system; many measures aim at improving the energy efficiency of lighting systems and building envelopes; several measures target space heating and hot water systems, by promoting either energy efficient boilers or the use of renewables (notably through solar thermal collectors and biomass boilers); triggering behavioural changes is also a prominent area of intervention and a significant share of actions concern information and communication technologies (ICT). In terms of policy instruments, energy management is associated with 30 % of reported actions, mainly addressing municipal buildings. The second preferred instrument is awareness-raising and training, targeting, in particular, the residential sector. Grants and subsidies are also a quite common instrument, followed by public procurement, energy certification/labelling and building standards.
>
> In the transport sector, the large majority of the actions concerns cleaner/efficient vehicles and electric vehicles, showing that local authorities rely to a great extent on the gradual improvement of the fleet of vehicles, which are bound by European standards, and might also depend on national incentives and economic performance; local authorities then try to promote electric vehicles and to encourage a shift towards active mobility or towards public transport and to promote eco-driving. As to the policy instruments adopted in the transport sector, preference seems to be given to awareness-raising and training, followed by mobility planning regulation, by public procurement (to renew municipal fleet and vehicles used in public transport) and then by grants and subsidies (which may include tax reduction or subsidies for more efficient vehicles or incentives for the purchase of electric bikes)

The definition of adaptation goals is still a challenging component of the action plans. Data from submitted templates show unclear goal descriptions, and only a minor number is linked to reducing the risk of climate hazard risks and/or vulnerabilities. Additionally, the quantitative component of the goal is often incorrectly filled in, not allowing the monitoring of the "progress toward target". A clarification of this aspect could be highly beneficial for improving the quality of adaptation plans and their monitoring.

Despite the challenges on the definition of the adaptation goals, the definition of climate risks and vulnerabilities (RVA) has reached a fairly developed phase with more than 11 600 climate hazards reported with a good level of information. In fact, five characteristics are associated with each of them (current probability and impact, expected change in intensity and frequency, timeframe), and it is possible to analyse the most reported climate hazard, to highlight the high-risk ones in connection with specific contexts and geographical areas.

> **Box 6. Overall reported climate risks and vulnerabilities**
>
> The most reported climate hazards in signatories' RVAs are "Extreme heat" (15 %), "Heavy precipitation" (15 %), "Droughts & Water scarcity" (14 %), and "Floods & Sea level rise" (14 %). They are all reported with predominantly high/medium impact and with an expected increase in intensity, except the extreme cold, which is reported with the current lowest impact and is expected not to change or decrease in intensity. However, there are differences according to local context and local climate. "Extreme heat" is reported by 92% of cities with a RVA, and is also the most reported hazard among the high-risk ones.
>
> The most reported vulnerable sectors are: Food & Agriculture" reported as most vulnerable to "Droughts & Water scarcity", "Environment & Biodiversity" reported as most vulnerable to "Droughts & Water scarcity", "Public Health" reported as most vulnerable to "Extreme heat", "Civil protection & Emergency" reported as most vulnerable to "Floods & Sea level rise" and "Heavy precipitation", "Building" sector reported as most vulnerable to "Floods & Sea level rise" and "Heavy precipitation".
>
> The most reported vulnerable population groups are: "Elderly", reported as most vulnerable to "Extreme heat"; "Low-income households" reported as most vulnerable to "Extreme heat" , "Floods & sea level rise" and "Heavy precipitation"; "Persons living in sub-standard housing" reported as most vulnerable to "Heavy precipitation".

Despite it being optional information in the reporting requirements, signatories reported vulnerable population groups exposed to climate hazards. High-value information can be obtained from action plans if reporting information on social vulnerabilities is encouraged and perhaps required in future developments.

Considering only the signatories reporting high-risk hazards, data shows an amount of population affected of more than 65.3 million inhabitants.

More than 20 **170** adaptation actions are reported by signatories. Since the beginning of the Mayors Adapt and the Covenant of Mayors 2030 initiative up to 2020, the number of actions implemented has grown every year with a peak in 2020, while a decrease in the following years. Data shows potential incoherencies or "gaps" among the reported hazards and the hazards most addressed by actions. At the same time, the most reported vulnerable sectors are not the most targeted sectors by actions. However, the gap can be linked to difficulties by signatories in developing actions in sectors in which they have limited jurisdictional competence or financial capacity.

> **Box 7. Adaptation actions**
>
> The most addressed hazards are: "Extreme heat", "Droughts & Water scarcity", and "Heavy precipitation".
>
> The most targeted sectors are: "Water supply & sanitation", "Environment, Biodiversity, Forestry", and "Buildings".
>
> The most targeted population groups are : "Children" and "Elderly".
>
> Considering the overall number of signatories reporting high-risk hazards (834), 68 % are also reporting at least one matching action to address it. Among signatories reporting vulnerable sectors (2066), 45% are also are also reporting at least one matching action to address it.
>
> However, among signatories reporting vulnerable population groups (833), only 16% are also are also reporting at least one matching action to address them.

7.3   Final conclusions

The Covenant of Mayors has been instrumental in creating a community of almost 11 400 cities and local authorities in Europe and beyond, committed to fighting climate change. It supports signatories' efforts through the provision of guidance, technical assistance, sharing of best practices and peer learning. At the same time, it helps consolidate practices to monitor and report on energy consumption and GHG emissions as well as risks and vulnerabilities at the local level, allowing decision-makers to identify priority sectors, set emission reduction targets and adaptation goals and plan relevant measures. All these are considered key strengths of the initiative where the JRC has played a major role in continuously maintaining and fortifying its technical bases.

At a closer look, the vast majority of the Covenant signatories are still committed to a 2020 mitigation target, not including adaptation. This is also confirmed by the analysis of the action plans, a majority of which have a timeframe limited to 2020 while only a small share have a target to 2030 and address the adaptation pillar at the same time. Nevertheless, the number of plans with a 2030 or 2050 emission reduction target is constantly growing and currently represents 25% of the mitigation plans and 39% of the population. EU-27 signatories

with a 2030 climate mitigation plan have an overall commitment of 55.2% emission reduction by 2030, well aligned with the EU 2030 climate target. The forecasts for 2030, based on monitoring emission inventories submitted so far by 676 signatories, however, are less optimistic, with preliminary results showing a delivery gap of 8 percentage points in comparison to the overall targeted reduction.

On adaptation, while committed signatories and adaptation action plans are less numerous than for mitigation, figures are constantly growing. For example, the number of adaptation actions has been growing every year with a peak of 5 554 actions with implementation year in 2020, while a decrease in the following years is recorded. That is particularly significant considering that, under the current reporting guidelines, signatories are not required (and therefore not encouraged) to report actions in the first two years from registration; consequently, the real complete adaptation action plans and actions might be underrepresented in the figure submitted in the reporting platforms and presented in this report.

While some challenges remain in some aspects of the adaptation pillar, such as the definition of adaptation goals, internal gaps/incoherence of action plans, unaddressed vulnerable population groups, and the reporting requirement of adaptation actions, much can be done in providing further guidance to signatories and further developing the template for the collection of high-quality information.

This report is expected to inform further reflections on the future of the initiative, with a view to building on its key strengths in order to deliver more tangible results on the ground. Further analyses could aim at better understanding, for example through a broad consultation of Covenant cities and local authorities, the reasons that are preventing them from renewing their commitments to 2030 or 2050 targets. It would also be beneficial to explore the factors contributing to the rather low number of monitoring reports.. Gaining a better understanding of all these issues could allow the European Commission to provide more targeted and effective support and tap into the potential of cities and local authorities to address the climate challenge.

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List of abbreviations, formulations and definitions

AR	Assessment Report
BAU	Business-as-usual
BEI	Baseline Emission Inventory
CH_4	Methane
CHP	Combined Heat and Power
CO_2	Carbon Dioxide
CO_2-eq	CO_2-equivalents
CoM	Covenant of Mayors for Climate and Energy
CoM-East	Covenant of Mayors East (Eastern Partnership countries)
CoM-South	Covenant of Mayors South (Southern Mediterranean Partner countries)
CoM-SSA	Covenant of Mayors in Sub-Saharan Africa
CRF	Common Reporting Framework
DG ENER	European Commission's Directorate-General for Energy
DG CLIMA	European Commission's Directorate-General for Climate Action
EC	European Commission
EDGAR	Emissions Database for Global Atmospheric Research
EEA	European Environment Agency
EFTA	European Free Trade Association
EI	Emission Inventory
ETS	Emissions Trading System
EU	European Union
EU-27	European Union with 27 Member States
GCoM	Global Covenant of Mayors for Climate and Energy
GHG	Greenhouse Gas
IEA	International Energy Agency
ICT	Information and Communication Technologies
IPCC	Intergovernmental Panel on Climate Change
JRC	Joint Research Centre
KPI	Key Performance Indicator
kWh	Kilowatt Hour
LAU	Local Administrative Units
LCA	Life-Cycle Assessment
MEI	Monitoring Emission Inventory
Mt	Million Tonnes
MWh	Megawatt Hour
N_2O	Nitrous Oxide
NDC	Nationally Determined Contributions
NUTS	Nomenclature of Territorial Units for Statistics

NUTS2	Level 2 regions based on the Nomenclature of Territorial Units for Statistics
NUTS3	Level 3 regions based on the Nomenclature of Territorial Units for Statistics
RVA	Risk and Vulnerability Assessment
SEAP	Sustainable Energy Action Plan
SECAP	Sustainable Energy and Climate Action Plan
TWG	Technical Working Group
UNFCCC	United Nations Framework Convention on Climate Change

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Annex 1. Signatories and population covered by country

Table A1. Signatories by country and commitment

Country	CoM 2020	Mayors Adapt	CoM 2030	CoM 2050
Albania	3	1	3	1
Algeria	3			
Andorra				1
Armenia	13		26	
Austria	27	1	4	1
Azerbaijan	1		8	1
Belarus	14		53	
Belgium	292	15	508	31
Bosnia-herzegovina	19		45	7
Bulgaria	43	2	3	4
Croatia	76	3	40	26
Cyprus	25		4	1
Czechia	13		64	119
Denmark	40	4	7	4
Estonia	7	1	2	
Finland	10		14	1
France	161	6	40	13
Georgia	12		25	2
Germany	76	11	21	12
Greece	173	14	77	15
Hungary	60	2	176	124
Iceland	1		1	
Ireland	12	1	11	2
Israel	7	30	30	
Italy	4448	69	1183	180
Jordan	1	18	18	
Kazakhstan	9			
Kosovo	2			
Kyrgyzstan	5			
Latvia	21	2	6	1
Lebanon	18	18	18	
Lithuania	15		2	1
Luxembourg	11		1	1
Malta	36			
Moldova, Republic Of	32		80	7
Montenegro	5		1	2
Morocco	6	10	10	
Netherlands	28	2	8	1
North Macedonia	5	1		1
Norway	8		12	2
Palestine	7	17	17	
Poland	69	1	16	4
Portugal	138	15	51	22
Romania	144	2	48	20

Country	CoM 2020	Mayors Adapt	CoM 2030	CoM 2050
Serbia	12		3	3
Slovakia	13	2	27	
Slovenia	37	2	24	15
Spain	1833	22	1364	185
Sweden	62	1	17	3
Switzerland	11		1	1
Tajikistan	1			
Tunisia	3	12	12	
Türkiye	12	2	24	26
Ukraine	123	1	232	19
United Kingdom	45	6	12	6
Total	8248	294	4349	865

Source: JRC elaboration based on GCoM data

Table A2. Population covered by country and commitment

Country	CoM 2020	Mayors Adapt	CoM 2030	CoM 2050
Albania	1 199 450	915 850	978 350	208 600
Algeria	692 500			
Andorra				24 000
Armenia	1 486 485		1 697 569	
Austria	2 161 967	1 914 743	2 031 611	11 756
Azerbaijan	4 000		894 325	102 861
Belarus	1 084 364		3 854 979	
Belgium	7 934 755	2 502 790	9 679 332	1 218 693
Bosnia-herzegovina	1 751 845		1 772 069	157 286
Brazil				
Bulgaria	3 140 774	261 288	1 506 564	210 352
Croatia	2 009 539	24 998	1 597 664	274 689
Cyprus	526 492		154 284	7 000
Czechia	1 639 851		2 266 223	2 114 528
Denmark	3 470 444	718 120	351 963	460 768
Estonia	594 573	445 000	454 600	
Finland	2 061 897		2 248 859	76 850
France	19 211 295	1 336 022	10 624 347	10 980 513
Georgia	1 889 943		1 211 300	12 967
Germany	18 804 904	4 818 546	10 260 943	3 714 051
Greece	7 045 397	570 989	3 787 900	1 312 524
Hungary	3 050 886	64 078	6 567 905	1 170 780
Iceland	118 427		118 427	
Ireland	1 799 415	332 015	2 315 718	290 500
Israel	462 244	1 715 053	1 715 053	
Italy	45 140 322	2 951 835	23 671 379	4 363 970
Jordan	160 000	3 827 901	3 827 901	
Kazakhstan	2 621 055			
Kosovo	180 514			
Kyrgyzstan	294 900			
Latvia	1 131 739	66 257	283 858	650 640

Country	CoM 2020	Mayors Adapt	CoM 2030	CoM 2050
Lebanon	233 700	342 100	342 100	
Lithuania	1 467 009		65 805	87 590
Luxembourg	128 302		22 100	22 100
Malta	243 906			
Moldova Republic Of	1 591 529		1 027 340	82 505
Montenegro	273 822		15 697	45 031
Morocco	2 850 001	1 493 728	1 493 728	
Netherlands	4 964 707	749 271	669 852	29 022
North Macedonia	877 768	38 092		63 376
Norway	1 511 683		666 406	284 994
Palestine	1 104 466	1 085 233	1 085 233	
Poland	4 192 673	122 000	2 641 091	2 435 715
Portugal	6 469 455	913 342	4 073 804	874 251
Romania	8 703 543	69 041	4 594 056	1 076 769
Serbia	830 077		1 701 073	550 000
Slovakia	579 215	469 647	512 313	
Slovenia	885 558	13 700	354 327	133 910
Spain	30 636 987	5 479 357	21 263 071	6 560 252
Sweden	4 630 967	124 935	2 586 847	1 494 631
Switzerland	909 198		146 000	146 000
Tajikistan	30 000			
Tunisia	592 000	708 967	708 967	
Türkiye	10 605 567	590 204	19 673 983	22 479 787
Ukraine	14 051 711	98 953	12 042 347	1 494 553
United Kingdom	21 112 244	4 503 799	4 600 711	1 227 025
Total	251 146 065	39 267 854	174 159 974	66 450 839

Source: JRC elaboration based on GCoM data

Table A3. Overall commitment by 2030, based on submitted action plans per country

Country	Total emissions in BEI [t CO$_2$-eq/year]	Targeted emission in 2030 [t CO$_2$-eq/year]	Overall committed reduction by 2030
Albania	473 634	278 490	41%
Austria	105 392	53 714	49%
Belgium	41 578 974	22 848 931	45%
Bosnia-herzegovina	1 693 726	1 157 938	32%
Bulgaria	5 469 933	3 573 806	35%
Croatia	5 437 256	2 518 399	54%
Cyprus	640 630	398 708	38%
Czechia	12 636 437	6 955 653	45%
Denmark	7 048 582	1 248 686	82%
Estonia	481 660	329 766	32%
Finland	12 390 511	2 768 286	78%
France	24 143 271	12 649 581	48%
Germany	51 839 507	20 248 921	61%
Greece	19 501 055	8 513 782	56%
Hungary	18 305 184	9 517 755	48%
Iceland	272 938	72 141	74%
Ireland	13 636 123	8 725 004	36%
Italy	95 598 895	40 079 868	58%
Latvia	2 546 271	1 908 897	25%
Luxembourg	158 467	59 766	62%
Netherlands	37 726 458	15 321 027	59%
Norway	3 660 232	368 352	90%
Poland	21 273 366	13 590 676	36%
Portugal	15 193 005	6 028 941	60%
Romania	2 005 581	1 098 376	45%
Serbia	7 770 216	4 517 062	42%
Slovakia	1 035 314	593 089	43%
Slovenia	3 314 948	1 521 337	54%
Spain	70 291 776	28 300 622	60%
Sweden	6 737 618	1 307 159	81%
Switzerland	5 279 993	1 946 008	63%
Türkiye	73 550 938	69 400 925	6%
United Kingdom	122 470 482	8 810 884	93%

*Source: JRC elaboration based on GCoM data*

Annex 2. Statistical methodology

In this Annex 2, the brief explanation presented in Section 3.2.3 is extended, offering greater details on the statistical methods for the estimation and prediction of emissions for each signatory. Firstly, the base year is set to 2005, being the reference year for measuring the performance of the cities' mitigation actions. In this way, for cities reporting a base year earlier than 2005, the estimated emissions in 2005 are taken according to the linear equation between the city's reported baseline inventory and its last monitoring inventory (see Figure A1, the 2005 estimation of "city1"). Meanwhile, for cities with a base year occurring after 2005 (see Figure A1, for "city2"), their corresponding baseline emissions are adjusted according to f, which considers NE_{2005} y NE_{base}, as in

$$f = \frac{NE_{2005}}{NE_{base}}.$$

The models for estimating the cities' emissions in 2030 followed a machine learning methodology, minimizing the error over the last known value, as it will be explained below (see also Franco et al. 2022b). The input data for the development of the models consists in the cities' reported emissions for their baseline and the following monitoring inventories, projecting their emissions to 2030, as shown in Figure A1.

Figure A1. Picture of the statistical methodology for the estimation of the cities' emissions. Cities report their emission inventories (marked with o) for a given year, and their emissions are estimated for 2005 (marked with x) and forecasted to the target year (marked with +) of 2030.
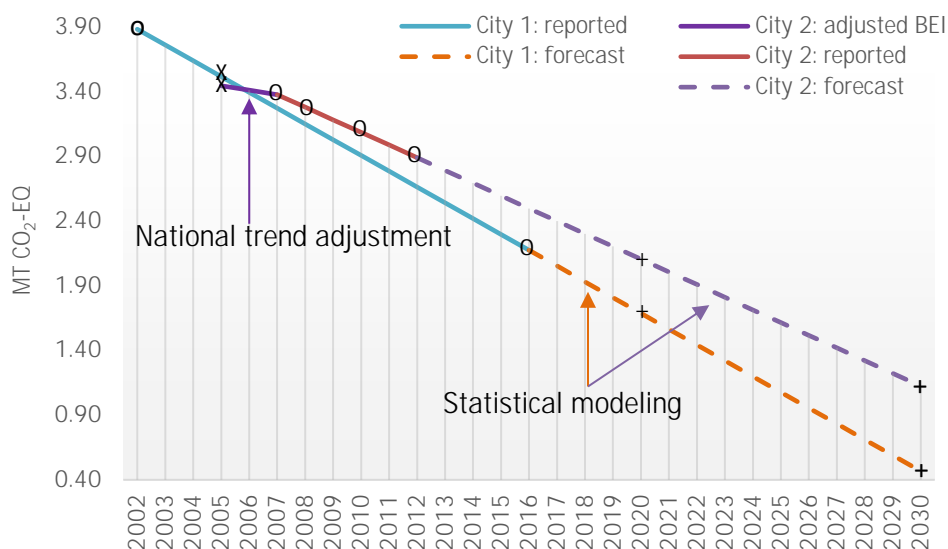
Source: Own elaboration

Therefore, each city has a sparse time series with a yearly frequency, being sparse because many years in between the base and the last monitoring years have missing values. Hence, firstly, the imputation of data is performed, building the yearly time series on which the algorithms can learn the stochastic process explaining their behaviour. This is done by continuing the linear trend between the years holding the known emissions values (see again Figure A1). Secondly, the best model is identified for each city (i), according to the minimum error ($error_i$) for the predicted value ($\hat{y}_{it}$), computed over the last known emissions value (y_{it}^*). This last known emissions value consists in the emissions value coming from the city's last MEI. This error was computed for each city, by

$$error_i = \frac{|\hat{y}_{it} - y_{it}^*|}{y_{it}^*}.$$

Therefore, the last known value is left out for validation, and the best model is identified that achieves the minimum prediction error. Then, the complete time series is fitted again under the same functional form of the identified model, and the corresponding prediction is taken for the cities' emissions in the target years.

Under this methodology, the time series are modelled after three different approaches. One approach consisted in a Double Exponential Smoothing (DES) (Box et al., 2016), characterizing the level and the trend of the series, according to

$$\hat{y}_{t+1} = L_t + T_t,$$

where L_t and T_t, respectively, stand for the smoothed level and trend of the time series. A second approach consists in an Auto-Regressive Integrated Moving Average process (Box et al.; 2016), commonly known as an ARIMA(p,d,q), implementing linear filters to characterize the series, in the form of

$$\hat{y}'_t = Z_t + \sum_{j=1}^{p} \phi_j y'_{t-j} + \sum_{j=1}^{q} \theta_j Z_{t-j},$$

where y' stands for the differentiated series to the order of d, and p and q respectively stand for the number of lagged observations and the number of standard-normal innovations included in the process. The ARIMA(p,d,q) models are validated by the Ljung--Box test (see again Box et al., 2016), checking that no significant correlation among the residuals is left unexplained.

The third and last approach to modelling the series consists in an auto-regressive feed-forward neural network with one hidden layer, estimating non-linear functions with a fair level of complexity (Hornik et al. 1989). This architecture is examined with different number of neurons, namely 3, 5, 7 or 10 neurons in the single hidden layer, receiving as input from 1 to 5 lagged observations (depending on the available data).

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