



Covenant of Mayors 2023 Energy figures

Achievements in energy savings and renewable energy generation

Franco De Los Rios, C., Hernandez Moral, G., Bezerra, P.,
Melica, G., Todeschi, V., Treville, A.

2024



This document is a publication by the Joint Research Centre (JRC), the European Commission's science and knowledge service. It aims to provide evidence-based scientific support to the European policymaking process. The contents of this publication do not necessarily reflect the position or opinion of the European Commission. Neither the European Commission nor any person acting on behalf of the Commission is responsible for the use that might be made of this publication. For information on the methodology and quality underlying the data used in this publication for which the source is neither Eurostat nor other Commission services, users should contact the referenced source. The designations employed **and the** presentation of material on the maps do not imply the expression of any opinion whatsoever on the part of the European Union concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries.

Contact information

Name: Giulia Melica
Address: TP 450 Via E. Fermi 2749 (Ispra, Italy)
Email: giulia.melica@ec.europa.eu
Tel.: +39 033278-9842

EU Science Hub

<https://joint-research-centre.ec.europa.eu>

JRC139210

EUR 40151

PDF ISBN 978-92-68-22799-2 ISSN 1831-9424 doi:10.2760/1828459 KJ-01-24-202-EN-N

Luxembourg: Publications Office of the European Union, 2024

© European Union, 2024



The reuse policy of the European Commission documents is implemented by the Commission Decision 2011/833/EU of 12 December 2011 on the reuse of Commission documents (OJ L 330, 14.12.2011, p. 39). Unless otherwise noted, the reuse of this document is authorised under the Creative Commons Attribution 4.0 International (CC BY 4.0) licence (<https://creativecommons.org/licenses/by/4.0/>). This means that reuse is allowed provided appropriate credit is given and any changes are indicated.

For any use or reproduction of photos or other material that is not owned by the European Union permission must be sought directly from the copyright holders.

Cover page illustration, © dreamscape-stock.adobe.com

How to cite this report: European Commission: Joint Research Centre, Franco De Los Rios, C., Hernandez Moral, G., Bezerra, P., Melica, G., Todeschi, V. and Treville, A., *Covenant of Mayors 2023 Energy figures*, Publications Office of the European Union, Luxembourg, 2024, <https://data.europa.eu/doi/10.2760/1828459>, JRC139210.

Contents

Abstract	2
Acknowledgements	3
1 Introduction.....	4
1.1 Energy data reported by local authorities	5
1.2 Analysed data and report structure.....	8
2 Energy consumption and savings in EU-27	10
2.1 BEI energy consumption.....	10
2.2 BEI energy supply	14
2.2.1 Local electricity production and purchases of renewable energy certificates	14
2.2.2 Local heat/cold production.....	16
2.3 Estimated energy savings and renewable energy production	17
2.3.1 Estimated savings	17
2.3.2 Estimated renewable energy production.....	19
2.4 MEI energy consumption.....	21
2.5 MEI energy supply.....	25
2.5.1 Local electricity production and purchases of renewable energy certificates	25
2.5.2 Local heat/cold production.....	27
2.6 Achievements in energy savings and renewable energy generation	28
2.6.1 Energy savings.....	28
2.6.2 Renewable energy production.....	30
3 Local policies accomplishing energy savings and renewable energy production	32
3.1 Local policies accomplishing energy savings	32
3.2 Local mitigation policies from GCoM signatories (MyCovenant+CDP).....	34
4 Conclusions.....	36
References	37
List of abbreviations and definitions	39
List of figures	40
List of tables.....	41
Annexes	42
Annex 1. Proportion of signatories with 2030 commitments by reporting platform and country	42
Annex 2. Methodology for forecasting energy consumption	44

Abstract

Local authorities are key players in addressing climate change. Since 2008, the European Commission 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 best practices to monitor and report on energy consumption and GHG emissions as well as on 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.

This report complements the Covenant of Mayors 2023 Assessment report (Melica et al., 2023), describing the CoM energy activity and estimated savings, based on data for local authorities in EU-27 with a 2030 commitment declared through the MyCovenant reporting platform, through the Baseline Emission Inventories (BEIs), Monitoring Emission Inventories (MEIs) and actions descriptions. It examines energy consumption and production and offers an overview on the progress made on energy savings and renewable energy generation. As a novelty, this data is complemented in this year's report with CDP-ICLEI track data for the analysis of actions on renewable energy generation.

Overall, fossil fuels have the greatest weight in total consumption, followed by electricity, and district heating and cooling with a low share. Lastly, the minimum share is that of renewable fuels, suggesting that the transition to a greener energy system still requires more time and additional efforts to achieve EU targets. In particular, the analysed data shows that non-renewable energy has the highest share, with 98.67%, representing almost the totality of the BEI heat/cold consumption for the local authorities reporting local heat/cold production. Meanwhile, the sector with the highest share in the reported consumption is stationary energy (especially the subsector of residential buildings), followed by transport, where private and commercial transport are especially significant.

Regarding local electricity production, the highest shares in the baseline emission inventories correspond to photovoltaics, whereas other sources such as combined heat and power (CHP), hydroelectric power, and wind power follow at a significant distance. Considering local heat/cold production, the highest shares correspond to district heating (heat only) and CHP, using mostly non-renewable energy sources and covering a high percentage of the entire heat/cold baseline consumption.

Based on the analysis of the (1 317) BEIs with reported data on estimated energy savings, signatories aim to achieve a reduction of 3.96 MWh/year per capita, mainly focused on the stationary and the transport sector. This is complemented by a renewable energy production estimation that focuses mainly on local electricity production and stationary energy, which would achieve 1.17 MWh/year per capita.

The key findings show that the energy savings that were accomplished by 639 signatories, looking at the difference between BEI and MEI, amount to 45.7 TWh/year, which correspond to 1.98 MWh/year per capita. On the other hand, the 174 signatories reporting data on renewable energy generation in their BEI and MEI, reported in BEI the production of 14.15 TWh/year (1.3 MWh/year per capita) and in MEI, 12.4 TWh/year (1.07 MWh/year per capita). Hence, on average, exceeding their renewable energy generation targets at the beginning of the implementation of their plans, but falling short as their implementation advanced according to their latest MEI.

When policies reported by local authorities are analysed, it can be observed that, in terms of numbers of actions, the main focus is placed on buildings (mainly linked to municipal buildings) and transport. With respect to the main action areas, the ones with the highest shares are efficient and electric vehicles, integrated actions, building envelope and efficiency, behavioural changes and efficient lighting systems. The most common instrument is awareness raising and training, and energy management. Renewable energy policies are mainly focused on the generation of electricity through hydropower, solar, wind and geothermal.

It should be acknowledged that the results presented in this document correspond to a broad yet not necessarily representative sample of local authorities in the EU. Therefore, conclusions cannot be generalised to the EU level.

Acknowledgements

Authors would like to thank the European Commission's Directorate-General for Energy (DG ENER) and Directorate-General for Climate Action (DG CLIMA) for their leadership and strategic guidance in the context of the Covenant of Mayors initiative.

Authors would also thank the Covenant of Mayors Office for taking care of relations with signatories, and in particular the IT team for managing the MyCovenant reporting platform and cooperating with the Joint Research Centre in order to continuously improve the data collection process.

1 Introduction

The European Union (EU) has committed to becoming the world's first climate-neutral continent by 2050¹. In this context, local authorities are key actors in the fight against climate change. According to the IPCC, urban areas can create opportunities to increase resource efficiency and mitigate greenhouse gas (GHG) emissions through the systemic transition of infrastructure and urban form towards net-zero emissions (IPCC, 2022). In fact, being the level of governance closest to citizens, 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 and urban settings.

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, 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 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.

The Sustainable Energy and Climate Action Plan (SECAP) is the key document to translate into climate action the vision of local authorities for both mitigation and adaptation to climate change. Detailed methodological guidance on how to develop a SECAP (Bertoldi, 2018) as well as guidelines on how to report the SECAP², covering both mitigation and adaptation, are publicly available in the Common Reporting Framework (GCoM, 2018). Besides, the energy poverty pillar has been recently launched and is now publicly available (GCoM, 2022). Some key requirements of the initiative are briefly illustrated hereafter.

Within two years of signing up to the initiative, local authorities have to approve and submit their SECAP. Such a 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. On 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. On the adaptation pillar, the SECAP includes the assessment of climate risks and vulnerabilities within the territory³, the definition of at least one adaptation goal, and a set of actions (including at least three key actions) to increase the resilience of the critical sectors and vulnerable groups.

Therefore, a local authority willing to develop a climate mitigation plan should start by developing a Baseline Emission Inventory (BEI), standing as the reference against which the achievements of the emission reductions in the target year can be measured. The BEI quantifies the level of GHG emissions in a base year according to a common methodological approach (Bertoldi, 2018), identifying the main emitting sectors and consequently prioritising areas for action. Following the SECAP submission, local authorities should present, ideally every two years, a monitoring report with its corresponding monitoring emission inventory (MEI), enabling to follow the performance of their proposed actions according to their declared ambitions.

This report on *Energy Figures* complements the Covenant of Mayors 2023 Assessment report (Melica et al., 2023), which presents an overview of the status of the initiative in relation to the mitigation and adaptation pillars, and is also based on the fourth release of the GCoM 2023 data set (Baldi et al., 2023). This report presents key energy figures and actions for European local authorities reporting their energy activity inventories,

² Covenant of Mayors Office. (2020). Reporting guidelines.
<https://eu-mayors.ec.europa.eu/en/home?task=download&id=815>

including energy consumption and energy supply, and their estimates on energy savings and energy production by the target year 2030 for each one of the sectors targeted by their action plans, as long as the sectors are consistently reported on throughout their inventories. The distribution of signatories by EU-27 Member State is presented in Annex 1.

It should be acknowledged that the results presented in this document correspond to a broad yet not necessarily representative sample of local authorities in the EU. Therefore, conclusions cannot be generalised to the EU level.

1.1 Energy data reported by local authorities

As far as energy data are concerned, MyCovenant template requires signatories to report final energy consumption (activity data) for their baseline emission inventory and subsequent monitoring emission inventories years. These data are then multiplied by the appropriate emission factors (also reported by local authorities) to obtain the level of emissions in various sectors. Signatories are also requested to report energy generation data, which are not accounted for in the total emissions, but are used to calculate emission factors for grid supplied energy (i.e., electricity and district heating/cooling). Finally, local authorities are requested to report estimated energy savings and renewable energy production by the target year for each relevant sector/subsector and for the key mitigation actions of their action plan.

Final energy consumption is reported for the following carriers:

- Electricity
- District heating and cooling
- Fossil fuels, further split into:
 - Natural gas
 - Liquid gas
 - Heating oil
 - Diesel
 - Gasoline Lignite
 - Coal
 - Other fossil fuels
- Renewable energies, further split into:
 - Plant oil
 - Biofuel
 - Other biomass
 - Solar thermal
 - Geothermal
 - Biogas
 - For the sake of simplicity, in this report non-grid-supplied energy is grouped under fossil fuels and renewable energies.

Additionally, final energy consumption data are reported for the following main sectors and subsectors:

- Stationary Energy / Buildings:
 - Municipal buildings, equipment/facilities
 - Public lighting

- Tertiary buildings, equipment/facilities
- Residential buildings
- Industries
- Agriculture/Forestry/Fisheries
- Transport:
 - Municipal fleet
 - Public transport
 - Private and commercial transport

Energy supply data are reported according to the following structure:

- Certified green electricity:
 - Purchases Guarantees of Origins (within the municipality boundaries)
 - Sales Guarantees of Origins (within the municipality boundaries)
- Local/distributed electricity production (Renewable energy only):
 - Wind
 - Hydroelectric
 - Photovoltaics
 - Geothermal
 - Other
- Local/distributed electricity production:
 - Combined Heat and Power
 - Other (ETS and large-scale plants > 20 MW not recommended)
- Local heat/cold production:
 - Combined Heat and Power
 - District heating (heat-only)
 - Other

Estimated energy savings and renewable energy production by the target year are reported for the following mitigation sectors/subsectors (when relevant):

- Municipal buildings, equipment/facilities
- Tertiary (non-municipal) buildings, equipment/facilities
- Residential buildings
- Industry
- Transport
- Waste
- Local Electricity Production
- Local Heat/Cold Production
- Others

In this context, it is worth to note that there are four sectors classified as key: municipal buildings, tertiary (non-municipal) buildings³, residential buildings and transport. According to the Covenant Guidelines, local authorities have to assess at least three out of four key sectors in their BEIs/MEIs; and ensure that their actions address at least two key sectors. For this reason, these sectors are better represented in the data reported by the local authorities, where for instance waste assessments are sometimes lacking. This insight can contribute in interpreting the presented results and available data.

It is also worth to note that in this report the data from My Covenant platform has been expanded with CDP–ICLEI Track data, in particular, to analyse the accomplishments of the local authorities in renewable energy generation (see section 3.2). Due to the differences in the information elicited by the local authorities in both reporting platforms along the years (especially for CDP, where the most recent questionnaires lack detailed energy consumption on fossil or renewable energy carriers), it has not been feasible to fully combine both datasets for assessing the signatories' accomplishments on energy savings. Nonetheless, whenever the fusion among both was possible (dealing with renewable energy production), whenever a city reported in both platforms (as local authorities are free to choose to report both in MyCovenant as well as in CDP-ICLEI Track) the latest available data has been chosen for the analysis. Further information on the formats that the local authorities use to report this data can be found in the following links: [MyCovenant](#) and [CDP-ICLEI Track](#). The following section showcases the available data processed in this report.

³ Tertiary buildings refer to buildings used for services (e.g. offices of private companies, banks, commercial and retail activities, private schools, hospitals, etc.). Local authorities should report all final energy consumption due to operation (e.g. electricity for pumping, natural gas for heating, etc.) of private water supply system, solid waste and wastewater treatment and disposal facilities.

1.2 Analysed data and report structure

The following available data from EU-27 signatories with a 2030 commitment has been analysed in this report in each of the corresponding sections.

Table 1. EU-27 signatories with 2030 commitments: analysed data, number of signatories and population

Analysed data	Number of signatories		Population (million)		Section	Comments on data considered
	BEI	MEI	BEI	MEI		
BEI and MEI analyses						
Energy consumption	1 565	639	58.42	33.28	2.1 [BEI] & 2.4 [MEI]	Based on energy consumption reported in the inventories (in the BEI or MEI, as applicable)
Energy supply	-	-	-	-	2.2 [BEI] & 2.5 [MEI]	The energy supply is reported in MyCovenant in the BEI and MEI in three different sections (local electricity production, purchases of RES certificates, and local heat/cold production). Local authorities could, for instance, report local electricity production, but not report any local heat/cold production. Therefore, the 121 signatories reporting RES certificates in the BEI do not necessarily represent a subgroup of the 531 signatories reporting local electricity production in the BEI. Also, the 390 signatories reporting local electricity production in the MEI might not have reported the same information in the BEI (thus, they might not be accounted for within the 531). This explains the significant deviations in the population values.
Local electricity production	531	390	25.88	24.01	2.2.1 [BEI] & 2.5.1 [MEI]	
Purchases of renewable energy certificates	121	112	4.05	10.22	2.2.1 [BEI] & 2.5.1 [MEI]	
Local heat/cold production	40	22	6.76	4.61	2.2.2 [BEI] & 2.5.2 [MEI]	
Estimated energy savings and renewable energy production	1 317	-	45.7	-	2.3	Signatories report in MyCovenant, within My Actions Overview, the estimated savings and renewable energy production they aim at achieving in the target year. Only BEIs are considered, as here is where the “targets” are established.
Achieved energy savings and renewable energy production	-	-	-	-	-	Based on the comparison of MEIs and corresponding BEIs it is possible to analyse the achievements in energy savings and renewable energy production. Thus, the same signatories are

Achievements in energy savings	441	22.5	23.86	2.6.1	considered in the BEIs as in the MEIs. Population differs as signatories update the value in the MEI to the population in the MEI reporting year.
Renewable energy production	174	10.9	11.5	2.6.2	
Policies analyses					
Policies achieving impact on savings	465	22.43	23.04	3.1	Based on the subset of EU-27 signatories achieving energy savings according to their annual savings rate. The annual savings rate is computed from the BEI and MEI, such as the sample of signatories considered here are those accomplishing a positive savings rate.
*Renewable energy generation	*1 400	*82.63		3.2	Data analysed in this section includes not only MyCovenant data from 1317 signatories achieving energy savings or producing renewable energy, but is also complemented with 83 signatories reporting on CPD ICLEI-Track.

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

As it can be observed from the above table, there are significant variations in the number of plans that can be analysed depending on how many local authorities have reported determined concepts. For instance, while data on energy consumption is available in all local authorities' reported data, only around a third of them report on local energy production.

2 Energy consumption and savings in EU-27

In this section, the analysis focuses on EU-27 signatories with a commitment for the target year of 2030.

2.1 BEI energy consumption

Considering signatories in EU-27 with 2030 commitments, there are 1 565 signatories with a BEI, representing 58.42 million inhabitants, reporting a total of 967.24 TWh/year. It can be seen that the type of energy carrier associated with the greatest share of total consumption corresponds to fossil fuels (67.81%), followed by electricity (24.29%), while the sector carrying the highest share of energy consumption is residential buildings (34.27%), followed by private and commercial transport (27.40%). See Tables 2-4 for the absolute, percentage and per capita values, respectively, and Figures 1-2 for the visualisation of the shares for the most significant sectors and fuel sources, respectively.

Examining the per capita consumption, it is informative to recognize that fossil fuels represent the maximum consumption value, with 11.22 MWh/year per capita, while renewable fuels have the lowest value, with 0.40 MWh/year per capita. Focusing on the activity sectors, residential buildings have the highest consumption value of 5.67 MWh/year per capita, followed by private and commercial transport, with 4.54 MWh/year per capita; while other sectors, such as municipal buildings, industry-ETS (not recommended for reporting in the CoM context), municipal fleet, public transport, and agriculture, forestry and fisheries all have a per capita consumption less than 1 MWh/year.

Table 2. Energy consumption reported in BEIs related to 2030 commitments – EU-27 (units TWh/year)

Sector / Sub-sector	Electricity	District heating and cooling	Fossil fuels	Renewable fuels	TOTAL	SHARE
Municipal buildings, equipment/facilities	11.1142	2.4959	8.2079	0.0905	21.9085	2.27%
Residential buildings	78.9165	30.8227	205.3619	16.3863	331.4875	34.27%
Tertiary (non- municipal) buildings, equipment/facilities	79.4868	12.4531	74.2932	2.6286	168.8617	17.46%
Industry Non-ETS	50.4878	5.2215	64.2011	1.3157	121.2261	12.53%
Industry-ETS	1.6779		8.6082	0.0059	10.2919	1.06%
Buildings, equipment/facilities non-allocated	4.8958	0.0739	1.4059	0.0177	6.3932	0.66%
Subtotal - Stationary energy	226.5791	51.0671	362.0782	20.4446	660.1690	68.25%
Municipal fleet	0.0031		3.1605	0.1050	3.2686	0.34%
Public transport	3.3840		10.8990	0.2050	14.4880	1.50%
Private and commercial transport	2.7977		259.6070	2.6206	265.0253	27.40%
Transport non- allocated	0.1963		13.4332	0.0436	13.6731	1.41%
Subtotal - Transport	6.3811		287.0997	2.9742	296.4551	30.65%
Agriculture, Forestry, Fisheries	1.5401	1.4090	6.2154	0.0685	9.2329	0.95%
Other non-allocated	0.4839	0.3986	0.5026	0.0007	1.3857	0.14%
Subtotal - Other	2.0239	1.8076	6.7180	0.0691	10.6187	1.10%
TOTAL	234.9842	52.8747	655.8959	23.4879	967.2427	
SHARE	24.29%	5.47%	67.81%	2.43%	24.29%	5.47%

Source: JRC elaboration based on GCoM data

Table 3. Energy consumption reported in BEIs related to 2030 commitments – EU-27 (units %)

Sector / Sub-sector	Electricity	District heating and cooling	Fossil fuels	Renewable fuels	TOTAL
Municipal buildings, equipment/facilities	1.15%	0.26%	0.85%	0.01%	2.27%
Residential buildings	8.16%	3.19%	21.23%	1.69%	34.27%
Tertiary (non-municipal) buildings, equipment/facilities	8.22%	1.29%	7.68%	0.27%	17.46%
Industry Non-ETS	5.22%	0.54%	6.64%	0.14%	12.53%
Industry-ETS	0.17%		0.89%	0.00%	1.06%
Buildings, equipment/facilities non-allocated	0.51%	0.01%	0.15%	0.00%	0.66%
Subtotal - Stationary energy	23.43%	5.28%	37.43%	2.11%	68.25%
Municipal fleet	0.00%		0.33%	0.01%	0.34%
Public transport	0.35%		1.13%	0.02%	1.50%
Private and commercial transport	0.29%		26.84%	0.27%	27.40%
Transport non-allocated	0.02%		1.39%	0.00%	1.41%
Subtotal - Transport	0.66%	0.00%	29.68%	0.31%	30.65%
Agriculture, Forestry, Fisheries	0.16%	0.15%	0.64%	0.01%	0.95%
Other non-allocated	0.05%	0.04%	0.05%	0.00%	0.14%
Subtotal - Other	0.21%	0.19%	0.69%	0.01%	1.10%
TOTAL	24.29%	5.47%	67.81%	2.43%	

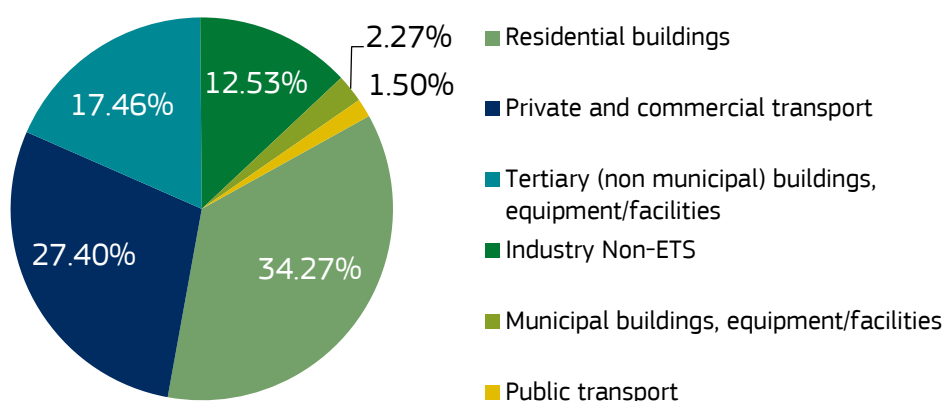
Source: JRC elaboration based on GCoM data

Table 4. Energy consumption pc reported in BEIs related to 2030 commitments – EU-27 (units MWh/year per capita)

Sector / Sub-sector	Electricity	District heating and cooling	Fossil fuels	Renewable fuels	TOTAL
Municipal buildings, equipment/facilities	0.1902	0.0427	0.1405	0.0015	0.3750
Residential buildings	1.3508	0.5276	3.5152	0.2805	5.6742
Tertiary (non-municipal) buildings, equipment/facilities	1.3606	0.2132	1.2717	0.0450	2.8904
Industry Non-ETS	0.8642	0.0894	1.0989	0.0225	2.0751
Industry-ETS	0.0287		0.1473	0.0001	0.1762
Buildings, equipment/facilities non-allocated	0.0838	0.0013	0.0241	0.0003	0.1094
Subtotal - Stationary energy	3.8784	0.8741	6.1978	0.3500	11.3003
Municipal fleet	0.0001		0.0541	0.0018	0.0559
Public transport	0.0579		0.1866	0.0035	0.2480
Private and commercial transport	0.0479		4.4438	0.0449	4.5365
Transport non-allocated	0.0034		0.2299	0.0007	0.2340
Subtotal - Transport	0.1092	0.0000	4.9144	0.0509	5.0745
Agriculture, Forestry, Fisheries	0.0264	0.0241	0.1064	0.0012	0.1580
Other non-allocated	0.0083	0.0068	0.0086	0.0000	0.0237
Subtotal - Other	0.0346	0.0309	0.1150	0.0012	0.1818
TOTAL	4.0223	0.9051	11.2271	0.4020	16.5565

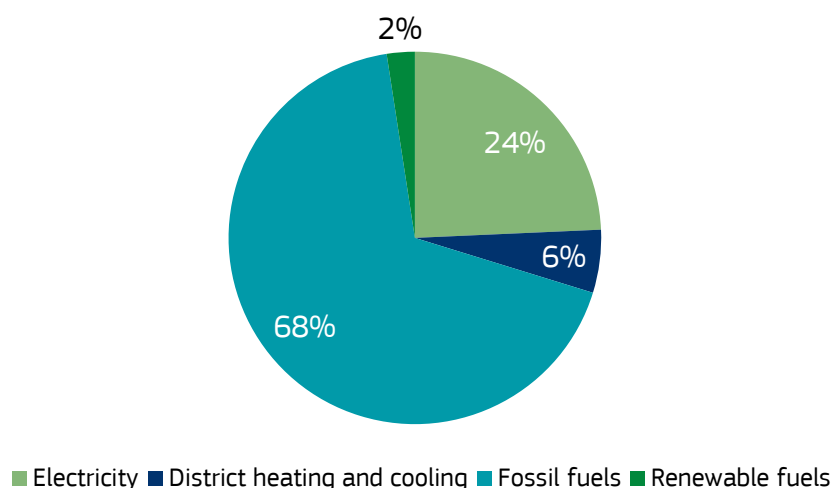
Source: JRC elaboration based on GCoM data

Figure 1. Shares of final energy consumption by sector reported in BEIs



Source: JRC elaboration based on GCoM data

Figure 2. Shares of final energy consumption by carrier reported in BEIs



Source: JRC elaboration based on GCoM data

2.2 BEI energy supply

Examining the reported energy supply from the signatories having reported a BEI, there are 531 signatories covering a population of 25.88 million having also reported local electricity production, 40 signatories (6.76 million inhabitants) having reported local heat/cold production and 121 signatories (4.05 million inhabitants) having reported purchases of renewable energy certificates.

2.2.1 Local electricity production and purchases of renewable energy certificates

The highest share of local electricity production corresponds to photovoltaics, with 74.13% of the total reported local electricity production. See Table 5 for the complete description of the total production by technology. Furthermore, renewable energy technologies have the highest share in total production, with 87.36% and represent 27.36% of the BEI electricity consumption for the local authorities reporting local electricity production. It is worth to note that for “electricity only” plants, the CoM guidebook recommends reporting only plants <20MW (see table 5 of the guidebook part II), which might explain the very low share. In per capita terms, see Table 6, the reported local electricity production amounts to 0.18 and 1.28 MWh/year for non-renewable and renewable technologies, respectively. Figure 3 shows the shares of the most representative electricity production sources and technologies.

Lastly, examining purchases of renewable energy certificates, there are 121 signatories reporting purchases (4.05 million inhabitants). These signatories come mainly from Belgium (80%), Italy (11%), Spain (3%) and France (2%). For all of these signatories, they report a total of 1.067 TWh/year in purchases, representing 3.79% of their total BEI electricity consumption. In per capita terms, the purchases amount to 0.26 MWh/year per capita.

Table 5. Local electricity production in BEIs related to 2030 commitments – EU-27 (units TWh/year)

Energy production technology	Non- renewable	Renewable	TOTAL	SHARE
Photovoltaics		28.2902	28.2902	74.13%
Wind		1.2742	1.2742	3.34%
Hydroelectric		3.2641	3.2641	8.55%
Geothermal		0.0124	0.0124	0.03%
Local electricity production plants - Combined Heat and Power	4.5548	0.4267	4.9815	13.05%
Local electricity production plants - Other	0.2688	0.0699	0.3388	0.89%
TOTAL	4.8236	33.3375	38.1611	
SHARE OF TOTAL ELECTRICITY PRODUCTION	12.64%	87.36%		
SHARE OF TOTAL ELECTRICITY CONSUMPTION*	2.05% (4.00%)	14.19% (27.63%)		

*Compared to the total electricity consumption in BEI (only for local authorities reporting local electricity production)

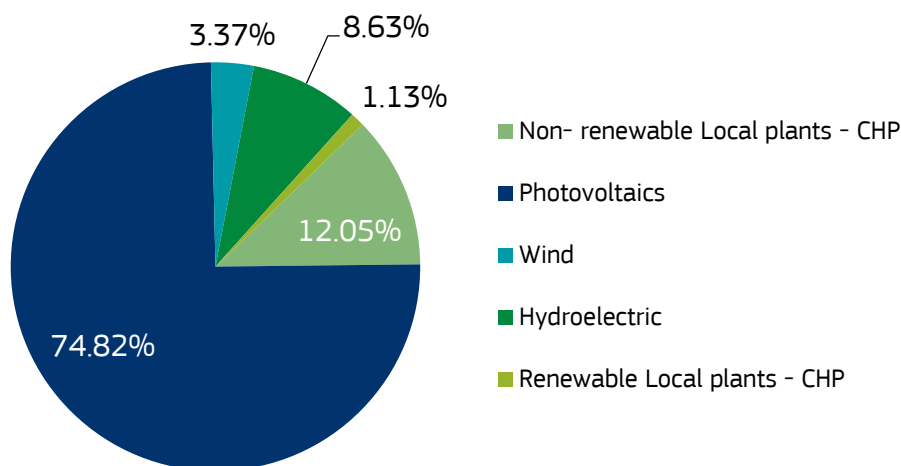
Source: JRC elaboration based on GCoM data

Table 6. Local electricity production in BEIs related to 2030 commitments – EU-27 (units MWh/year per capita)

Energy production technology	Non- renewable	Renewable	TOTAL
Photovoltaics		1.0931	1.0931
Wind		0.0492	0.0492
Hydroelectric		0.1261	0.1261
Geothermal		0.0005	0.0005
Local electricity production plants - Combined Heat and Power	0.1760	0.0165	0.1925
Local electricity production plants - Other	0.0104	0.0027	0.0131
TOTAL	0.1864	1.2881	1.4745

Source: JRC elaboration based on GCoM data

Figure 3. Shares of local electricity production by technology, reported in BEIs related to 2030 commitments – EU-27



Source: JRC elaboration based on GCoM data

2.2.2 Local heat/cold production

There are 40 local authorities that have reported local heat/cold production, corresponding to 6.76 million inhabitants. Considering local heat/cold supply, the highest share of local heat/cold production corresponds to district heating (heat only), with 59.98% of the total reported local heat/cold production, followed by combined heat and power (CHP), with 39.87%. See Table 7 for the complete description of the total production by technology. Furthermore, comparing non-renewable with renewable energy technologies, non-renewable energy has the highest share, with 98.67%, representing almost the totality of the BEI heat/cold consumption for the local authorities reporting local heat/cold production. As shown in Table 8, the per capita production with non-renewable fuels amounts to 1.90 MWh/year.

Figure 4 shows the shares of the most representative heat/cold production sources and technologies.

Table 7. Local heat/cold production in BEIs related to 2030 commitments – EU-27 (units TWh/year)

Energy production technology	Non- renewable	Renewable	TOTAL	SHARE
Local heat/cold production plants - Combined Heat and Power	5.2087		5.2087	39.87%
Local heat/cold production plants - District heating (heat-only)	7.6617	0.1731	7.8348	59.98%
Local heat/cold production plants – Other	0.0188	0.0003	0.0191	0.15%
TOTAL	12.8892	0.1734	13.0625	
SHARE ON TOTAL HEAT/COLD PRODUCTION	98.67%	1.33%		
SHARE ON TOTAL HEAT/COLD CONSUMPTION*	24.38% (85.63%)	0.33% (1.15%)		

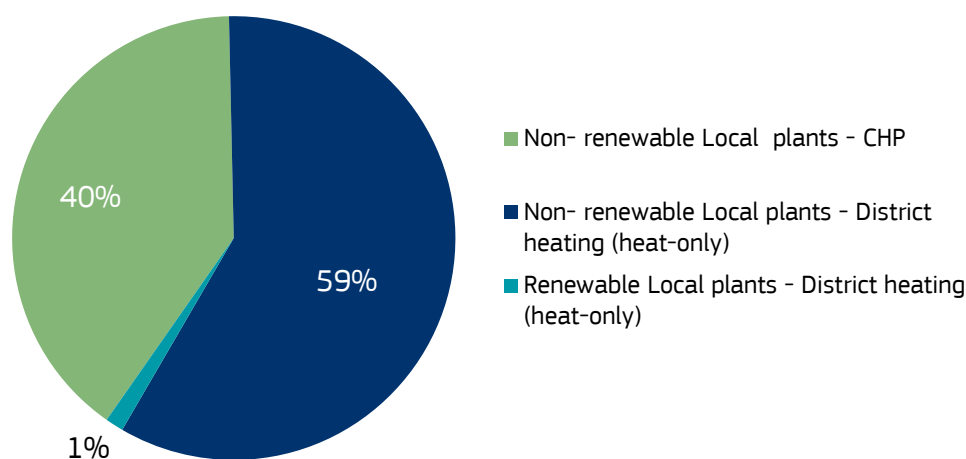
* Compared to the total heat/cold consumption in BEI (only for local authorities reporting local heat/cold production)

Source: JRC elaboration based on GCoM data

Table 8. Local heat/cold production in BEIs related to 2030 commitments – EU-27 (units MWh/year per capita)

Energy production technology	Non- renewable	Renewable	TOTAL
Local heat/cold production plants – Combined Heat and Power	0.7701		0.7701
Local heat/cold production plants – District heating (heat-only)	1.1327	0.0256	1.1583
Local heat/cold production plants – Other	0.0028	0.0000	0.0028
TOTAL	1.9056	0.0256	1.9312

Source: JRC elaboration based on GCoM data

Figure 4. Shares of local heat/cold production by energy source and technology, reported in BEIs related to 2030 commitments – EU-27

Source: JRC elaboration based on GCoM data

2.3 Estimated energy savings and renewable energy production

Signatories are asked to report their estimates on energy savings and energy production by the target year, for each sector targeted by their action plan. Out of the 1565 signatories that reported a BEI, 1317 also reported some estimated energy savings and renewable energy production.

2.3.1 Estimated savings

The highest share of estimated savings corresponds to stationary energy, with 58.70% of the total estimated savings, followed by transport (32.80%). The details can be seen in Table 9. The total savings represent 22.96% of the reported consumption for these signatories (comparing the total consumption in BEI, only for local authorities having declared either energy savings or energy production by the target year). In total, as presented in Table 10, signatories estimated that they would have been able to save, on average, 3.96 MWh/year per capita, by 2030. Figure 5 shows the shares of each activity sector in the total estimated savings.

Table 9. Estimated energy savings by 2030 declared by signatories – EU-27 (units TWh/year)

Sector	Estimated energy savings	SHARE
Stationary energy (includes, Municipal buildings, Lighting, Residential buildings, Tertiary buildings, Industry)	106.6371	58.70%
Transport	59.5866	32.80%
Local electricity production	1.4186	0.78%
Local heat/cold production	10.4264	5.74%
Other	3.5870	1.97%
TOTAL	181.6557	

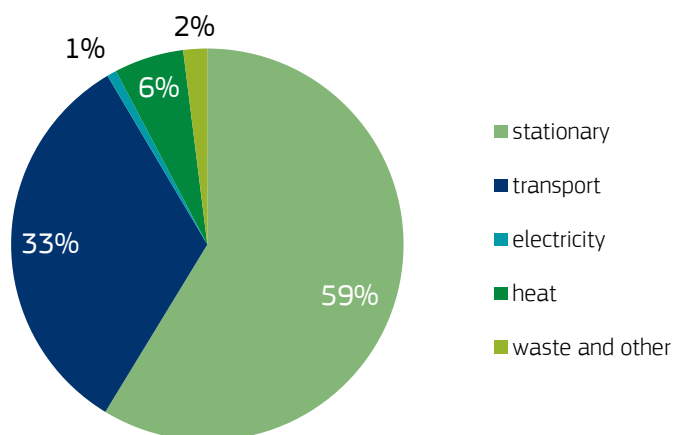
Source: JRC elaboration based on GCoM data

Table 10. Estimated energy savings by 2030 declared by signatories – EU-27 (units MWh/year per capita)

Sector	Estimated energy savings
Stationary energy (includes, Municipal buildings, Lighting, Residential buildings, Tertiary buildings, Industry)	2.3293
Transport	1.3016
Local electricity production	0.0310
Local heat/cold production	0.2277
Other	0.0784
TOTAL	3.9679

Source: JRC elaboration based on GCoM data

Figure 5. Shares of estimated savings by sector reported in in BEIs related to 2030 commitments – EU-27



Source: JRC elaboration based on GCoM data

2.3.2 Estimated renewable energy production

The highest share of renewable energy production corresponds to the local electricity production, 50.06%, followed by stationary energy reaching almost 30% of the total estimated renewable energy production. To understand these values, it should be noted that local authorities should report estimates related to solar thermal and geothermal for heat production under the stationary energy sector, whereas electricity production should be reported under “local electricity production”. The details can be seen in Table 11. The total renewable energy production represents 6.80% of the reported consumption for these signatories (comparing the total consumption in BEI, only for local authorities having declared either energy savings or energy production by the target year). In total, as presented in Table 12, signatories estimate that they will be able to produce, on average, 1.17 MWh/year of renewable energy per capita, by 2030.

Figure 6 shows the shares of each activity sector in the total estimated renewable energy production.

Table 11. Estimated renewable energy production by 2030 declared by signatories – EU-27 (units TWh/year).

Sector	Estimated renewable energy production	SHARE
Stationary energy (includes, Municipal buildings, Lighting, Residential buildings, Tertiary buildings, Industry)	15.9125	29.58%
Transport	1.6042	2.98%
Local electricity production	26.9278	50.06%
Local heat/cold production	8.5361	15.87%
Other	0.8075	1.50%
TOTAL	53.7881	

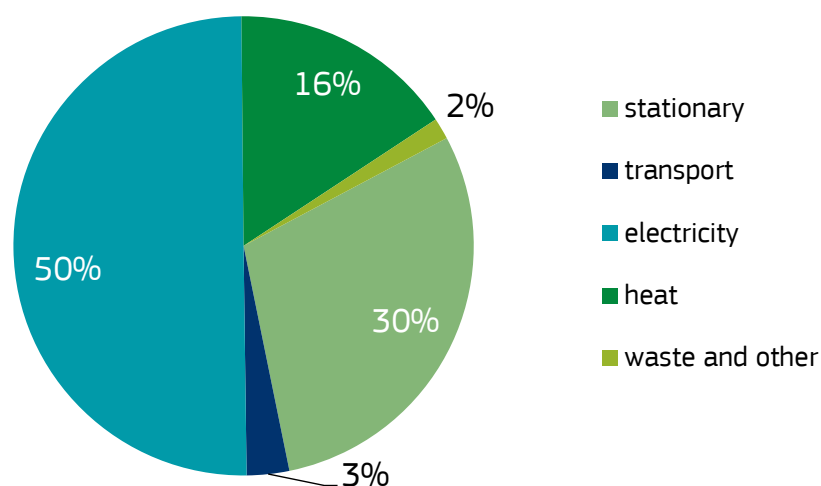
Source: JRC elaboration based on GCoM data

Table 12. Estimated renewable energy production by 2030 declared by signatories – EU-27 (units MWh/year per capita)

Sector	Estimated production	renewable energy
Stationary energy (includes, Municipal buildings, Lighting, Residential buildings, Tertiary buildings, Industry)	0.3476	
Transport	0.0350	
Local electricity production	0.5882	
Local heat/cold production	0.1865	
Other	0.0176	
TOTAL	1.1749	

Source: JRC elaboration based on GCoM data

Figure 6. Shares of estimated renewable energy production by sector, reported in BEIs related to 2030 commitments – EU-27



Source: JRC elaboration based on GCoM data

2.4 MEI energy consumption

Following the BEI, signatories should monitor the performance of their action plans in the subsequent years, and generate their corresponding Monitoring Emission Inventories (MEI). Nonetheless, due to different reasons, not all of them comply with this requirement. There are 639 action plans having a reported MEI, representing 33.28 million inhabitants. For monitoring reports, the type of fuel with the greatest total share of consumption is fossil fuels (63.81%), followed by electricity (25.86%). Thus, there is a slight decrease in terms of fossil fuels (-4%) and a slight increase in terms of electricity (+1.57%) consumption, when comparing the MEI against the BEI. Additionally, the sector with the highest share in the reported energy consumption is residential buildings (32.23%), followed by private and commercial transport (25.61%). See Tables 12-14 for the absolute, percentage and per capita values, respectively, of the energy consumption reported in MEIs, and Figures 7-8 for the visualisation of the shares for the most significant sectors and fuel sources, respectively.

Examining the per capita consumption, it can be highlighted that fossil fuels represent the maximum consumption value, with 9.29 MWh/year per capita, 1.93 MWh/year less than the average consumption of local authorities declared in the BEIs. On the other hand, renewable fuels have the lowest value, with 0.41 MWh/year per capita. Meanwhile, for the sectors, residential buildings have the highest consumption value, with 4.69 MWh/year per capita, followed by private and commercial transport, having 3.73 MWh/year per capita, as opposed to other sectors, such as municipal buildings, industry-ETS, municipal fleet, public transport, and agriculture, forestry and fisheries, that have a consumption lower than 1 MWh/year per capita. Overall, the situation depicted in the MEIs is very much in line with what was reported in the BEIs, with respect to both the shares for types of fuel and sectors, as well as for the per capita consumption, suggesting that the transition to a greener energy future still requires additional efforts to achieve EU targets.

Table 13. Energy consumption reported in MEIs related to 2030 commitments – EU-27 (units TWh/year)

Sector / Sub-sector	Electricity	District heating and cooling	Fossil fuels	Renewable fuels	TOTAL	SHARE
Municipal buildings, equipment/facilities	5.4091	2.0241	3.3174	0.1237	10.8743	2.24%
Residential buildings	41.2378	20.4094	86.2571	8.3450	156.2494	32.23%
Tertiary (non- municipal) buildings, equipment/facilities	48.4539	8.6656	33.7387	0.8430	91.7013	18.92%
Industry Non-ETS	26.7044	4.6924	35.6342	0.6919	67.7229	13.97%
Industry-ETS	0.7944		11.4762		12.2706	2.53%
Buildings, equipment/facilities non-allocated	0.0369	0.0353	0.1508	0.0234	0.2463	0.05%
Subtotal - Stationary energy	122.6365	35.8267	170.5745	10.0270	339.0648	69.94%
Municipal fleet	0.0255		1.8126	0.0469	1.8850	0.39%
Public transport	1.8005		9.9076	0.2482	11.9563	2.47%
Private and commercial transport	0.1848		120.7206	3.2561	124.1615	25.61%
Transport non- allocated	0.1537		3.7019	0.2968	4.1524	0.86%
Subtotal - Transport	2.1645		136.1427	3.8480	142.1553	29.32%
Agriculture, Forestry, Fisheries	0.4707	0.3030	2.4237	0.0579	3.2553	0.67%
Other non-allocated	0.1031		0.1962	0.0000	0.2994	0.06%
Subtotal - Other	0.5738	0.3030	2.6199	0.0579	3.5547	0.73%
TOTAL	125.3749	36.1298	309.3372	13.9330	484.7748	
SHARE	25.86%	7.45%	63.81%	2.87%		

Source: JRC elaboration based on GCoM data

Table 14. Energy consumption reported in MEIs related to 2030 commitments – EU-27 (units %)

Sector / Sub-sector	Electricity	District heating and cooling	Fossil fuels	Renewable fuels	TOTAL
Municipal buildings, equipment/facilities	1.12%	0.42%	0.68%	0.03%	2.24%
Residential buildings	8.51%	4.21%	17.79%	1.72%	32.23%
Tertiary (non-municipal) buildings, equipment/facilities	10.00%	1.79%	6.96%	0.17%	18.92%
Industry Non-ETS	5.51%	0.97%	7.35%	0.14%	13.97%
Industry-ETS	0.16%		2.37%		2.53%
Buildings, equipment/facilities non-allocated	0.01%	0.01%	0.03%	0.00%	0.05%
Subtotal - Stationary energy	25.30%	7.39%	35.19%	2.07%	69.94%
Municipal fleet	0.01%		0.37%	0.01%	0.39%
Public transport	0.37%		2.04%	0.05%	2.47%
Private and commercial transport	0.04%		24.90%	0.67%	25.61%
Transport non-allocated	0.03%		0.76%	0.06%	0.86%
Subtotal - Transport	0.45%	0.00%	28.08%	0.79%	29.32%
Agriculture, Forestry, Fisheries	0.10%	0.06%	0.50%	0.01%	0.67%
Other non-allocated	0.02%		0.04%	0.00%	0.06%
Subtotal - Other	0.12%	0.06%	0.54%	0.01%	0.73%
TOTAL	25.86%	7.45%	63.81%	2.87%	

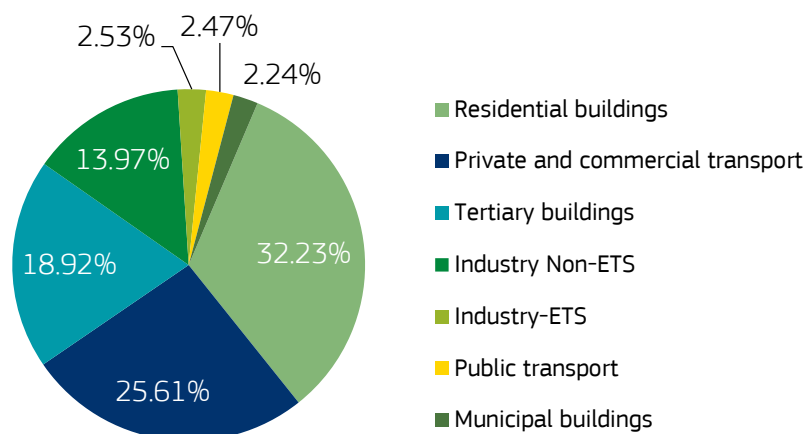
Source: JRC elaboration based on GCoM data

Table 15. Energy consumption reported in MEIs related to 2030 commitments – EU-27 (units MWh/year per capita)

Sector / Sub-sector	Electricity	District heating and cooling	Fossil fuels	Renewable fuels	TOTAL
Municipal buildings, equipment/facilities	0.1625	0.0608	0.0997	0.0037	0.3267
Residential buildings	1.2389	0.6131	2.5914	0.2507	4.6941
Tertiary (non-municipal) buildings, equipment/facilities	1.4557	0.2603	1.0136	0.0253	2.7549
Industry Non-ETS	0.8023	0.1410	1.0705	0.0208	2.0346
Industry-ETS	0.0239		0.3448		0.3686
Buildings, equipment/facilities non-allocated	0.0011	0.0011	0.0045	0.0007	0.0074
Subtotal - Stationary energy	3.6843	1.0763	5.1245	0.3012	10.1863
Municipal fleet	0.0008		0.0545	0.0014	0.0566
Public transport	0.0541		0.2976	0.0075	0.3592
Private and commercial transport	0.0056		3.6267	0.0978	3.7301
Transport non-allocated	0.0046		0.1112	0.0089	0.1247
Subtotal - Transport	0.0650	0.0000	4.0901	0.1156	4.2707
Agriculture, Forestry, Fisheries	0.0141	0.0091	0.0728	0.0017	0.0978
Other non-allocated	0.0031		0.0059	0.0000	0.0090
Subtotal - Other	0.0172	0.0091	0.0787	0.0017	0.1068
TOTAL	3.7666	1.0854	9.2932	0.4186	14.5638

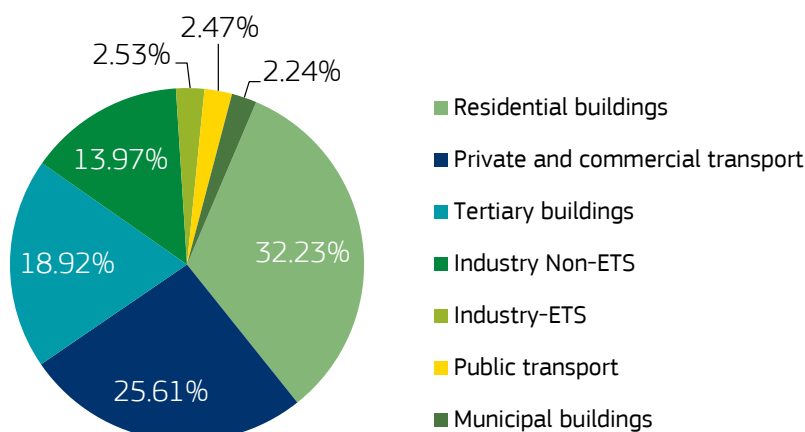
Source: JRC elaboration based on GCoM data

Figure 7. Shares of energy consumption by sector, reported in MEIs related to 2030 commitments – EU-27



Source: JRC elaboration based on GCoM data

Figure 8. Shares of energy consumption by fuel type, reported in MEIs related to 2030 commitments – EU-27



Source: JRC elaboration based on GCoM data

2.5 MEI energy supply

Examining the reported energy output from the 639 signatories having reported both BEI and MEI, there are 390 signatories having also reported some local electricity production (24.01 million inhabitants), 22 signatories having reported local heat/cold production (4.61 million inhabitants) and 112 signatories (10.22 million inhabitants) having reported purchases of renewable energy certificates.

2.5.1 Local electricity production and purchases of renewable energy certificates

The highest share of local electricity production corresponds to photovoltaics, with 31.52%, followed by hydroelectric (29.84%) and CHP (24.01%). Wind follows, with a lower share, of 12.33%. This represents an important change with respect to the shares of energy production declared in the BEI. This can be specially observed in photovoltaics (-42.61% share in MEI with respect to BEI), hydroelectric (+21.29%) and CHP (+10.96%). See Table 16 for the complete description of the total production by technology. Furthermore, comparing non-renewable with renewable energy technologies, renewable energy has the highest share in total production, with around 81.88%, representing almost 17% of the MEI electricity consumption for the local authorities reporting local electricity production. In per capita terms, the reported local electricity production amounts to 0.13 and 0.59 MWh/year for non-renewable and renewable technologies, respectively. Figure 9 shows the shares of the most representative electricity production sources and technologies.

Lastly, examining purchases of renewable energy certificates, there are 112 signatories reporting purchases (coming mainly from Belgium (50%), Italy (31%), Spain (8%), Sweden (4%) and Finland (3%), representing a population of 10.22 million), with a total of 2.17 TWh/year, representing 7% of their total MEI electricity consumption. In per capita terms, it amounts to 0.21 MWh/year per capita.

Table 16. Local electricity production in MEIs related to 2030 commitments - EU-27 (units TWh/year)

Energy production technology	Non-renewable	Renewable	TOTAL	SHARE
Photovoltaics		5.5232	5.5232	31.52%
Wind		2.1604	2.1604	12.33%
Hydroelectric		5.2280	5.2280	29.84%
Geothermal		0.0133	0.0133	0.08%
Local electricity production plants - Combined Heat and Power	3.0849	1.1215	4.2064	24.01%
Local electricity production plants - Other	0.0892	0.3010	0.3902	2.23%
TOTAL	3.1741	14.3473	17.5214	
SHARE OF TOTAL ELECTRICITY PRODUCTION	18.12%	81.88%		
SHARE OF TOTAL ELECTRICITY CONSUMPTION*	2.53% (3.74%)	11.44% (16.90%)		

*Compared to the total electricity consumption in MEI (only for local authorities reporting local electricity production)

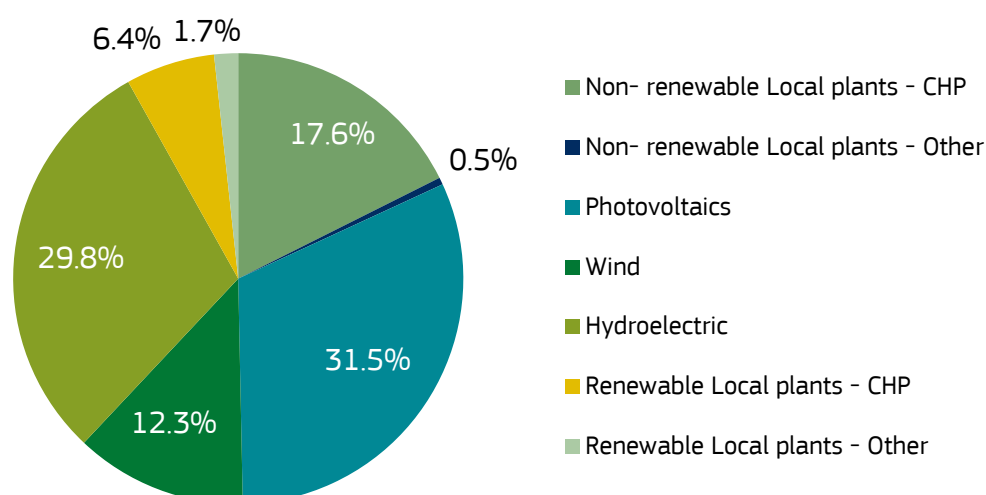
Source: JRC elaboration based on GCoM data

Table 17. Local electricity production in MEIs related to 2030 commitments - EU-27 (units MWh/year per capita)

Energy production technology	Non-renewable	Renewable	TOTAL
Photovoltaics		0.2299	0.2299
Wind		0.0899	0.0899
Hydroelectric		0.2177	0.2177
Geothermal		0.0006	0.0006
Local electricity production plants - Combined Heat and Power	0.1284	0.0467	0.1751
Local electricity production plants - Other	0.0037	0.0125	0.0162
TOTAL	0.1321	0.5973	0.7295

Source: JRC elaboration based on GCoM data

Figure 9. Shares of local electricity production by energy source and technology, reported in MEIs related to 2030 commitments – EU-27



Source: JRC elaboration based on GCoM data

2.5.2 Local heat/cold production

Considering local heat/cold supply within the 22 local authorities that have reported it (4.61 million inhabitants), the highest share of local heat/cold production corresponds to non-renewable CHP, with 76.92%. See Table 18 for the complete description of the total production by technology. Furthermore, comparing non-renewable with renewable energy technologies, non-renewable energy has the highest share, with 77.87%, representing a high share of the totality of the MEI heat/cold consumption for the local authorities reporting local heat/cold production. As shown in Table 19, the per capita production with non-renewable fuels amounts to 2.60 MWh/year. Figure 10 shows the shares of the most representative heat/cold production sources and technologies.

Table 18. Local heat/cold production in MEIs related to 2030 commitments - EU-27 (units TWh/year)

Energy production technology				Non- renewable	Renewable	TOTAL	SHARE
Local heat/cold production plants - Combined Heat and Power				9.8746	1.9943	11.8689	76.92%
Local heat/cold production plants - District heating (heat-only)				1.8310	1.1420	2.9730	19.27%
Local heat/cold production plants - Other				0.3097	0.2785	0.5881	3.81%
TOTAL				12.0152	3.4148	15.4300	
SHARE ON PRODUCTION	ON	TOTAL	HEAT/COLD	77.87%	22.13%		
SHARE ON CONSUMPTION*	ON	TOTAL	HEAT/COLD	33.26% (90.66%)	9.45% (25.77%)		

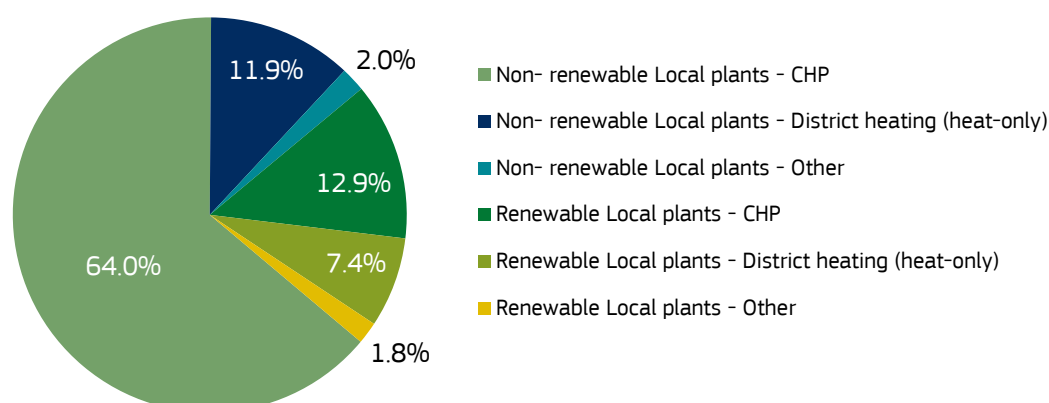
* Compared to the total heat/cold consumption in BEI (only for local authorities reporting local heat/cold production)

Source: JRC elaboration based on GCoM data

Table 19. Local heat/cold production in MEIs related to 2030 commitments – EU-27 (units MWh/year per capita)

Energy production technology	Non-renewable	Renewable	TOTAL
Local heat/cold production plants – Combined Heat and Power	2.1391	0.4320	2.5712
Local heat/cold production plants – District heating (heat-only)	0.3966	0.2474	0.6440
Local heat/cold production plants – Other	0.0671	0.0603	0.1274
TOTAL	2.6029	0.7397	3.3426

Source: JRC elaboration based on GCoM data

Figure 10. Shares of local heat/cold production by energy source and technology, reported in MEIs related to 2030 commitments – EU-27

Source: JRC elaboration based on GCoM data

2.6 Achievements in energy savings and renewable energy generation

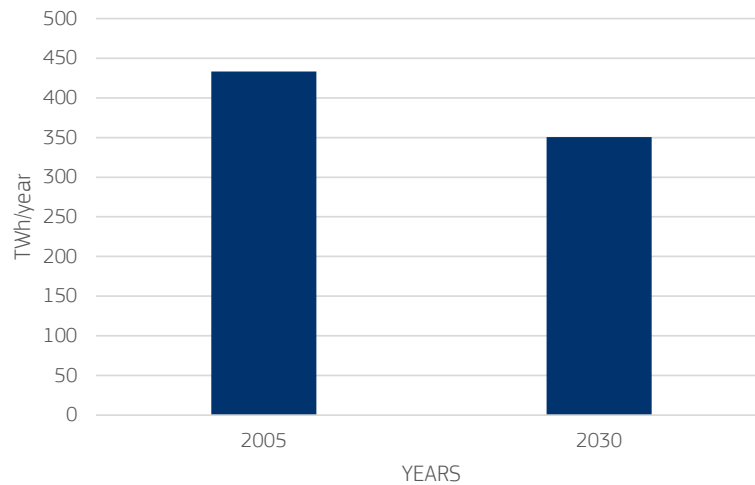
Once the reported estimated savings and the MEI consumption have been presented, it is possible to verify the actual savings for signatories holding a MEI (and having also reported their initial energy savings estimates). Thus, identifying the most successful signatories in accomplishing significant savings.

2.6.1 Energy savings

Taking the complete sample of MEIs (for the 639 signatories), together with their respective BEI, the total savings, when computing the difference between the BEI and the MEI consumption for the signatories, it amounts to 45.7 TWh/year (1.98 MWh/year per capita). Overall, the total reduced consumption here would be 8.6% of the reported BEI, and 9.4% of the MEI consumption.

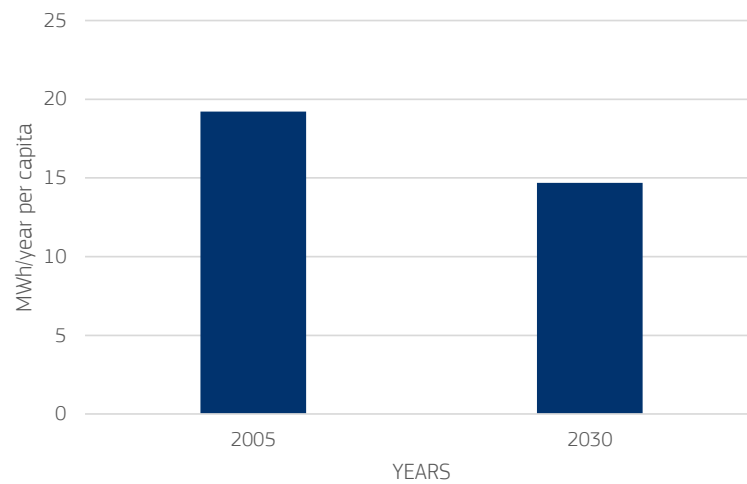
Now, considering only the signatories that reported initial estimates for energy savings and reported a MEI as well, the energy consumption is projected for 2030 (following an analogous forecasting methodology as the one followed in Melica et al., 2023 for GHG emissions), computing the expected savings of signatories according to their reported energy inventories (see Appendix 2 for the overview of the statistical methodology). In this way, for this sample of 441 signatories, they accomplished a **mean annual rate** of per capita energy savings of 0.18 MWh/year, falling short from the initially reported/estimated rate of 0.20 MWh/year (see Figure 11a and Figure 12b).

Figure 11a. Mean yearly energy consumption (units TWh/year)



Source: JRC elaboration based on GCoM data

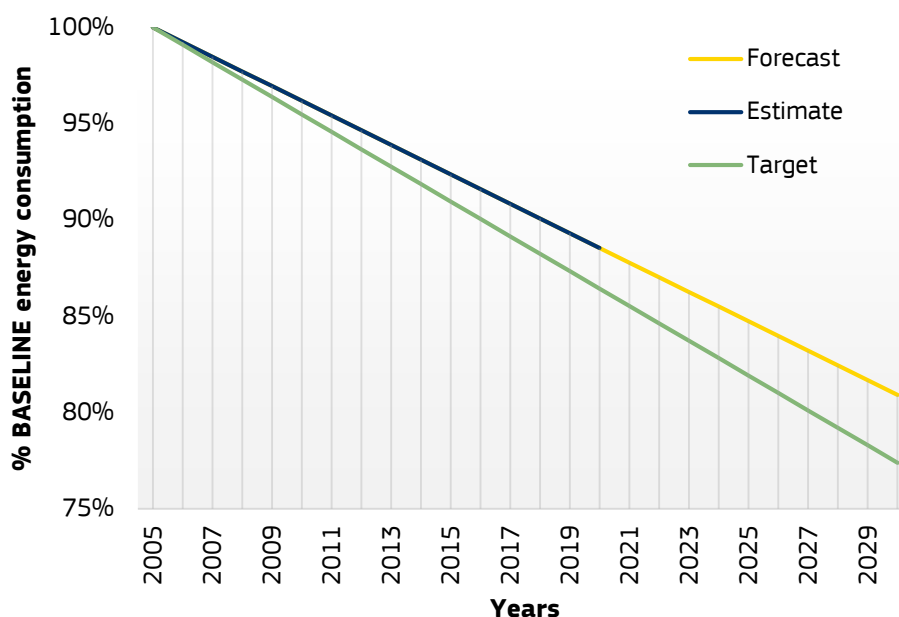
Figure 12b. Mean yearly energy consumption (units MWh/year per capita)



Source: JRC elaboration based on GCoM data

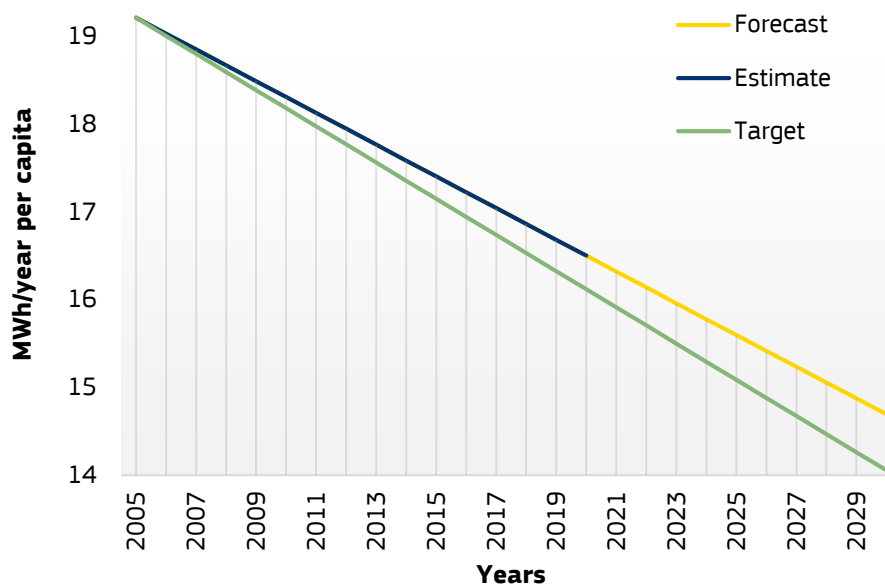
As it can be seen in Figure 13 and Figure 14 below, the analysed local authorities would fall short from their initially reported targets.

Figure 13. Projected trajectories of baseline energy consumption for EU-27 signatories until 2030 (unit: %)



Source: JRC elaboration based on GCoM data

Figure 14. Projected trajectories of per capita energy consumption for EU-27 until 2030 (unit: MWh/year per capita)



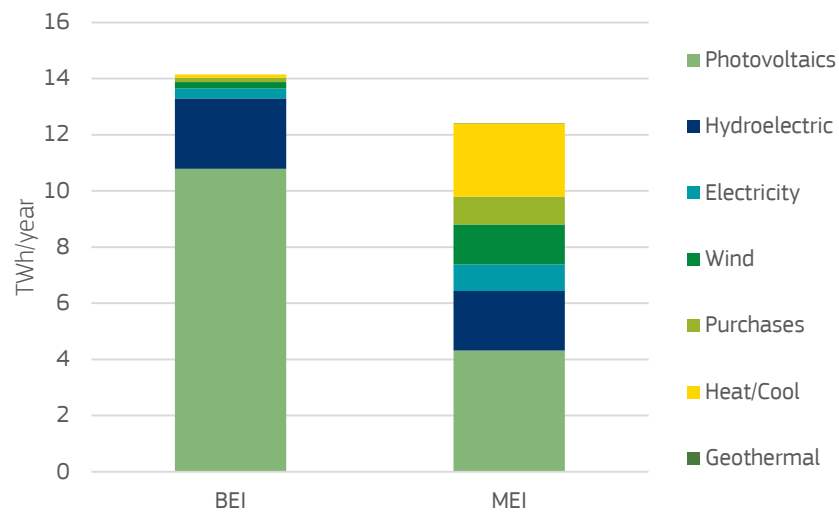
Source: JRC elaboration based on GCoM data

2.6.2 Renewable energy production

Based on the BEIs and MEIs, it can also be monitored what signatories are achieving in terms of local renewable energy production (174 signatories, representing around 11 million inhabitants). Figure 15 compares the profiles for renewable energy production, where notable differences can be observed. The profiles change significantly: photovoltaics are the most significant source of energy production in the BEI, but its representativeness is more than halved in the MEIs; hydroelectric also experiences a reduction, even when less significant. On the other hand, heating and cooling, wind, and purchases, while not being especially representative in the BEIs, increase significantly their share in the MEIs, as does the electricity. Geothermal remains in both cases not significant.

Also, it can be observed that the amount of renewable energy production is reduced by more than 1.5 TWh/year in between the BEI and the MEIs.

Figure 15. Renewable energy production profiles (TWh/year), related to 2030 commitments (BEI vs MEI) – EU-27



Source: JRC elaboration based on GCoM data

3 Local policies accomplishing energy savings and renewable energy production

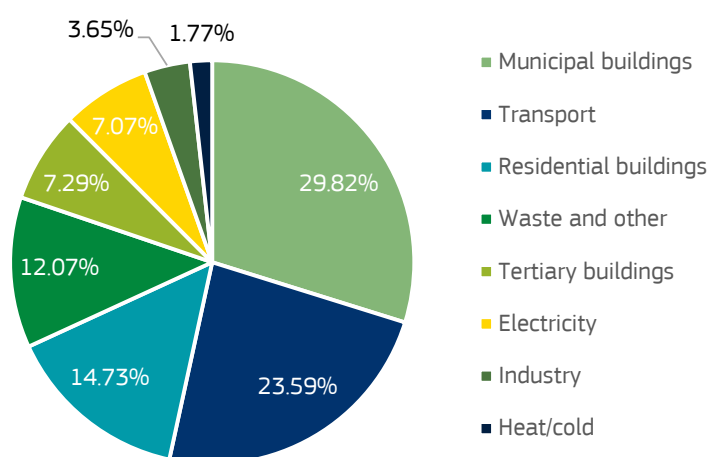
Considering the actions and strategies that GCoM signatories plan and implement to achieve their ambitions, it is relevant to examine the general statistics on the sectors, areas and instruments reported in their SECAP. In this section, an overview is given on the main policies mentioning energy savings, consumption, efficiency, or management, taking only the subset of EU-27 signatories achieving energy savings according to their submitted reports and inventories. In this way, the analysis only concerns the local authorities accomplishing a positive annual savings rate.

The following section 3.1 presents data coming from GCoM signatories reporting only at MyCovenant. 3.1 On the other hand, taking the availability of data on renewable energy generation as it is reported through the CDP-ICLEI Track platform, section 3.2 includes in the analysis not only signatories reporting at MyCovenant, but also those local authorities reporting at CDP-ICLEI Track. In the latter section, as already explained at the end of section 1.1, if a city has reported in both platforms, the latest dataset has been considered for the analysis performed in section 3.2.⁴

3.1 Local policies accomplishing energy savings

Based on the data reported in MyCovenant (465 signatories, 22.43 million inhabitants), it is possible to analyse the reported local actions (a total of 13 874 individual actions) from three perspectives: main action sectors addressed, main action areas, and main instruments used in their deployment. Concerning mitigation action sectors, the greatest share of actions addresses buildings, including municipal, residential and tertiary buildings, representing 51.84% of the total number of actions. Transport also has an important share with 23.59% of planned measures, as well as waste and other sectors (12.07%). This is coherent with the previous analysis on the BEI and MEI, where buildings and transport are the two sectors with the highest relevance for the local authorities. However, when analysing building-related actions in more depth, it is worth to note that more actions linked to municipal buildings (29.82%) are reported, than linked to residential buildings (14.73%), even when the relative share of energy consumption linked to these subsectors (2.27% and 34.27%, respectively) suggests that more actions should be devoted to residential buildings. Figure 16 presents the shares of sectors for the local authorities that reported actions expecting to accomplish savings in EU-27 (excluding missing and “other sectors”).⁵

Figure 16. Main action sectors in EU-27 (total number = 13 874)



Source: JRC elaboration based on GCoM data

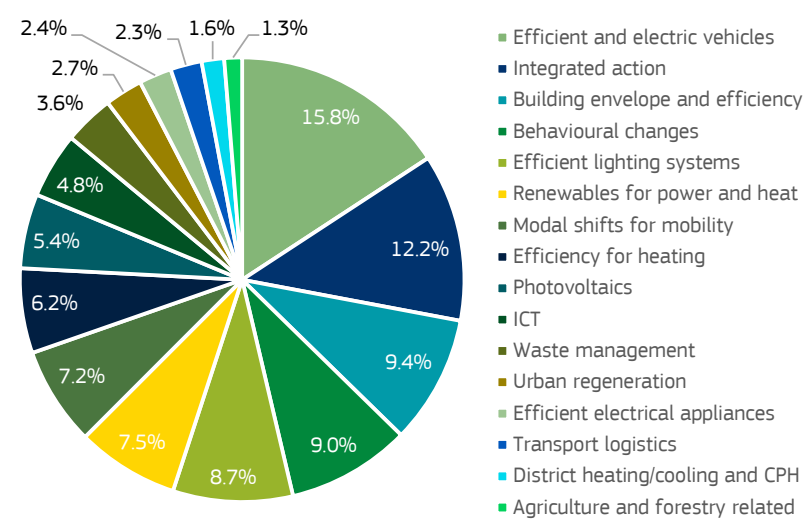
Regarding the mitigation action areas, local authorities focused their attention on Efficiency in the lighting systems, Integrated action (tackling several energy/climate aspects), Building envelope and efficiency,

⁴ Due to the missing information at the ICLEI-CDP platform, concerning the consistent reporting of energy consumption data, it has not been possible to combine both datasets to analyse within section 3.1 the main action areas or the instruments used for cities accomplishing energy savings.

⁵ Tertiary buildings refers to Tertiary (non municipal) buildings, equipment/facilities

Behavioural changes (including Eco-driving) and Efficient lighting systems, each one of them with a share ranging from 15.8% to 8.7%. The figure below presents the complete shares for the areas, where Renewables for power and heat includes the sub-areas of Renewable energy for heating, Wind power, Hydroelectric power, Industry renewable energy and Biomass power plant; Modal mobility shifts includes Modal shift to walking and cycling, to public transport, and car sharing; Transport logistics include Road network optimization and Urban freight transport; and District heating/cooling and CHP includes District heating/cooling network, Combined heat and power (CHP) and District heating/cooling plants.

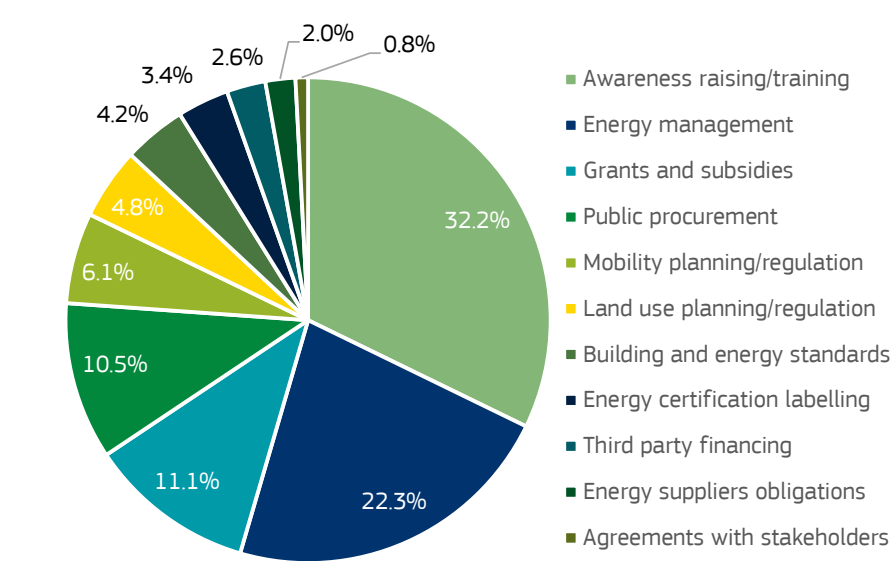
Figure 17. Main action areas in EU-27, excluding missing and “other areas”, as well as the less frequent Energy efficiency in industrial processes, Industry other, Mixed use development and sprawl containment and Smart grids



Source: JRC elaboration based on GCoM data

Lastly, for the instruments being used by the local authorities, Awareness raising and training campaigns receive the highest share (32.2%), followed by Energy management (22.3%), Grants and subsidies (11.1%) and Public procurement (10.5%). The complete picture of the instruments taking part of the local authorities’ actions can be seen in Figure 18**Error! Reference source not found.**

Figure 18. Main action instruments in EU-27 (excluding missing, not applicable and “other instruments”, as well as the less frequent Integrated ticketing and charging, Energy carbon taxes and Road pricing)



Source: JRC elaboration based on GCoM data

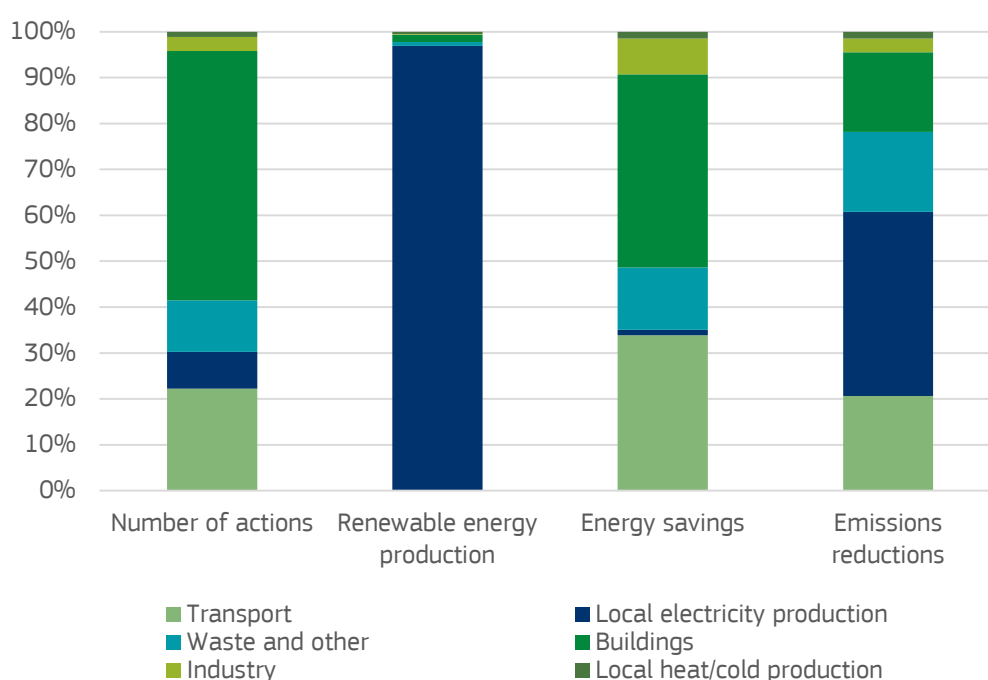
3.2 Local mitigation policies from GCoM signatories (MyCovenant+CDP)

Placing a deeper focus on the reported mitigation actions for energy savings or renewable energy generation, a series of insights can be observed (see Figure 19). For 1 400 signatories (82.63 million inhabitants) reporting either at MyCovenant (1 317), or CDP-ICLEI Track (83)⁶, a total of 46 161 mitigation actions have been reported. The majority of the reported actions (25 082, 54.3%) is linked to the building sector, followed by the transport (10 264 actions, 22.2%) and the waste and “other” sectors (5 165 actions, 11.2%). Electricity remains in the fourth place (3 713 actions, 8%). Even when having expanded the pool of signatories, the shares of actions in each sector are consistent with those presented above (section 3.1).

In terms of renewable energy production, almost all actions are linked to the production of electricity, whereas other carriers represent less than 3.2%. Energy savings are mostly reaped by the building sector (42%) and the transport sector (33.8%). These are followed by waste and other, with a 14% share, and industry (8%).

Last but not least, it can be observed that emissions reductions are not directly relatable to neither the number of actions, the renewable energy nor the energy savings produced. Most emissions reductions are achieved in the electricity sector (40%), which is followed by transport, buildings and waste and other sectors, with a similar share (ranging from 20% to 17%). The discrepancy that can be observed underlines the importance of analysing the relative impacts obtained by the actions, and suggests difficulties encountered in reducing emissions in some sectors.

Figure 19. Mitigation actions and estimated impact by sector

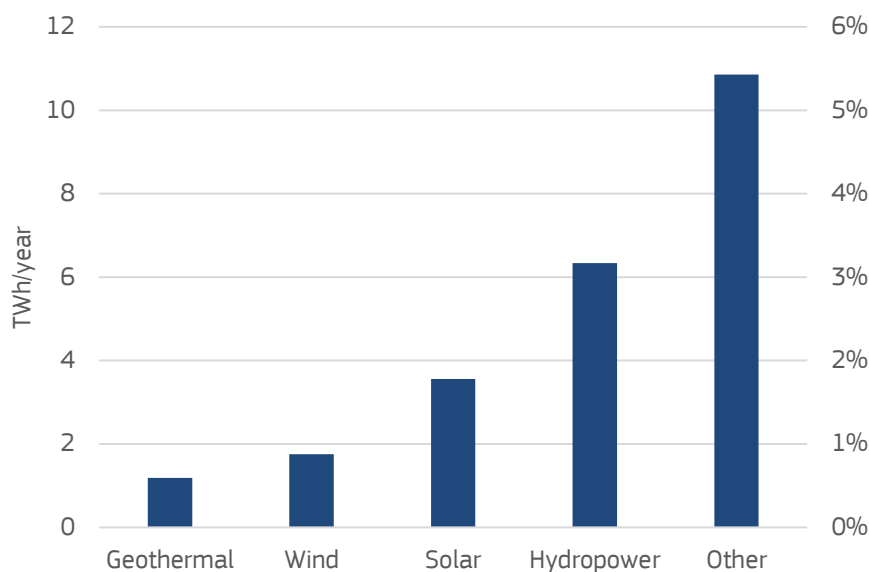


Source: JRC elaboration based on GCoM and CDP-ICLEI Track data

If a deeper focus is placed on the sources for renewable energy generation reported in My Covenant and CDP (see Figure 20), it can be observed that the most common technology is hydropower followed by solar sources (which includes PV and solar thermal), whereas wind and geothermal are the least used.

⁶ As explained in a previous section, when a city has reported in both platforms, the latest data has been considered.

Figure 20. Renewable energy generation by source reported in local policies



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

The “other” source remains however the most prevalent and groups different renewable technologies as depicted in the table below. This is due to the combination of data sources used in the analysis, which do not enable a direct comparison among RES technologies.

Table 20. Renewable energy generation by source reported in MyCovenant and CDP

Graph	MyCovenant	CDP
Geothermal	Geothermal	Geothermal
Hydropower	Hydropower	Hydropower
Other	Local electricity production plants > 20 MW not recommended); Local heat/cold production plants - Combined Heat and Power; Local heat/cold production plants - District heating (heat-only); Local heat/cold production plants - Other; Purchases Guarantees of Origins	Bioenergy (Biomass and Biofuels); Other
Solar	Photovoltaics	Solar PV Solar thermal
Wind	Wind	Wind

Source: JRC elaboration based on GCoM data

Based on the analysis of policies, at first sight, several differences can be observed with respect to what signatories have reported in the BEI and MEIs (sections 2.2 and 2.5, respectively); however, even though they might potentially signal some trend, they cannot be fully confirmed, as due to data availability reasons, the typology and size of signatory is different in each case.

4 Conclusions

The evidence collected in this report suggests that, on average, fossil fuels hold the greatest share in the total energy consumption in EU-27 signatories with 2030 commitments, representing around 65% (slightly higher in the BEI with respect to the MEI). The share of fossils is followed by electricity, with around 25% in both BEI and MEI. District heating and cooling is in third place, with around 5.5% in BEI and 7.5% in MEI and lastly, renewable energies (2.4% in BEI and 2.8% in MEI). These findings suggest that still more effort is required to meet the EU targets for a successful transition to a greener energy system. Meanwhile, the sector with the highest share in the reported consumption is residential buildings (more than 30%), followed by private and commercial transport (with shares of around 25%-27%).

The reported estimates by 2030 for renewable energy production amounts to 1.17 MWh/year per capita, considering all sectors based on the BEI (1 317 signatories). When focusing only on local renewable electricity production reported in the BEI, the highest shares correspond to photovoltaics (74%), followed by hydroelectric (8.55%). The shares change on average according to the activity reported in the MEI, where the highest share still corresponds to photovoltaics with a significantly lower share of 31.5%, followed by hydroelectric (29.8%). Renewable energy has the highest share in the total local electricity production (ranging from 87.3% in BEIs to 81.8% in MEIs), representing around 14% of the BEI electricity consumption, and around 11.5% of the MEI consumption. Purchases of renewable energy certificates represent a small share of the reported electricity consumption (around 3.8% and 7% for the consumption in BEI and in MEI, respectively). On the other hand, considering local heat/cold production, the highest shares correspond to district heating (heat only) and CHP, using almost entirely non-renewable energy sources in the BEI (98.6%, and 77.8% in MEI) and covering approximately the entire heat/cold consumption of the analysed signatories (85.6% in the BEI and 90.6% in the MEI). The MEIs see an increase in the share of local heat/cold production through renewable sources with respect to the BEIs of around 22%, which shows that some improvement is being performed.

Furthermore, based on the analysis of both BEIs and MEIs it has been established that the achieved savings amount to 0.18 MWh/year per capita, falling short of the declared estimated annual rate of 0.2 MWh/year, suggesting that more effort is required to increase the local authorities' energy savings. When comparing the profiles for renewable energy production declared in the BEIs and MEIs, a decrease is also observed, as well as a change in the share of the sources: BEIs show a predominance of photovoltaics, while in MEIs the share of photovoltaics is reduced and a more varied combination of other renewable energy sources can be observed.

Last but not least, the report analyses the reported policies and estimated impact on energy savings and renewable energy production (i.e. estimates declared through the reported actions by the local authorities). The main focus of the policies that achieve energy savings is placed on buildings (in particular municipal buildings), and transport. The most common actions are linked to efficient and electric vehicles, integrated actions and building envelope and efficiency, whereas the main action instruments are awareness raising / training, energy management, and grants and subsidies. On the other hand, it can be observed that the actions that report renewable energy production are predominantly focused on electricity production (hydropower, solar and wind).

All in all, the most challenging aspect is extracting insights linked to renewable energy based on the available data. Significant drops in relevant technologies such as photovoltaics are observed when comparing BEIs and MEIs, which cannot be easily explained. While potential sources of these discrepancies could stem from the quality of the data reported by the local authorities, further analyses needs to be performed to clearly understand the status quo of RES in local authorities and their contribution towards EU's clean energy transition. However, it should be acknowledged that the results presented in this document correspond to a broad yet not necessarily representative sample of local authorities in the EU. Therefore, conclusions cannot be generalised to the EU level.

References

- Baldi, Marta; Franco de Los Rios, Camilo; Melica, Giulia; Treville, Aldo; Bertoldi, Paolo (2023): GCoM - MyCovenant, 4th Release - March 2023. European Commission, Joint Research Centre (JRC) [Dataset] PID: <http://data.europa.eu/89h/b425918f-53a1-495c-8619-cd370c302eb0>
- Bertoldi, P. (2018). *Guidebook 'How to develop a Sustainable Energy and Climate Action Plan (SECAP)'*. Luxembourg: Publications Office of the European Union
- Bertoldi, P., Kona, A., Rivas, S. & Dallemand, J. (2018) Towards a global comprehensive and transparent framework for cities and local governments enabling and effective contribution to the Paris Climate Agreement. *Current Opinion in Environmental Sustainability*, 67-74
- Cerutti, A. K., Iancu, A., Janssens-Maenhout, G., Melica, G., Paina, F. & Bertoldi, P. (2013) The Covenant of Mayors in Figures 5-Year Assessment (EUR 25992). Publications Office of the European Union, Luxembourg, <https://doi.org/10.2788/1062>
- Franco, C., Melica, G., Bertoldi, P. (2022a) Covenant of Mayors 2021 Energy figures. Publications Office of the European Union, Luxembourg, JRC129962
- Franco, C., Melica, G., Treville, A., Baldi, M., Pisoni, E., Thiel, Ch., Bertoldi, P. (2022b) Prediction of greenhouse gas emissions for cities and local municipalities monitoring their advances to mitigate and adapt to climate change. *Sustainable Cities and Society* 86, 104114
- GCoM (2018). Global Covenant of Mayors Common Reporting Framework. Available online: <https://www.globalcovenantofmayors.org/our-initiatives/data4cities/common-global-reporting-framework/>
- GCoM (2022). Global Covenant of Mayors. Energy Access and Poverty Pillar (EAPP) Annex Common Reporting Framework. Available online: <https://www.globalcovenantofmayors.org/wp-content/uploads/2022/11/Energy-Access-and-Poverty-Pillar-Annex-to-the-CRF.pdf>
- IPCC (2022). Climate Change 2022: Mitigation of Climate Change. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. P. Shukla et al. (Eds.). Cambridge, UK: Cambridge University Press. 10.1017/9781009157926
- Kona, A., Bertoldi, P. & Kilikş, S. (2019) Covenant of Mayors: Local energy generation, methodology, policies and good practice examples. *Energies* 12, 985
- Kona, A., Bertoldi, P., Monforti-Ferrario, F., Rivas, S. & Dallemand, J.F. (2018) Covenant of mayors signatories leading the way towards 1.5 degree global warming pathway. *Sustainable Cities and Society* 41, 568-575
- Melica, G., Bertoldi, P., Kona, A., Iancu, A., Rivas, S. & Zancanella, P. (2018). Multilevel governance of sustainable energy policies: The role of regions and provinces to support the participation of small local authorities in the Covenant of Mayors. *Sustainable Cities and Society*, 729-739
- Melica, G., Treville, A., Franco, C., Baldi, M., Monforti-Ferrario F., Palermo, V., ... & Bertoldi, P. (2022) Covenant of Mayors: 2021 assessment. Publications Office of the European Union, Luxembourg, JRC128104
- Melica, G., Treville, A., Franco De Los Rios, C., Palermo, V., Monforti Ferrario, F., Baldi, M., Ulpiani, G., Ortega Hortelano, A., Barbosa, P., Bertoldi, P., Covenant of Mayors: 2022 assessment, Publications Office of the European Union, Luxembourg, 2022, doi:10.2760/930988, JRC130957
- 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. (2023), Covenant of Mayors: 2023 assessment, Publications Office of the European Union, Luxembourg, 2024, doi:10.2760/835080, JRC137368.
- Monforti-Ferrario, F., Kona, A., Peduzzi, E., Pernigotti, D., Pisoni, E. (2018) The impact on air quality of energy saving measures in the major cities signatories of the Covenant of Mayors initiative. *Environment International* 118, 222-234
- Palermo, V., Bertoldi, P., Apostoulu, M., Kona, A. & Rivas, S. (2020) Assessment of climate change mitigation policies in 315 cities in the Covenant of Mayors initiative. *Sustainable Cities and Society* 60, 102258

- Peduzzi, E., Baldi, M.G., Pisoni, E., Kona, A., Bertoldi, P., Monforti-Ferrario, F. Impacts of a climate change initiative on air pollutant emissions: Insights from the Covenant of Mayors, *Environment International* 145, 106029
- Rivas, S., Urraca, R., Bertoldi, P., Thiel, C. (2021) Towards the EU Green Deal: Local key factors to achieve ambitious 2030 climate targets. *Journal of Cleaner Production* 320, 128878

List of abbreviations and definitions

BEI	Baseline Emission Inventory
CDP	Carbon Disclosure Project
CoM	Covenant of Mayors
CHP	Combined Heat and Power
CRF	Common Reporting Framework
DG	Directorate General
EC	European Commission
ETS	Emission Trading System
EU	European Union
GCoM	Global Covenant of Mayors
GHG	Greenhouse Gas
IPCC	Intergovernmental Panel on Climate Change
IT	Information Technologies
JRC	Joint Research Centre
MEI	Monitoring Emission Inventory
NDC	Nationally Determined Contribution
SEAP	Sustainable Energy Action Plan
SECAP	Sustainable Energy and Climate Action Plan
TWG	Technical Working Group
UNFCCC	United Nations Framework Convention on Climate Change

List of figures

Figure 1. Shares of final energy consumption by sector reported in BEIs	14
Figure 2. Shares of final energy consumption by carrier reported in BEIs	14
Figure 3. Shares of local electricity production by technology, reported in BEIs related to 2030 commitments – EU-27	16
Figure 4. Shares of local heat/cold production by energy source and technology, reported in BEIs related to 2030 commitments – EU-27	17
Figure 5. Shares of estimated savings by sector reported in in BEIs related to 2030 commitments – EU-27	19
Figure 6. Shares of estimated renewable energy production by sector, reported in BEIs related to 2030 commitments – EU-27	20
Figure 7. Shares of energy consumption by sector, reported in MEIs related to 2030 commitments – EU-27	25
Figure 8. Shares of energy consumption by fuel type, reported in MEIs related to 2030 commitments – EU-27	25
Figure 9. Shares of local electricity production by energy source and technology, reported in MEIs related to 2030 commitments – EU-27	27
Figure 10. Shares of local heat/cold production by energy source and technology, reported in MEIs related to 2030 commitments – EU-27	28
Figure 11a. Mean yearly energy consumption (units TWh/year)	29
Figure 11b. Mean yearly energy consumption (units MWh/year per capita)	29
Figure 12. Projected trajectories of baseline energy consumption for EU-27 signatories until 2030 (unit: %)	30
Figure 13. Projected trajectories of per capita energy consumption for EU-27 until 2030 (unit: MWh/year per capita)	30
Figure 14. Renewable energy production profiles (TWh/year), related to 2030 commitments (BEI vs MEI) – EU-27	31
Figure 15. Main action sectors in EU-27 (total number = 13 874)	32
Figure 16. Main action areas in EU-27, excluding missing and “other areas”, as well as the less frequent Energy efficiency in industrial processes, Industry other, Mixed use development and sprawl containment and Smart grids.....	33
Figure 17. Main action instruments in EU-27 (excluding missing, not applicable and “other instruments”, as well as the less frequent Integrated ticketing and charging, Energy carbon taxes and Road pricing)	33
Figure 18. Mitigation actions and estimated impact by sector	34
Figure 18. Renewable energy generation by source reported in local policies.....	35
Figure A1. Proportion of signatories by country (GCoM).....	43
Figure A2. Proportion of signatories by country (CDP).....	43
Figure A3. Picture of the statistical methodology for the estimation of the cities’ energy consumption. Cities report their energy inventories (marked with o) for a given year, and their consumption is estimated for 2005 (marked with x) and forecasted to the target year (marked with +) of 2030.	44

List of tables

Table 1. EU-27 signatories with 2030 commitments: analysed data, number of signatories and population .	8
Table 2. Energy consumption reported in BEIs related to 2030 commitments – EU-27 (units TWh/year)	11
Table 3. Energy consumption reported in BEIs related to 2030 commitments – EU-27 (units %)	12
Table 4. Energy consumption pc reported in BEIs related to 2030 commitments – EU-27 (units MWh/year per capita)	13
Table 5. Local electricity production in BEIs related to 2030 commitments – EU-27 (units TWh/year)	15
Table 6. Local electricity production in BEIs related to 2030 commitments – EU-27 (units MWh/year per capita)	15
Table 7. Local heat/cold production in BEIs related to 2030 commitments – EU-27 (units TWh/year)	16
Table 8. Local heat/cold production in BEIs related to 2030 commitments – EU-27 (units MWh/year per capita)	17
Table 9. Estimated energy savings by 2030 declared by signatories – EU-27 (units TWh/year)	18
Table 10. Estimated energy savings by 2030 declared by signatories – EU-27 (units MWh/year per capita)	18
Table 11. Estimated renewable energy production by 2030 declared by signatories – EU-27 (units TWh/year).	19
Table 12. Estimated renewable energy production by 2030 declared by signatories – EU-27 (units MWh/year per capita)	20
Table 13. Energy consumption reported in MEIs related to 2030 commitments – EU-27 (units TWh/year) ..	22
Table 14. Energy consumption reported in MEIs related to 2030 commitments – EU-27 (units %)	23
Table 15. Energy consumption reported in MEIs related to 2030 commitments – EU-27 (units MWh/year per capita)	24
Table 16. Local electricity production in MEIs related to 2030 commitments – EU-27 (units TWh/year)	26
Table 17. Local electricity production in MEIs related to 2030 commitments – EU-27 (units MWh/year per capita)	26
Table 18. Local heat/cold production in MEIs related to 2030 commitments – EU-27 (units TWh/year)	27
Table 19. Local heat/cold production in MEIs related to 2030 commitments – EU-27 (units MWh/year per capita)	28
Table 20. Renewable energy generation by source reported in MyCovenant and CDP	35
Table A1. Proportion of signatories with a BEI by reporting platform and country – EU-27 (units %)	42

Annexes

Annex 1. Proportion of signatories with 2030 commitments by reporting platform and country

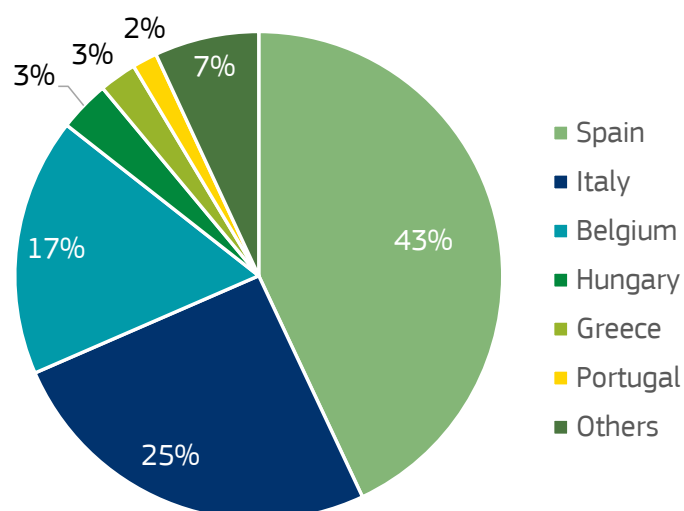
Table A1. Proportion of signatories with a BEI by reporting platform and country - EU-27 (units %)

Country	MyCovenant (%)	CDP (%)
Austria	0.06%	-
Belgium	17.09%	0.70%
Bulgaria	0.13%	2.11%
Cyprus	0.13%	-
Czech Republic	0.57%	0.70%
Germany	0.44%	6.34%
Denmark	-	13.38%
Estonia		0.70%
Greece	2.48%	-
Spain	43.01%	4.93%
Finland	0.70%	4.23%
France	0.83%	2.82%
Croatia	1.33%	1.41%
Hungary	3.37%	-
Ireland	0.44%	-
Italy	25.48%	23.24%
Lithuania	-	-
Luxembourg	0.06%	-
Latvia	0.13%	-
Malta	-	-
Netherlands	0.13%	4.93%
Poland	0.38%	2.82%
Portugal	1.65%	16.20%
Romania	0.95%	3.52%
Sweden	0.38%	11.27%

Slovenia	0.13%	-
Slovakia	0.13%	0.70%

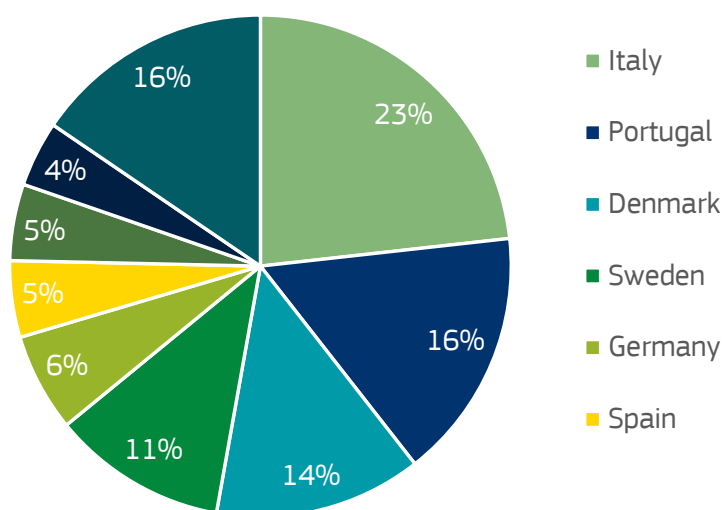
Source: JRC elaboration based on GCoM and CDP data

Figure A1. Proportion of signatories by country (GCoM)



Source: JRC elaboration based on GCoM data

Figure A2. Proportion of signatories by country (CDP)



Source: JRC elaboration based on CDP data

Annex 2. Methodology for forecasting energy consumption

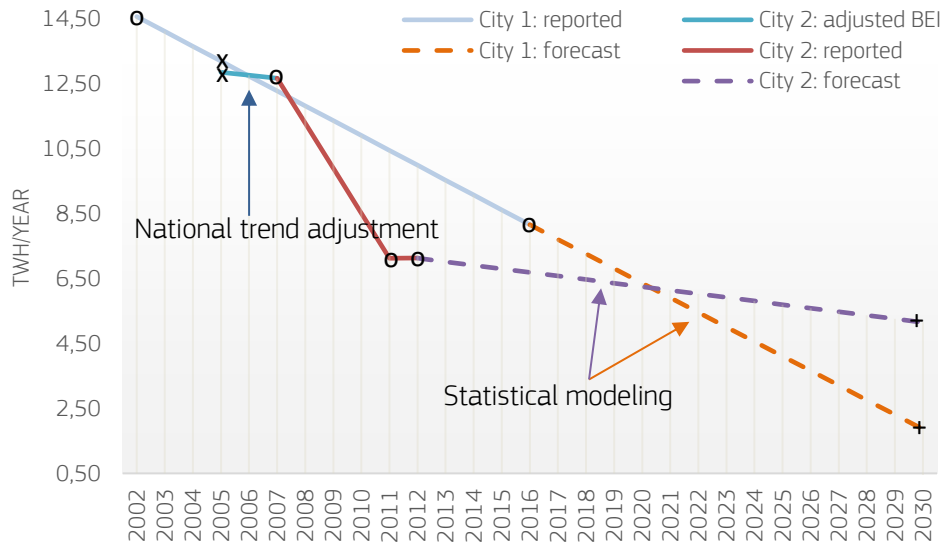
In this Annex 2, the brief explanation is given on the statistical methods for the estimation and prediction of energy consumption for each signatory.

Firstly, the base year was set to 2005, being the reference year for measuring the performance of the cities' actions. In this way, for cities reporting a base year earlier than 2005, the estimated energy consumption in 2005 was 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 energy consumption were adjusted according to the factor f , which considered the National Energy consumption (taken from IEA-EDGAR data base: https://edgar.jrc.ec.europa.eu/dataset_ghg70#p1) for 2005 NE_{2005} , and for the base year NE_{base} , as in

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

The models for estimating the cities' energy consumption in 2030 followed a machine learning methodology, minimizing the error over the last known value (see Franco et al. 2022). The input data for the development of the models consisted in the cities' reported energy inventories for their baseline and the following monitoring inventories, projecting their energy activity up to 2030, as shown in Figure A3.

Figure A3. Picture of the statistical methodology for the estimation of the cities' energy consumption. Cities report their energy inventories (marked with o) for a given year, and their consumption is estimated for 2005 (marked with x) and forecasted to the target year (marked with +) of 2030.



Source: JRC elaboration

Therefore, each city had a sparse time series with a yearly frequency, being sparse because many years in between the base and the last monitoring years had missing values. Hence, firstly, the imputation of data was performed, building the yearly time series on which the algorithms could learn the stochastic process explaining their behaviour. This was done by continuing the linear trend between the years holding the known energy values (see again Figure A3). Secondly, the best model was identified for each city (i), according to the minimum error ($error_i$) for the predicted value (\hat{y}_{it}), computed over the last known energy value (y_{it}^*). Such a last known energy value consisted in the value coming from the city's last MEI. This error was computed for each city as the mean absolute percentage error, given by

$$error_i = \frac{|\hat{y}_{it} - y_{it}^*|}{y_{it}^*}. \quad (1)$$

In this way, the last known value was left out for validation, and the best model was identified achieving the minimum prediction error. Here, according to Eq. (1), the methodology obtained a mean prediction error of 14%.

Finally, the complete time series was fitted again under the same functional form of the identified model, and the corresponding prediction was taken for the cities' energy consumption in the target year 2030.

Under this methodology, the time series were modelled after three different approaches, automatically selecting the best model from the three.

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 consisted 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 were validated by the Ljung--Box test (see again Box et al., 2016), checking that no significant correlation among the residuals was left unexplained.

The third and last approach to modelling the series consisted 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), but not too complex as the behaviour being modelled was rather simple (with no seasonality component). This architecture was 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).

Getting in touch with the EU

In person

All over the European Union there are hundreds of Europe Direct centres. You can find the address of the centre nearest you online (european-union.europa.eu/contact-eu/meet-us_en).

On the phone or in writing

Europe Direct is a service that answers your questions about the European Union. You can contact this service:

- by freephone: 00 800 6 7 8 9 10 11 (certain operators may charge for these calls),
- at the following standard number: +32 22999696,
- via the following form: european-union.europa.eu/contact-eu/write-us_en.

Finding information about the EU

Online

Information about the European Union in all the official languages of the EU is available on the Europa website (european-union.europa.eu).

EU publications

You can view or order EU publications at op.europa.eu/en/publications. Multiple copies of free publications can be obtained by contacting Europe Direct or your local documentation centre (european-union.europa.eu/contact-eu/meet-us_en).

EU law and related documents

For access to legal information from the EU, including all EU law since 1951 in all the official language versions, go to EUR-Lex (eur-lex.europa.eu).

EU open data

The portal data.europa.eu provides access to open datasets from the EU institutions, bodies and agencies. These can be downloaded and reused for free, for both commercial and non-commercial purposes. The portal also provides access to a wealth of datasets from European countries.

Science for policy

The Joint Research Centre (JRC) provides independent, evidence-based knowledge and science, supporting EU policies to positively impact society



EU Science Hub

[Joint-research-centre.ec.europa.eu](https://joint-research-centre.ec.europa.eu)



Publications Office
of the European Union